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LUCAS Soil 2015 in the Western Balkans

Overview and analysis of ancillary data

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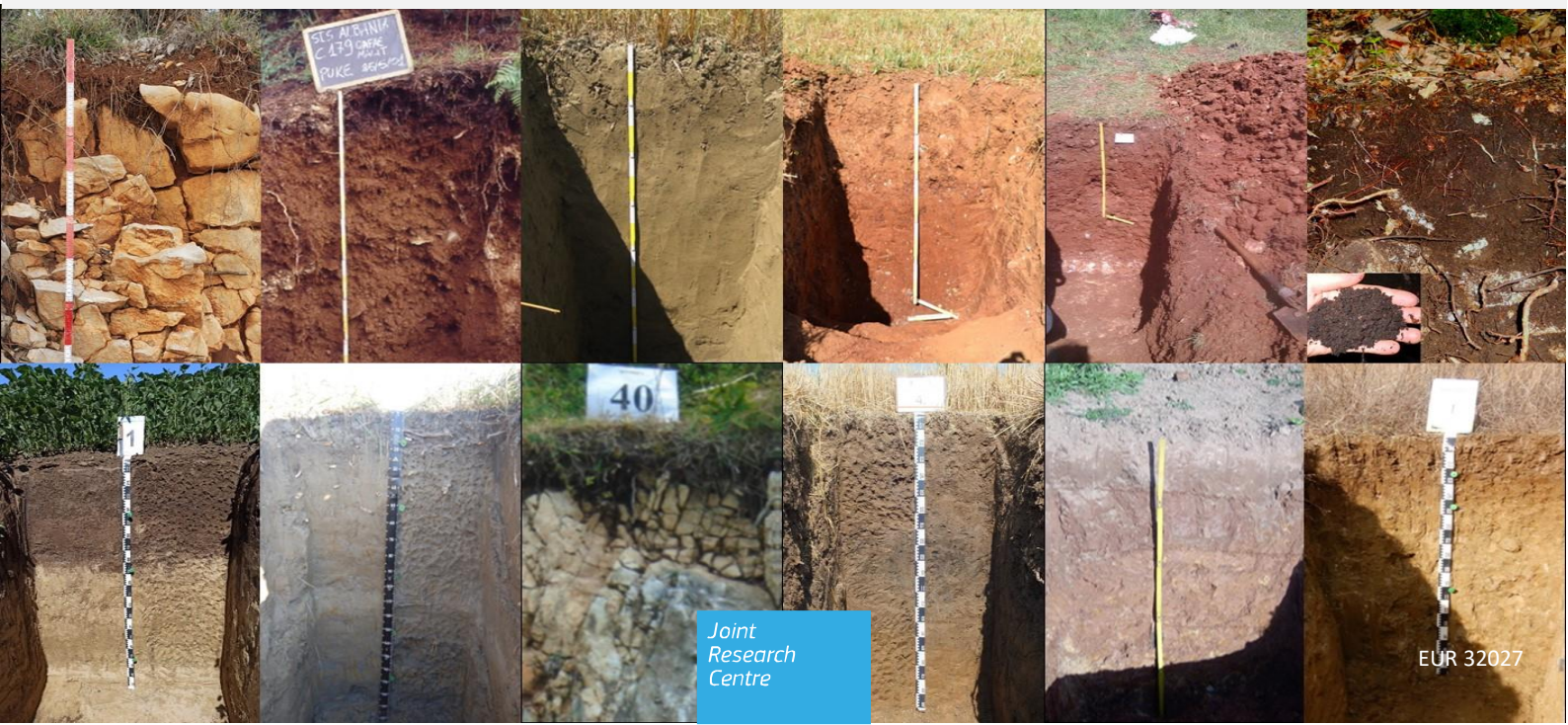

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Contents

Abstract

The Green Agenda for the Western Balkans, aligned with the European Green Deal, emphasizes five pillars: climate action, circular economy, biodiversity, pollution control, and sustainable food systems. Soil condition is crucial for achieving these targets, highlighting the policy relevance of maintaining and improving soil health to support regional environmental and agricultural sustainability. In 2015, the European Commission, under the Joint Research Centre's (JRC) Enlargement and Integration Programme, launched the first soil sampling in the Western Balkans (Albania, Bosnia and Herzegovina, North Macedonia, Montenegro, and Serbia) as part of the LUCAS survey, collecting 1,015 soil samples. This initiative is part of JRC project on Environment and Climate in Enlargement and contributes to the Western Balkans Agenda on Innovation, Research, Education, Culture, Youth, and Sports. This report provides ancillary environmental data for these sampling locations, offering context on factors influencing soil characteristics. The findings support the development of an updated soil database for the Western Balkan region, facilitating evidence-based policy-making and regional cooperation.

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[1] This designation is without prejudice to positions on status and is in line with UNSCR 1244/1999 and the ICJ Opinion on the Kosovo declaration of independence

1 Introduction: The Green Agenda for the Western Balkans

The Green Agenda for the Western Balkans, envisaged by the European Green Deal (EGD), details five pillars of action targeting: (1) climate action, (2) circular economy, (3) biodiversity, (4) **fighting pollution of air, water, and soil** and (5) sustainable food systems and rural areas. Digitalisation will be a key enabler for the above five pillars in line with the concept of the dual green and digital transition. The ten-year experience in the environmental and climate topics in South-East Europe and the available policy-oriented tools place the Joint Research Centre (JRC) in a unique position to support sustainable policies in this region.

Based on the EGD targets, soil condition is recognized as a vital element of these five pillars. In particular:

- The vision for healthy soils being developed under the EU Soil Strategy and Legally Binding Soil Restoration Targets that are being developed under the Biodiversity Strategy,
- the EU Climate Law notes the need for **increased sequestration of organic carbon by agricultural soils** as a major component of climate regulation and in mitigation of the effects of emissions,
- more **efficient nutrient cycles** (consequently less pollution of soil and water) and reduction in soil sealing which are explicit objectives of the Circular Economy Action Plan,
- a **Soil Pollution Watch List** together with a Clean Soil Monitoring and Outlook Report are foreseen under the **Zero Pollution Action**,
- sustainable agriculture objectives under the Farm2Fork Strategy are built on balanced soil nutrient management and the **reduction of pesticide residues in soil**,
- Research and innovation challenges set by the Soil Mission under Horizon Europe.

Soil degradation is prevalent and extensive throughout the Western Balkans region (Zdruli *et al.*, 2022). Soils are under pressure, but the intensity of various soil health indicators varies between them and among the countries. It is very difficult to make a regional assessment on the extent of unhealthy soils in the Western Balkans because of the limited data availability. Implementation of a soil protection framework to ensure heathy soils is a priority for the implementation of the Green Deal across the Western Balkans. Data to characterize the overall suite of pressures on soil are largely lacking, making it difficult to quantify the geographical extent of the pressure or establish quantitative trend assessments of overall soil health.

In 2015, the European Commission, under JRC's Enlargement and Integration Programme, launched the first soil sampling in the Western Balkans (Albania, Bosnia and Herzegovina, North Macedonia, Montenegro, and Serbia) as part of the Land Use and Coverage Area frame Survey (LUCAS) survey, collecting 1,015 soil samples. The JRC wishes to publish an assessment of soil characteristics based on the analysis of samples collected during the LUCAS 2015 Survey. The assessment should describe the spatial patterns of soil parameters by biogeographic regions and main land cover types. The purpose of this report is to provide technical support to the publication of an updated soil database for the Western Balkan Region based on LUCAS Soil Module.

2 LUCAS SOIL 2015: Ancillary environmental information for the soil sampling locations

As part of the LUCAS 2015 Survey, a total of 1,015 soil samples were collected across five countries in the Western Balkans (Figure 1, Table 1). This section includes ancillary environmental information (e.g. climate, topographic setting, land cover, soil regions, NATURA 2000 sites, etc.) for soil sampling locations to provide context and insight into the factors that might influence the characteristics of the soil in those specific locations. An additional supplementary dataset containing ancillary environmental information for the soil sampling locations is also available to download from the European Soil Data Centre (ESDAC). This extensive dataset allows for a thorough analysis of environmental variables that may affect soil properties, offering valuable insights into regional soil health and composition.

The geographic coordinate of the location from where a soil sample was taken during the 2015 LUCAS Survey was overlain by a spatial dataset describing an environmental variable. The intersect value from the environmental variable was then assigned to the LUCAS Point. The relevant data sources and some additional considerations are presented below.

Figure 1 Distribution of LUCAS 2015 soil points in Western Balkan

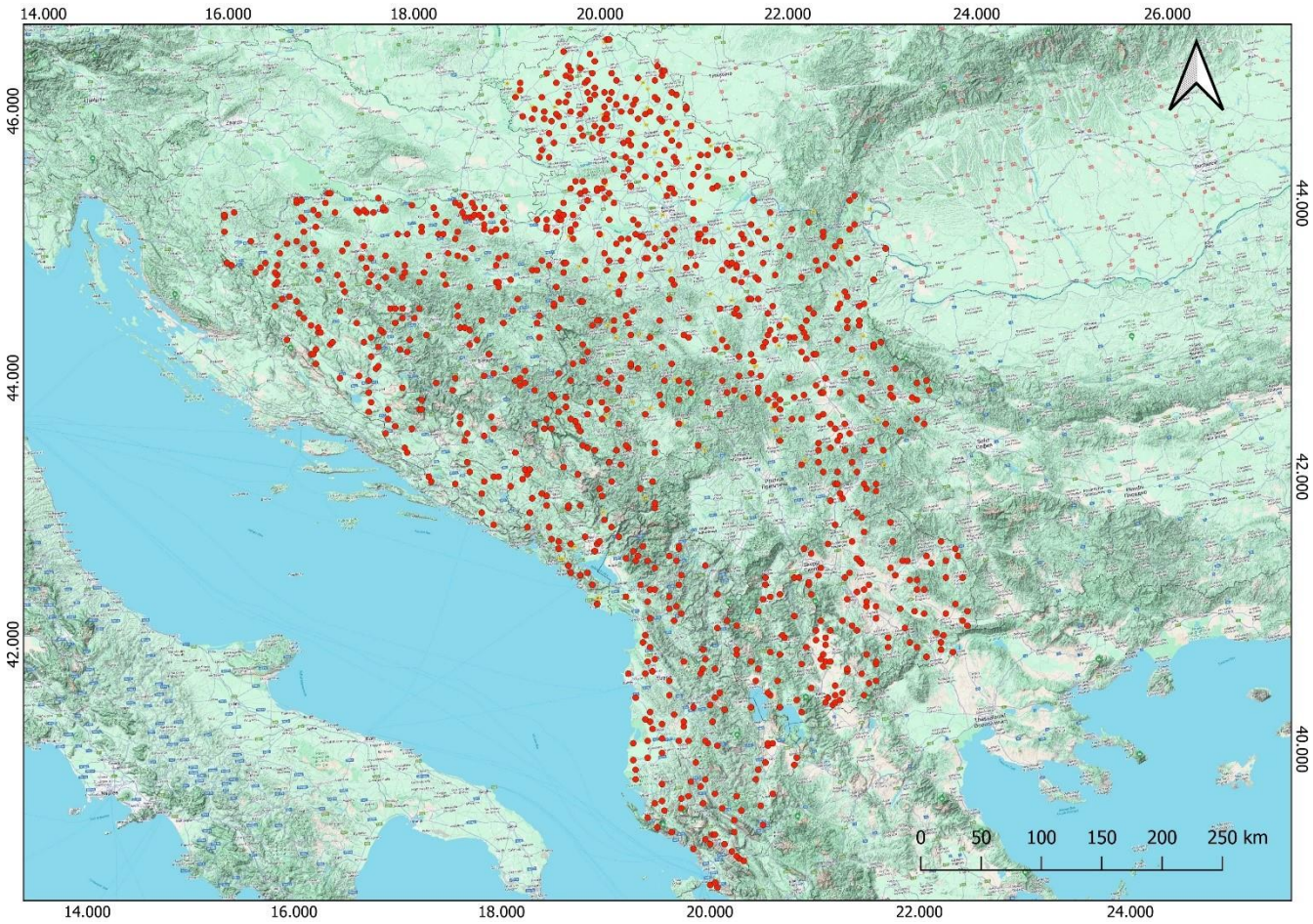


Table 1 Distribution of Western Balkans LUCAS soil points by country.

Country	Number	%
Albania	120	12
Montenegro	120	12
North Macedonia	120	12
Bosnia and Herzegovina	243	24
Serbia	412	40
Western Balkan TOTAL	1015	100

2.1.1 Climate zones

To define the climatic characteristics of the sampled points we used the Main Climatic Zones for Europe map (Beck *et al.*, 2018) . The climatic definition was based on Köppen-Geiger climate zones in the sense that to each LUCAS point a climatic value was assigned (Figure 2).

Figure 2 Distribution of LUCAS points in the Western Balkan region within climatic zones

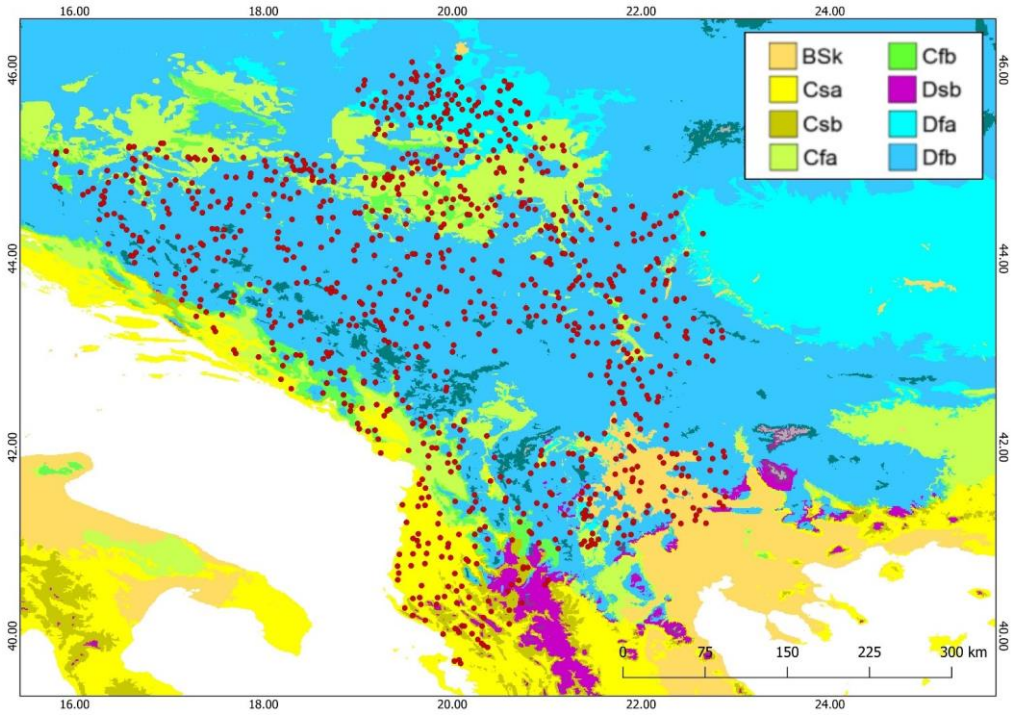


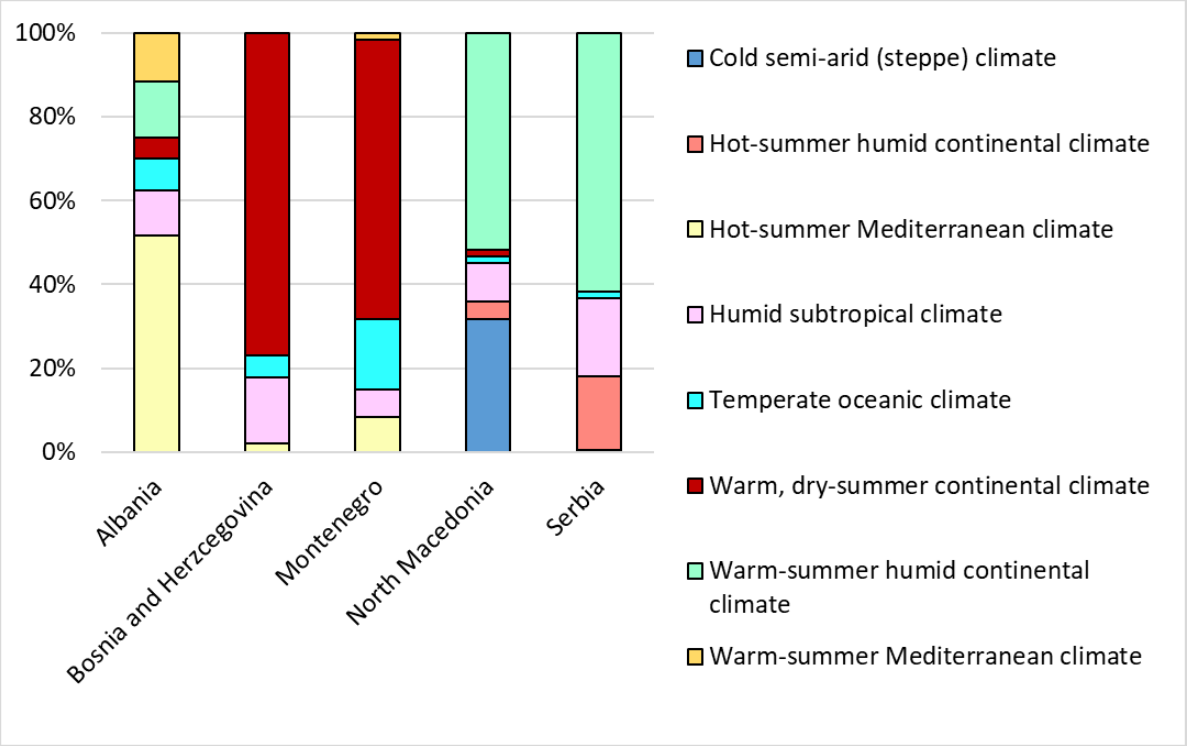
Table 2 illustrates the distribution of Köppen-Geiger climate zones on Western Balkans LUCAS soil points. There is dominance of the Dfb classification (warm-summer humid continental climate), with 599 points accounting for 59% of the total. Additionally, other significant classifications include the Cfa (humid subtropical climate), with 147 points (14.5%), and the Csa (hot-summer Mediterranean climate), with 77 points (7.6%). Less prevalent classifications include the BSk (cold semi-arid climate), with 40 points (3.9%), and the Dsb (warm, dry-summer continental climate), with only 8 points (0.8%).

Table 2 Descriptions of Köppen-Geiger climate zones on Western Balkans LUCAS soil points

Code	**Description**	**Group**	**Number of LUCAS points**	**%**
BSk	Cold semi-arid (steppe) climate	Arid	40	3.9
Cfa	Humid subtropical climate	Temperate	147	14.5
Cfb	Temperate oceanic climate	Temperate	51	5
Csa	Hot-summer Mediterranean climate	Temperate	77	7.6
Csb	Warm-summer Mediterranean climate	Temperate	16	1.6
Dfa	Hot-summer humid continental climate	Continental	77	7.6
Dfb	Warm-summer humid continental climate	Continental	599	59
Dsb	Warm, dry-summer continental climate	Continental	8	0.8

Figure 3 presents the distribution of Western Balkans LUCAS soil points across various climatic zones by country. In Albania, significant representation is observed in hot-summer Mediterranean climate (62 points, 6.1%) and warm-summer Mediterranean climate (14 points, 1.4%). Bosnia and Herzegovina shows substantial presence in warm-summer humid continental climate (187 points, 18.4%), followed by humid subtropical climate (38 points, 3.7%). Montenegro has notable points in warm, dry-summer continental climate (80 points, 7.9%) and temperate oceanic climate (20 points, 2%). North Macedonia exhibits a concentration in cold semi-arid (steppe) climate (38 points, 3.7%), while Serbia in warm-summer humid continental climate (254 points, 25%) and humid subtropical climate (77 points, 7.6%). Some climatic zones are absent or minimally represented in certain countries.

Figure 3 Distribution of Western Balkans LUCAS soil points by country and climatic zone.



2.1.2 Topographic data

The region, considered mountainous in its own right, includes the Dinaric Arc mountain range, which stretches across Albania, Croatia, Bosnia and Herzegovina, Serbia, Montenegro, and Kosovo*. The terrain of the region is complex and spreads over hilly and mountain regions on the south and west, foreshore area on the east, and over a low altitude of the Pannonia Valley on the north, covering an area of 250,000 km^2 (Figure 4).

Figure 4 Elevation map of the Western Balkans

Source: (GRID-Arendal, 2015)

Table 3 illustrates the distribution of elevation ranges among Western Balkans LUCAS soil points across various countries. In Albania, the majority of soil points fall below 500 meters, constituting 60 points (5.9%), followed by the 500-1000 meter range with 41 points (4%). Similarly, Bosnia and Herzegovina shows a significant presence in the below 500 meter elevation range with 122 points (12%), while Montenegro has the least representation in this category with only 16 points (1.6%). Moving on, North Macedonia and Serbia both demonstrate notable soil points below 500 meters with 31 points (3.1%) and 314 points (30.9%) respectively. In the 500-1000 meter elevation range, Bosnia and Herzegovina leads with 75 points (7.4%), followed by North Macedonia with 59 points (5.8%). Notably, Albania has the lowest representation in this category with only 41 points (4%). In the 1000-1500 meter range, Montenegro displays the highest number of soil points with 56 points (5.5%), while Bosnia and Herzegovina follows closely with 46 points (4.5%). Serbia has the least representation in this range with 23 points (2.3%). There are minimal soil points recorded at elevations exceeding 1500 meters, with only 4 points (0.4%) in Albania.

Table 3 Distribution of Western Balkans LUCAS soil points based on elevation

Elevation (m)	Albania	Bosnia and Herzegovina	Montenegro	North Macedonia	Serbia	Total
<500	60	122	16	31	314	543 (53.5%)
500 - 1000	41	75	48	59	75	298 (29.4%)
1000 - 1500	15	46	56	30	23	170 (16.7%)
> 1500	4	0	0	0	0	4 (0.4%)

2.1.3 Biogeographical regions

The entire Western Balkan is a biodiversity hot spot with a characteristic climate, landscapes, and habitats, many of European interest. The region also has a large percentage of forest cover, many free-flowing rivers, creating the conditions for the vast number of habitats. Flora diversity is very present, with a high rate of endemism (10-20% of all the plants are endemic to the region). The karst ecosystem is the largest in Europe and contains a significant underground freshwater reservoir with the most extended network of subterranean rivers and lakes in Europe, as well as wetlands of international importance.

Percentages of the protected areas in the Western Balkan are hardly approaching the 20 % mark and some countries have less than 5 % of their territory under protection, as is the case with Bosnia and Herzegovina. Western Balkan countries are not part of Natura 2000, the largest European network for nature protection, but they are part of the ecological network Emerald. Emerald is an international ecological network composed of a Network of Areas of Special Conservation Interest.

Biogeographical regions are useful geographical reference units for describing habitat types and species which live under similar conditions in different countries. Biogeographical Regions were automatically assigned by extracting values from European Environment Agency (EEA) Biogeographical Regions dataset (EEA, 2016) for each LUCAS point.

There are four biogeographical regions represented in the Western Balkans LUCAS 2015 dataset (Table 4). The Continental biome is the most represented, comprising 429 points, which accounts for 42.3% of the total. The Alpine region, with 251 points, makes up 24.7% of the dataset. The Mediterranean biome with 188 points, contributes 18.5% to the overall distribution. The Pannonian biome exhibits 147 points, representing 14.5% of the total soil points recorded. There are 86 Western Balkans LUCAS soil points within the Emerald Network sites.

Table 4 Distribution of Western Balkan LUCAS soil points in biogeographical regions**.**

Biogeographical region	**Number of WESTERN BALKANS LUCAS points**	**%**
Alpine	251	24.7
Continental	429	42.3
Mediterranean	188	18.5
Pannonian	147	14.5

The summary of the distribution of Bio-geographical regions across Albania, Bosnia and Herzegovina, Montenegro, North Macedonia, and Serbia reveals distinct patterns in each country (Figure 5). Albania exhibits a significant number of points in the Alpine region (21 points, 2.1%) and in the Mediterranean region (99 points, 9.8%). Bosnia and Herzegovina shows dominance of points in the Continental region (108 points, 10.6%), with notable representation in the Alpine region (104 points, 10.2%). In Montenegro, there is considerable presence of LUCAS points in the Alpine region (62 points, 6.1%) and in the Mediterranean region (58 points, 5.7%). North Macedonia has notable representation of LUCAS points in the Alpine region (55 points, 5.4%) and in the Continental region (65 points, 6.4%). Lastly, Serbia stands out with a substantial presence of LUCAS points in the Continental region (256 points, 25.2%) and significant representation in the Pannonian region (147 points, 14.5%). These variations highlight the diverse bio-geographical characteristics across the Western Balkan region.

Figure 5 Distribution of Western Balkans LUCAS soil points across biogeographical regions by country

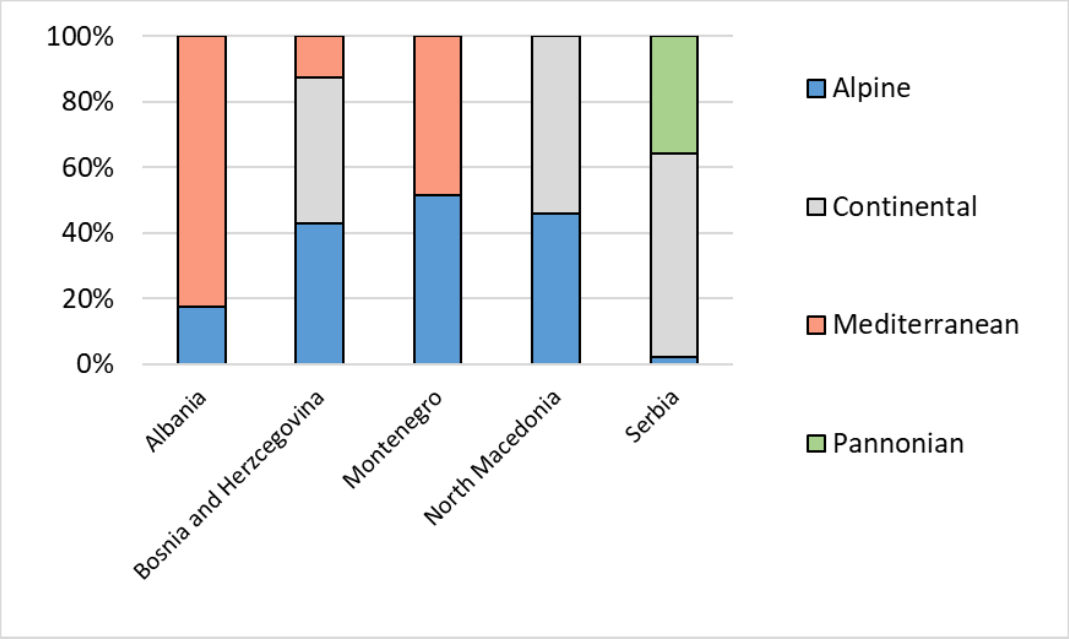


Table 5 outlines the distribution of Western Balkans LUCAS soil points across different biogeographical regions and elevation ranges. In the Alpine region, the majority of soil points are found in the 500-1000m elevation range (128 points, 12.6%), followed by the 1000-1500m range (105 points, 10.3%). In the Continental region, the most common elevation range is below 500m (296 points, 29.2%), with fewer points in the 500-1000m range (101 points, 10%). The Mediterranean region also sees a significant number of soil points below 500m (84 points, 8.3%), with substantial representation in the 500-1000m range (69 points, 6.8%). Notably, the Pannonian region shows a concentration of soil points below 500m (147 points, 14.5%). However, there are only four soil points at elevations above 1500m.

Table 5 Distribution of Western Balkans LUCAS soil points across biogeographical regions and elevation

Bio-geographical region	**Alpine**		**Continental**		**Mediterranean**		**Pannonian**	
Elevation (m)	Number	%	Number	%	Number	%	Number	%
<500	16	1.6	296	29.2	84	8.3	147	14.5
500-1000	128	12.6	101	10	69	6.8	0	0
1000-1500	105	10.3	32	3.2	33	33	0	0
>1500	2	0.2	0	0	2	0.2	0	0

2.1.4 Land cover data

CORINE Land Cover (CLC) dataset is a component of the European Environment Agency's Copernicus Land Monitoring Service. In its current form, CLC product offers a pan-European land cover and land use inventory with 44 thematic classes. The dataset has a Minimum Mapping Unit (MMU) of 25 hectares (ha) for areal phenomena and a Minimum Mapping Width (MMW) of 100 m for linear phenomena and is available as vector and as 100 m raster data. The product is updated with new status and change layers every six years—with the most recent update made in 2018. CORINE Land Cover was automatically assigned by extracting values from the Copernicus Land Monitoring Service for each Western Balkan LUCAS point (EEA, 2020).

An analysis of land cover data shows that Western Balkans is a very rich and diverse region. The regional composition of the land cover mosaic is influenced by many biogeographical and socioeconomic factors. Natural and climatic factors form the basis for land cover by setting the boundaries within which different land cover types coexist in regional patterns. Land cover is also the basis for socio-economic activities and hence influences land use in the area. Land cover and land use are in constant interaction.

Some conclusions can be drawn from analyzing land cover in Western Balkans (Vidojevic *et al.*, 2022):

— Forest and semi-natural areas have the largest share of the land in the region (55.5%), followed by Agricultural areas with 40.0%.

— Montenegro has the largest share of Forest and semi natural areas in the region (79.2%), and Serbia has the largest portion of Agricultural areas (55.1%).

— More than 2.8 % of Western Balkans land is used as Artificial areas, which includes built-up areas and unbuilt surfaced areas such as transport networks and associated areas.

The Land Cover distribution of the LUCAS point's data for the Western Balkans region (Figure 6) shows agricultural areas as the dominant land cover type surveyed, particularly in Serbia, constituting 27.6% of the total points. Forest and semi-natural areas are also present, notably in Bosnia and Herzegovina and Serbia. Point in artificial areas and water bodies are minimal.

Figure 6 Distribution of Western Balkans LUCAS Soil points per CLC class – Level 1 and per country

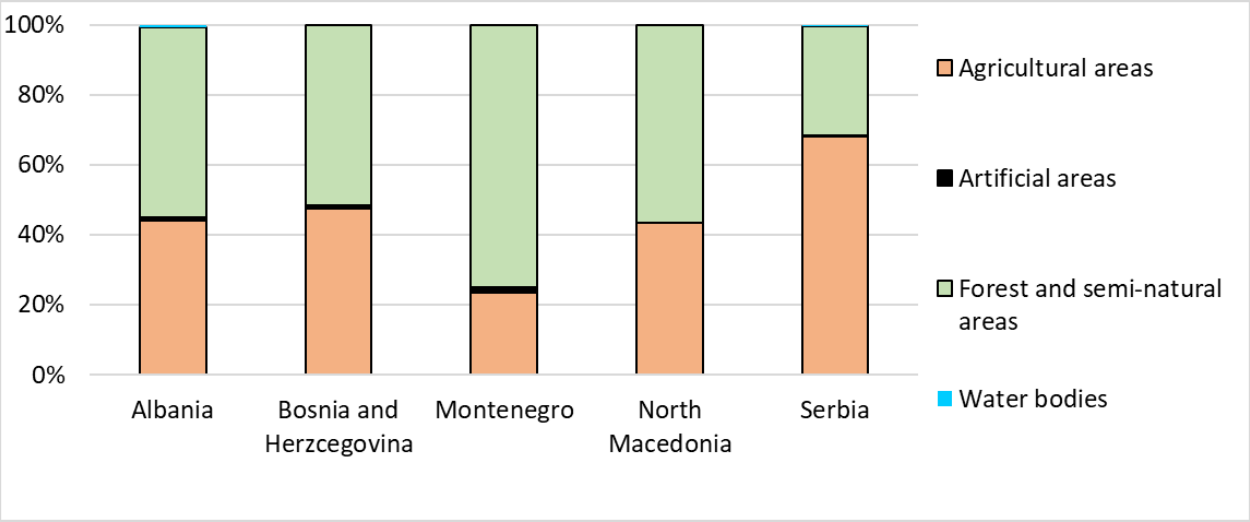


Table 6 shows the distribution of Western Balkans LUCAS Soil points per CLC classes – Level 3. Non-irrigated arable land dominates the distribution of LUCAS points, comprising 26.8% of the total points, followed by broad-leaved forest at 24%. Land principally occupied by agriculture with significant areas of natural vegetation and transitional woodland-shrub also contribute significantly, with 10% and 9.4% respectively. Other notable categories include complex cultivation patterns, pastures, and natural grasslands, each accounting for around 4% of the points.

Table 6 Distribution of Western Balkans LUCAS Soil points per CLC classes – Level 3

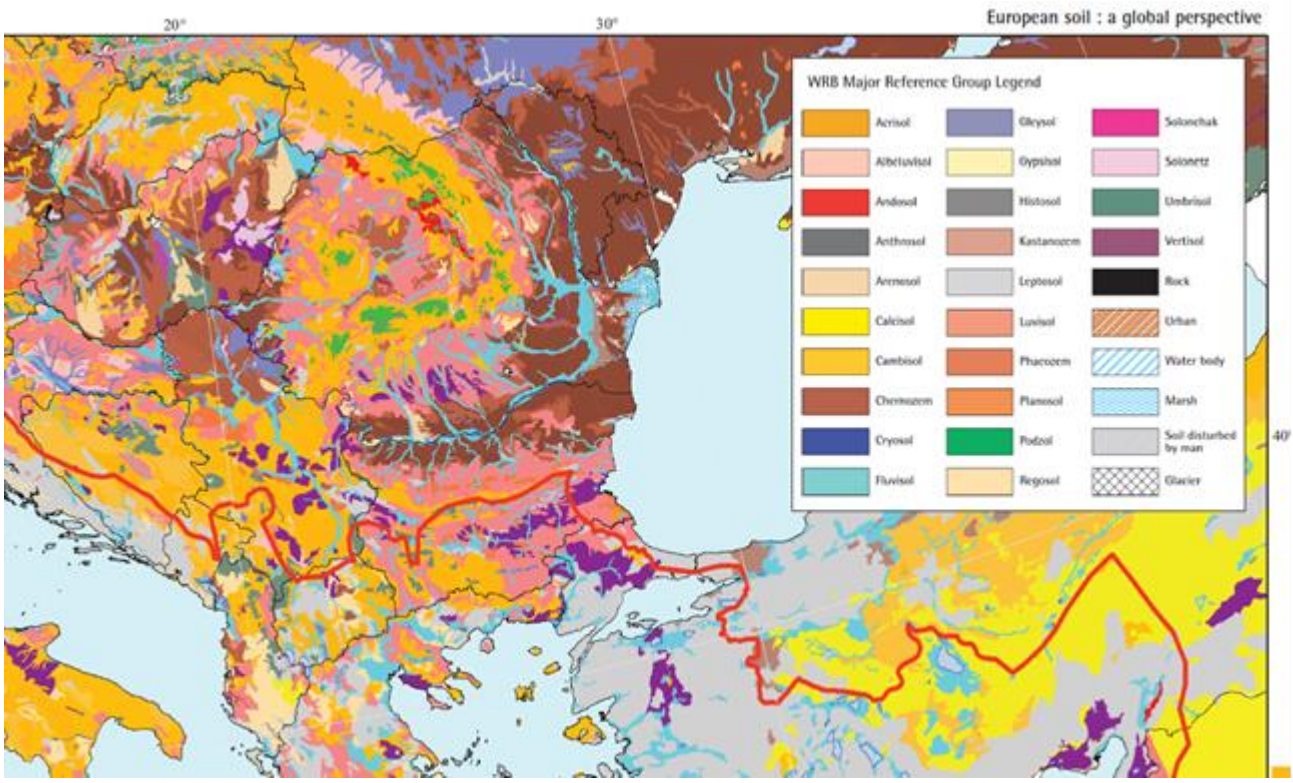
CLC Code	CORINE Land Cover class level 3	Number LUCAS points	% LUCAS points
112	Discontinuous urban fabric	5	0.5
121	Industrial or commercial units	2	0.2
142	Sport and leisure facilities	1	0.1
211	Non-irrigated arable land	272	26.8
212	Permanently irrigated land	8	0.8

221	Vineyards	4	0.4
222	Fruit trees and berry plantations	5	0.5
223	Olive groves	4	0.4
231	Pastures	45	4.4
242	Complex cultivation patterns	88	8.7
243	Land principally occupied by agriculture with significant areas of natural vegetation	102	10
311	Broad-leaved forest	244	24
242	Complex cultivation patterns	88	8.7
243	Land principally occupied by agriculture with significant areas of natural vegetation	102	10
311	Broad-leaved forest	244	24
312	Coniferous forest	29	2.9
313	Mixed forest	38	3.7
321	Natural grasslands	42	4.1
323	Sclerophyllous vegetation	15	1.5
324	Transitional woodland-shrub	95	9.4
331	Beaches - dunes - sands	2	0.2
333	Sparsely vegetated areas	9	0.9
334	Burnt areas	2	0.2
511	Water courses	3	0.3

3 Dominant soil groups

Soils of the Western Balkans are the result of the pedogenetic process dominated by lithology, topography and climate that play a dominant role in soil formation. The large diversity is represented by Cambisols, Luvisols, Chernozems, Kastanozems, Phaeozems, Umbrisols, Fluvisols, Gleysols, Histosols, Arenosols, Calcisols, Leptosols, Regosols, Vertisols, Solonchacks, Solonetz, Anthrosols, and Technosols (Figure 7).

Figure 7 General representation of the soil distribution in the Western Balkans. The red line shows the delineation of the Mediterranean watershed.



Source: (European Commision, 2005)

Cambisols, Luvisols, Chernozems, Kastanozems, Phaeozems, Umbrisols, and Fluvisols are very fertile soils, typical for flatlands as well as uplands and are used mostly for cereals, horticulture, fruit trees, olives, vines, and forage crops providing higher yields even with minimum inputs. However, they are under pressure from urban expansion, soil sealing, compaction, pollution and (perhaps) over fertilization causing chemical pollution.

Leptosols and Regosols are mostly located in the uplands and the mountain regions. They are often covered with forests, shrublands and natural pastures. Erosion and landslides are a problem, exacerbated by forest fires, and overgrazing. Histosols cover relatively small areas, Arenosols usually follow the coastal sand dunes, Solonchacks and Solonetz most widely found in Albania, North Macedonia, and Serbia, while Vertisols are also evident throughout the region. Gleysols have limited extent typically found in former drained wetlands and in depressions while Calcisols usually are found in the hilly areas of Albania, Montenegro and at limited extent all over the region. Large parts of them are used for the cultivation of olive groves and vines. Finally, Anthrosols and Technosols cover limited areas compared to other soils but are widely distributed in the vicinity of large urban areas as the best testimony of the urban sprawl.

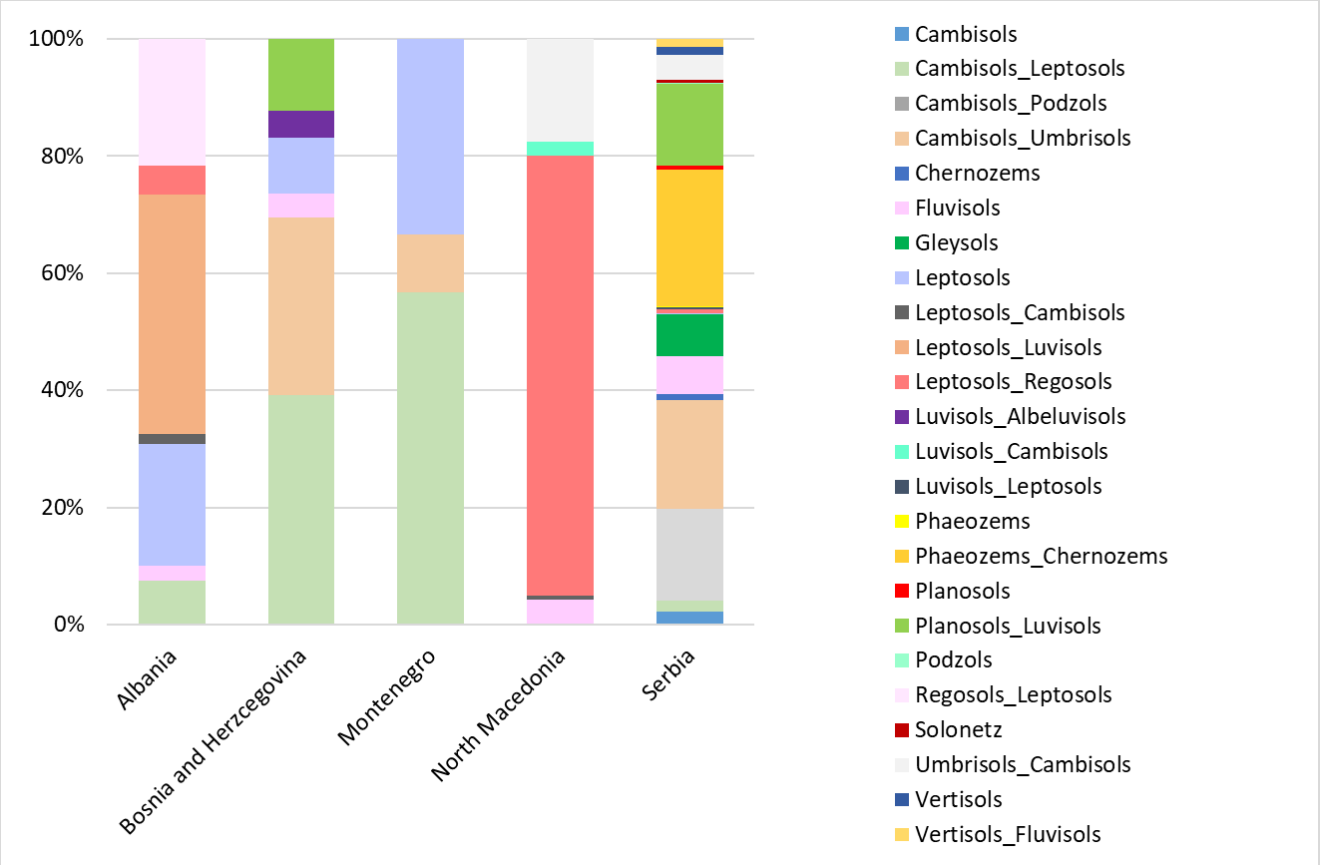
Dominant Soil Group has been assigned by extracting values from the Soil Regions of the European Union and Adjacent Countries dataset (BGR, 2005) at a scale of 1:5,000,000 for each LUCAS point. Soil regions are natural, cross-regional soil geographical units, which perform the highest spatial and content-based aggregation of European soils. For the 77 points where there was a justified suspicion that they did not belong to the appropriate soil group, the dominant soil group was assigned manually using the national soil maps. Table 7 shows the distribution of Western Balkans LUCAS soil points per dominant soil groups. The data highlights significant representation of Cambisols Leptosols, constituting 17.7% of the total points, followed by Cambisols Umbrisols (16%). Leptosols Regosols and Phaeozems Chernozems each account for 9.8% and 9.5% respectively. Other soil groups include Leptosols, Fluvisols, and Planosols Luvisols, ranging from 8.6% to 8.8%. Some soil groups have very few points, such as Solonetz (2 points, 0.2%), Podzols (1 point, 0.1%), and Luvisols Leptosols (1 point, 0.5%). It should be stressed that due to the very small scale of the European Soil Regions dataset, the assigned soil type is indicative of regional characteristics and does not necessarily reflect local conditions at the actual LUCAS point. All countries that participated in the LUCAS 2015 campaign have their own national soil maps on a scale of 1:50,000.

Table 7 Distribution of Western Balkans LUCAS soil points per dominant soil groups.

Dominant soil groups	**WESTERN BALKANS LUCAS points (number)**	**WESTERN BALKANS LUCAS points (%)**
Cambisols	9	0.9
Cambisols Leptosols	180	17.7
Cambisols Podzols	64	6.3
Cambisols Umbrisols	163	16
Chernozems	4	0.4
Fluvisols	45	4.4
Gleysols	29	2.8
Leptosols	89	8.8
Leptosols Cambisols	3	0.3
Leptosols Luvisols	49	4.8
Leptosols Regosols	99	9.8
Luvisols Albeluvisols	11	1.1
Luvisols Cambisols	3	0.3
Luvisols Leptosols	1	0.5
Phaeozems	1	0.1
Phaeozems Chernozems	96	9.5
Planosols	3	0.3
Planosols Luvisols	87	8.6
Podzols	1	0.1
Regosols Leptosols	26	2.6
Solonetz	2	0.2
Umbrisols Cambisols	39	3.8
Vertisols	5	0.5
Vertisols Fluvisols	6	0.6

Figure 8 provides a breakdown of Western Balkans LUCAS soil points by dominant soil groups across countries. Leptosols are prevalent across several countries, with significant percentages in Bosnia and Herzegovina (2.3%), Montenegro (3.9%), and North Macedonia (0.1%). Conversely, Cambisols Umbrisols exhibit considerable presence in Bosnia and Herzegovina (7.3%) and Serbia (7.6%). Fluvisols are noteworthy in Albania (0.3%) and North Macedonia (2.7%), while Phaeozems Chernozems dominate in Serbia (9.5%). Planosols Luvisols have a notable presence in Bosnia and Herzegovina (3%) and Serbia (5.6%).

Figure 8 Distribution of Western Balkans LUCAS soil points by country and dominant soil groups



Albania

The Albanian pedological landscape is very diverse. The dominant soils are Cambisols cover 30.5%, Luvisols cover 25.2%, Regosols cover 13.2%, Phaeozems cover 10.5%, Leptosols cover 8.8%, followed by the rest of the soil types (Vidojevic *et al.*, 2022). Most LUCAS Soil points in Albania occur in areas where Leptosols tend to predominate, followed by Regosols, Cambisols and Luvisols. Description of the dominant soils at LUCAS points is provided according to (Zdruli *et al.*, 2022):

— **Leptosols** are found all around the country from sea level to the highest mountains. Particularly they are widespread in the northern mountains of the Alps, to the Ionian Riviera and in the extreme south of Albania.

Geology: over compact basic, intermediate, and basic ultrabasic and carbonate rock. The morphologic properties of Leptosols are distinguished by weak horizontal differentiation, shallowness, and skeletonization of the profile. Its chemical and physical properties are dependent on the characteristics of the geological substrate. Although geology is the dominant factor of its properties, the formation of Leptosols is also related to the relief conditions and vegetation cover. Leptosols are not cultivated because of unsuitable chemical and physical characteristics (shallow soil, low water and nutrient holding capacity), but they are suitable for grazing and forestry development. Erosion is very high, which also results from their extension being on the steep areas of the mountains.

Photo 1 Leptosols (Location: Pogradec municipality)

Source: Sustainable Management of Agriculture Soil Program

— **Regosols** are distributed in the mountainous area of the northern, center and southern parts of the country.

Geology: Unconsolidated, generally fine-grained material. Parent materials, climate, vegetation and topography are factors of soil formation of Regosols. These soils are developed mainly on slopes and other eroded terrains. Regosols is represented by A horizons with subangular blocky structure, moderate development, clear wavy boundary, underlined by several C horizons, structure absent, clear undulating boundary and strong effervescence reaction to HCl. Regosols have little agricultural potential production and rarely support forest cover or pastures.

Photo 2 Regosols (Location: Pukë municipality)

Source: SIS Albania Project

— **Cambisols** are dominant soils in Albania and cover approximately 31% of the territory. They are found in all kinds of environments from flat coastal areas up to the high mountains and under a high diversity of vegetation types. They best characterize the relatively young age of the soils of Albania. Geology: They are derived mainly from medium and fine-textured parent materials derived from a wide range of rocks, mostly in colluvial, alluvial or aeolian deposits.

Main soil-forming processes of Cambisols are dissolution and removal of carbonates, alteration of primary minerals, formation of silicate clay and aggregation. The `typical' Cambisol profile has an ABC horizon sequence with an ochric, mollic or umbric A-horizon over a cambic B-horizon that has normally a yellowish-brown color but that may also be an intense red. Cambisols in poorly drained terrain positions may show `redoximorphic' features. The soil texture is loamy to clayey. Signs of beginning clay illuviation may be detectable in the cambic horizon but the clay content is normally still highest in the A-horizon. Cambisols are productive soils used for many uses.

Photo 3 Cambisols (Location: Cërrik municipality)

Source: Sustainable Management of Agriculture Soil Program

— **Luvisol** are the second most important group of soils in Albania. They have a fairly large extension and are found both on the hills and on the plains area.

Geology: Luvisols are formed over a wide range of geological formations comprising acidic, neutral, and basic rocks. They are formed under different climatic regimes that range from cool temperate to warm.

Luvisols have pedogenetic differentiation of clay content, with a lower content A horizon, and a higher content in the B horizon with subangular blocky structure, moderate development, and gradual smooth boundary. Luvisols are fertile soils and they are suitable for a range agricultural uses (crops, fruit trees, olives, etc).

Photo 4 Luvisols (Location: Dibër municipality)

Source: Sustainable Management of Agriculture Soil Program)

Bosnia and Herzegovina

Regarding soil types in Bosnia and Herzegovina, automorphic soils are the most represented, and they cover 86% of the total area of Bosnia and Herzegovina, while hydromorphic soils occupy the remaining 14%. The most widespread soil group is Leptosols, in national classification Calcomelanosol (Cambicsoil on limestone and dolomites) which covers 21.45%; Dystric Cambisol (acid brown soil) which covers 17.71%, and; Calcocambisol (brown soil on limestone) on 17.15% of the territory. The most widespread hydromorphic soils are the Fluvisol and Pseudogley soil types (Vidojevic *et al.*, 2022). A description of the dominant soils at LUCAS points is provided according to Resulovic, 2008 and (Kapovic Solomun & Markovic, 2022).

Most LUCAS Soil points in Bosnia and Herzegovina occur where Cambisols tend to predominate, followed by Leptosols and Luvisols.

Federation of Bosnia and Herzegovina

— **Cambisols** are characterized by their cambic B (brown) horizon, which is formed by the further evolution of the class of humus-accumulative soils. Cambisols are represented on all relief forms and in all parts of the Federation of Bosnia and Herzegovina. They constitute the most dominant group of soils in Bosnia and Herzegovina and occupy about 40% of the surface in relation to all other soils in the Federation of Bosnia and Herzegovina.

Geology: They are formed on different geological substrates. On solid limestones and dolomites (Leptic Cambisols or Rhodic Cambisols formed in the conditions of the Mediterranean climate). On quartz-silicate substrates (District Cambisols). On carbonate and base-rich substrates, but not on hard limestones and dolomites (Eutric Cambisols). According to fertility, they are different: from fertile (Rhodic Cambisols, Eutric Cambisols) to poorly fertile (Distric Cambisols). Their pH reaction is also in the domain of acidic-neutral to alkaline. They are shallow to medium deep in depth. Cambisols are used both in agriculture and forestry. Some of them, for more intensive use in agriculture, require greater agrotechnical measures such as fertilization and calcification (District Cambisols).

Photo 5 Distric Cambisols (Location: Nišići-Sarajevo)

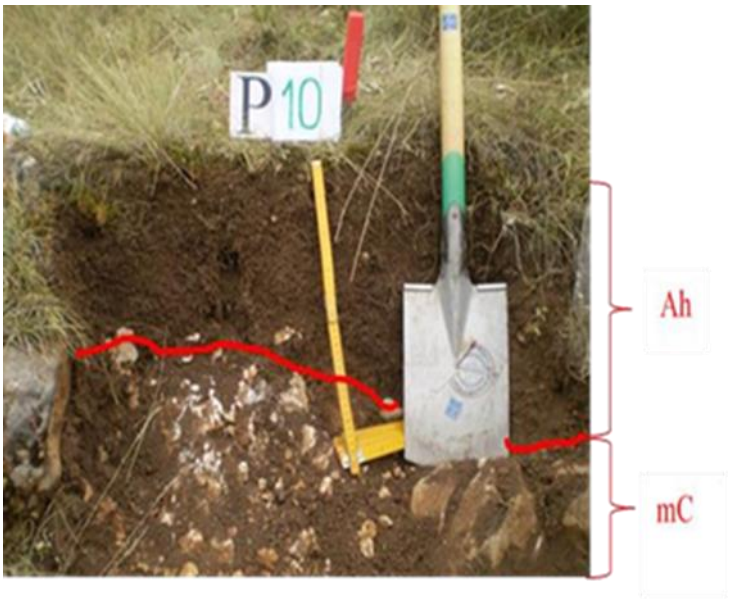
Source: M.Tvica

— **Leptosols** include very shallow soils formed on hard rock or are somewhat deeper soils that are extremely gravelly and/or stony with an A(B)R- or A(B)C-profiles with a thin A-horizon. These soils have an incomplete solum without clearly defined morphological features. According to the valid national classification in Bosnia and Herzegovina, this group of soils includes: Leptosols, Nudilithic (Kamenjar or Lithosol); Leptosols, Rendzic, Molic (Kalkomelanosol or Krečnjačko dolomitna crnica); Leptosols, Distric, Eutric, (Ranker). They are mostly found in mountainous areas, on steep slopes with marked erosion and they are represented in all climate zones. In FB&H they occupy areas of 597,059.02 ha or 22.93% of the total area.

Geology: These soils were formed on limestone, dolomite, or silicate rocks.

They have weakly expressed horizons, the depth of the upper humus horizon, if developed, is no deeper than 25 cm (Leptosol, Rendzic, Mollic), and in the case of Leptosols, Nudilithic, this depth is only a few centimeters. The physical and chemical characteristics of this soil depend exclusively on the geological base. They are mostly well-drained soils, but due to their shallowness and skeleton, they generally retain water poorly. Leptosols have potential for grazing in the wet season and as woodland. Erosion, altitude, shallowness of the humus horizon and skeletal structure are the main limiting factors for the successful use of these soils. However, there are also Leptosols that are somewhat more fertile or on which, with appropriate agrotechnical and other measures, it is possible to achieve that.

Photo 6 Leptosols Rendzic, Molic (Location: Krupa brook, near Pazarić, Sarajevo)



Source: E. Trako

— **Luvisols** are rich in clay, especially in the subsurface horizon. Below the surface Ah horizon, there is an E (eluvial) horizon from which the clay is washed down to an accumulation B (argic) horizon. They are formed on relatively favorable flat surfaces in a humid climate, but also at altitudes of 400 to 800 m above sea level. Therefore, the largest surfaces under the Luvisols are in the northern areas of BiH, from Bihać to Bjeljina. In other parts of BiH, it occurs sporadically and on smaller areas. They cover about 4.23% of the Federation of Bosnia and Herzegovina.

Geology: Parent material: a wide variety of unconsolidated materials including glacial alluvial and colluvial deposits or on quartz and sandy substrates. Luvisols have typically a brown to dark brown surface horizon over a (greyish) brown to strong brown or red argic subsurface horizon. Luvisols have favorable physical properties; they have granular or crumb surface soils that are porous and well aerated unless there is water stagnation that develops gley soil properties in and below the argic horizon. The chemical properties of the soil are favorable for the cultivation of most cultivated plants. Thus, the pH value is slightly acidic, and the properties of the adsorptive complex are very good in the Bt horizon. They contain a few percent organic matter.

Luvisols are favorable soils for successful crop production.

Republic of Srpska

- **Leptosols** includes a wide variety of soils with greatly differing chemical and physical properties.

Nudilithic Leptosols are undeveloped shallow, thin soils in mountain regions where frost disintegration is probably the main factor in the mechanical disintegration of rocks, and in high mountains, stony detritus can represent glacial relict. Another area of their greater distribution is the Mediterranean karst region. The dominance of the stone fraction gives the basic stamp to the physical properties of the rock solum. They are characterized by extreme water permeability and almost complete inability to retain water. Due to the minimal contact with the liquid phase, the chemical processes related to the solid phase are completely reduced, and therefore the differences in the mineral and chemical composition of the substrate do not come to the fore here.

Soils of minimal fertility, have no agricultural and forest economic significance, but are significant for nature protection or for aesthetic-recreational reasons (greening of coastal landscapes).

Mollic Leptosols are shallow, thin soils with an A-R soil profile, on hard and clean Mesozoic limestones and dolomites. Distribution is widespread on all limestone and dolomite mountains, in the Republic of Srpska (Manjača, Jahorina, Romanija, Javor, et.), occupying mostly higher mountain belts, at an altitude above 700 meters, but on steep slopes, they can also occur in very low belts. Morphologically, they are characterized by a clear and sharp transition between horizons. Shallow soils have little ability to retain water. The properties depend to the greatest extent on the degree of development. In the initial stages of development, their depth is only a few centimeters, and at full maturity it reaches up to 30 cm. Parallel to these quantitative changes, the quality of the soil changes, because the highly organogenic humus horizon of the initial stages is gradually enriched with mineral substances, which leads to the formation of an organo-mineral complex as a new quality. This breaking point divides this soil into two subtypes: organogenic and organomineral. The plants that grow on these soils depend to a large extent on the amount and distribution of atmospheric precipitation. As they are distributed over a large latitudinal and altitudinal interval, they can be extremely xerothermic habitats (dry regions, lower zones, southern exposures), and also mesophilic habitats (humid areas, higher zones and northern exposures). The productivity of these soils is not high on average.

Photo 7 Mollic Leptosols (Location: Javor mount, Han Pijesak, Republic of Srpska)

Source: Marijana Kapović Solomun

Eutric, Dystric Leptosols have a mollic, umbric or organic horizon, which most often lies directly on the hard rock occupy quite large areas on high silicate mountains, mainly in the eastern parts of Republic of Srpska. They are most widespread in the ophiolitic zone, especially on peridotites, on mountains: Kozara, Ljubić, Borja, Maglić, etc. and in the hilly parts near those mountains. Mostly shallow soils. The depth of the lithic varieties ranges from a few to 20-30 cm, and the entire solum of them also consists only of the humus horizon. A high skeleton content, usually 20-40%, is a common feature of almost all these soils. The physical, and especially the chemical, characteristics of rankers are variable, depending on the substrate on which they occur. These soils are mainly under grass vegetation or under forests.

Photo 8 Eutric, Dystric Leptosols (Location: Borja, Teslić, Republic of Srpska)

Source: Mihajlo Marković

Rendzic Leptosols are humus-accumulative soil, formed on carbonate parent material, mostly loose. Humus-accumulative horizon is carbonated, except in leached and browned forms in which it is non-carbonated, with the depth up to 40 cm. They are most abundant on the flysch series with marls in the valleys of the Dinaric Mountains and in the peripheral zone of the Pannonian Plain (northern part of Republic of Srpska, then Herzegovina area. On the dolomite are most widespread in the Vrbas and Drina basins and on mountains: Manjača, Čemernica, Lisina, Zelengora, etc. In the high limestone mountains above 1500 meters, in the zone of relict glaciers, there are moraine deposits with these soils. On the loess they have local distribution and are related to the lower areas of the Pannonian Plain. Physical properties vary widely. While on dolomite are loamy sands, on marl are usually clayey, and on moraine are always very skeletal. On loess has the most favorable clay composition. The chemical properties are very similar, because they are decisively influenced by the presence of active carbonates. The concentration of nutrients (N, P, K) is medium to high, but their total amount is sometimes limited if the profile is shallow.

As the eutrophic habitats, they are used predominantly in agricultural production (vineyards, orchards, grass, etc.). They are suitable for all types of forest trees, except for those that are sensitive to a high content of active carbonates.

— **Cambisols** encompass a diverse group of soils and occur in a wide variety of environments around the Republic of Srpska.

Eutric Cambisols are with horizon differentiation, visible in colour, texture, structure, and carbonate content. The main regions of distribution in the Republic of Srpska, are in the north and eastern flat areas (Lijevče polje and Semberija), slightly undulating hilly terrains up to 600 m altitude, then on mountains: Kozara, Borja, Javor etc. When they are formed on the peridotites, occupy mainly sandy and steep slopes up to 1000 m above sea level.

The formation and maintenance of these soils are best suited to loamy, normally drained substrates, rich in bases, such as loess, loamy lake and river sediments, neutral and basic eruptive rocks, etc. A specific variant of eutric cambisols is formed on ultrabasic rocks. These soils have favorable physical properties (good drainage, moderate field water capacity, favorable air regime). In varieties formed on compact substrates, especially in mountainous regions, the presence of skeletons in the profile can be significant (up to 70% by volume), which reduces the volume of the active soil layer and its productivity. The chemical properties are also very favorable, because they are weakly acidic to neutral soils, with a high degree of base saturation (70-80%) and a fairly high cation adsorption capacity.

The content of humus in forest soils is usually 4-7%, which, given the significant depth of the humus horizon, means a high reserve of humus of favorable quality. The content of nutrients is quite dependent on the parent substrate.

These soils, especially the varieties formed on leveled terrains and on deep loose substrates (on loess, lake sediments and alluvial-colluvial sediments), have been used as agricultural soils, suitable for growing all kinds of agricultural crops. Regolitic and Vertic varieties, in mountains and on slopes belong to the class of the best forest soils.

Dystric Cambisols are soils with horizon differentiation, evident in color, texture, structure, and carbonate content, formed on acidic parent material: sandstones, phyllites, clays, acidic eruptive and other quartz-silicate rocks. Those soils are the most widespread soils in hilly and mountainous regions of the Republic of Srpska, especially in western humid areas, but also in eastern areas, between 250-1,300 m above sea level. Those soil are deeper than 30 cm, most often 60-80 cm. The texture varies depending on the nature of the substrate, but it is most often sandy-loamy, with the frequent presence of a larger or smaller amount of skeletons. The content of humus varies a lot and mostly depends on the altitude, the content of clay and the slope of the terrain. The nitrogen content varies in parallel with a humus content in the range of 0.2-1%, and the C:N ratio is around 15 or more. The reaction of the soil is acidic and is usually around 4.5-5.5, and the degree of saturation with bases usually varies from 30-50%.

These soils are mainly under forest vegetation (beech zone; beech, fir and spruce zone; etc.).

Leptic Cambisols are formed on pure limestones and dolomites, which are mostly karstified. The entire solum is non-carbonated. It has a characteristic loamy or heavier granulometric composition and a very well-defined polyhedral structure. Distribution is widespread on all the limestone-dolomite mountains of the Republic of Srspka, occupying mostly medium-altitude zones and gentler slopes, and on leveled karst surfaces these soils have a medium-deep solum. The main distribution area of these soils is the central and outer parts of the Dinarides. Those soils are characterized by great spatial variability in depth. Generally have a heavier texture. The content of humus in them varies considerably. In the lower bands and on soils without forest cover, the humus horizon contains up to about 5% humus, and in higher regions and under forest, the humus content is more than 10%, while with the appearance of transitional humus, it exceeds 20%. They are carbonate-free, and carbonates can only appear in the form of a thin membrane in contact with the limestone skeleton. pH of the A horizon is most often in the interval of 5.5-6.5, and in the (B) horizon it is always higher and is in the area of neutral reaction. They have a high adsorption capacity, and the degree of saturation with bases is more than 50%, usually in the range of 60-80%. They are poorly supplied with phosphorus (most often below 1 mg/100 g), while the K2O content is quite high (10-20 mg/100 g and more). Those soils are mainly forest soils.

Rodic Cambisols, “terra rossa” includes soils of the Mediterranean and sub-Mediterranean area. These soils received name after its extremely red color, which comes from the mineral hematite. In the Republic of Srpska, on sub-Mediterranean karst, i.e. in the territory of Herzegovina, present on hard limestones and dolomites, more leveled areas and sinkholes. There are also these soils in the continental part of the Republic of Srpska. The height distribution generally does not exceed 500 meters above sea level. The relief is extremely karst. The basic specific pedogenetic process in the red rock is rubification. The content of humus of the low littoral belt is 1-2%, and in the sub-Mediterranean region the reds can have more than 4% of humus. Under normal conditions, the soil is carbonate-free, but secondary accumulation of $CaCO_3$ up to several percent can occur (especially in contact with flysch formations). The reaction is usually neutral, less often weakly acidic (pH 6-7), and the degree of base saturation is usually above 80% with a relatively high adsorption capacity (35-60 equivalents of millimoles H/100g). Scarce in nitrogen, which is related to the relatively low content of humus, and it is extremely poor in accessible forms of phosphorus (about 1mg/100g). The K_2O content is medium (10-20 mg/100g).

In the sub-Mediterranean region (Herzegovina area) used for the cultivation of intensive agricultural crops (tobacco, vineyards, orchards, vegetables), where intensive fertilization and often irrigation is applied. Shallow and eroded varieties is present under natural forest vegetation and it is usually maquis with low production potential.

— **Luvisols** are developed soils, with higher clay content in the subsoil than in the topsoil, as a result of pedogenetic processes (especially clay migration) leading to an argic subsoil horizon. Distribution is widespread in the Republic of Srpska, on loess plateaus, on old river and lake terraces and on other flat and slightly undulating terrains. In limestone regions, these soils are occupied by karst plains and sinkholes. They most often occur in the zone from 200 to 1,000 m above sea level.

  Formed on loamy parent materials or on rocks whose decay can lead to the formation of a deeper loamy profile. The most common substrate is loess, followed by old alluvial and lake deposits, glacial deposits, etc. The humus content under the forests is 3-5% in the lower zones, and up to 10% in the higher regions, while with the appearance of the semi-raw type, the humus content can be more than 20%. On arable soils, humus ranges from 1-2%. The reaction is weakly to moderately acidic (pH 5-6, rarely below 5), with depth it can slightly increase, but also decrease. The degree of base saturation is usually 40-70% and with depth it usually shows similar changes as the pH value. Luvisols are moderately supplied with nitrogen and potassium, while the content is affordable phosphorus is very low. Their natural vegetation consists mostly of oaks, and less often of beech-fir-spruce forests. Luvisols at lower altitudes ("in the oak belt"), whether they are on silicate or limestone parent substrates, are mainly used for agricultural production.

Montenegro

Based on the Soil Map of former Yugoslavia at a scale of 1:50000, the most common types of soil in Montenegro are Calcomelanosol (47%) and Dystric Cambisol (28%), followed by Eutric Cambisol (8%), Terra Rossa (6%), Fluvisols (2,4%), Rendzina (2,2%), while other soil types cover the remaining area (Vidojevic *et al.*, 2022). A description of the dominant soils at LUCAS points is provided according to Buric et al., 2017. Most LUCAS Soil points in Montenegro occur where Cambisols tend to predominate, followed by Leptosols.

— **Cambisols** in Montenegro encompass a diverse group of soils, including Brown dystric (acid) soil (Dystric Cambisol), Red soil (Terra rossa), Eutric brown soil (Eutric Cambisol), and Brown soil on limestone (Calcocambisol). These soils collectively cover a substantial area, around 550,000 hectares, exhibiting variations in depth, fertility, and geological origins. Cambisols are characterized by a developed brown or cambic (B) horizon, influenced by factors such as parent substratum, climate, and topography. Cambisols are widespread in Montenegro, with Brown dystric soil dominating the northeastern part of the country, Red soil forming in zones influenced by the Mediterranean climate, Eutric brown soil found in river valleys and various substrata, and Brown soil on limestone primarily appearing on pure limestone and dolomites, often in karstified terrains. The distribution varies based on geological conditions and altitudinal gradients. Cambisols form over a variety of substrata, including silicate rocks with low base ions, pure limestone under Mediterranean climate influence, various substrata like alluvium, sand, gravel, and flysch and pure limestone and dolomite. The genesis of Cambisols is influenced by factors such as parent substratum, climate, vegetation, and colluviation processes, leading to different sub-types and varieties within the Cambisol group.

Photo 9 Eutric Cambisol (Location: Montenegro)

Source: Burić et al., 2017

Cambisols exhibit diverse morphometric characteristics depending on the specific sub-type. They can have a deep profile, with variations in depth based on the substratum and relief. The terrain where Cambisols are found may include hillsides, slopes, and plains.

Physical and chemical characteristics: Dystric Cambisols are typically characterized by an acid reaction and low base content due to the influence of silicate rocks with low base ions. Tera Rossa, or red soil, has a clay composition with good porousness and permeability, making it suitable for agriculture. Eutric Cambisols, formed on various substrata, may have varying quality depending on factors such as inclination, water drainage, and land reclamation measures. Cambic Phaeozems, forming on pure limestone and dolomite, represent a transitional phase between limestone-dolomitic black soil and red soil, with productivity dependent on depth and relief.

Cambisols support diverse land uses based on their characteristics. Brown dystric soil is utilized for farming, meadows, and orchards. Red soil, with its stable structure, is favorable for agriculture and can support two harvests a year with irrigation. Eutric brown soil, particularly in river valleys, serves as arable land with satisfactory fertility. Brown soil on limestone is predominantly forest soil but can be suitable for agriculture in plateaux, depressions, and sinkholes. Effective land reclamation measures can improve the water percolation and overall soil quality in certain areas.

Leptosols in Montenegro encompass a variety of soil types, each with unique characteristics and distribution patterns. These soils are found in the initial stage of development, formed on compact or poorly crumbled rocks, and are influenced by factors such as climate, geological substrate, and erosional processes. The main types included are Lithosols, Limestone-dolomitic black soil (Calcomelanosols), Humus-silicate soil (Ranker), and Rendzina. Leptosols are characterized by varying depths, rocky compositions, and organic matter accumulation.

Photo 10 Leptosols (Calcomelanosol) (Location: Montenegro)

Source: Burić et al., 2017

Leptosols are widespread in Montenegro, with variations in distribution based on geological conditions and topography. Lithosols are found in areas where rocks undergo physical tear and wear, leading to soil formation. Limestone-dolomitic black soil covers a significant portion of the territory, particularly over carbonate rocks. Humus-silicate soil is present at higher altitudes above 1,200 m, while Rendzina is found on loose carbonate substratum in various karst fields and valleys. Leptosols form on a variety of parent materials, including unconsolidated sediments, volcanic ash, or rocky outcrops. Their genesis is influenced by factors such as weathering, erosion, and deposition. Leptosols are often found in areas with rapid soil formation processes, such as recently deposited alluvial fans or volcanic landscapes.

Leptosols typically exhibit a shallow profile with a limited development of soil horizons. They are characterized by a minimal horizon differentiation due to inhibited pedogenesis, often as a result of rocky fragments and rapid drainage. The terrain where leptosols are found can vary widely, including hillsides, slopes, and rocky terrains. Leptosols have a stony and shallow nature, with limited depth for root penetration. The soil is often characterized by a lack of well-defined horizons, and it may contain a high percentage of rock fragments. The low organic matter content makes leptosols less fertile for agriculture. Due to their shallow nature and limited water retention capacity, leptosols are prone to drought stress. Additionally, they may exhibit a wide range of textures depending on the parent material, from sandy to clayey.

In general, the management of Leptosols involves reclamation efforts such as afforestation to prevent erosion and improve soil productivity. Limestone-dolomitic black soil is used for forestry, pasture-land, and limited arable cultivation in sinkholes. Ranker supports pastures and forests at higher altitudes but has low productivity. Rendzina, though shallow, is utilized as arable land in karst fields for specific crops and covered with underbrush and forest in shallower areas.

North Macedonia

The dominant soil types in North Macedonia are Cambisols, Fluvisols (Alluvial and Diluvial sols), Regosols and Rendzic Leptosols, covering almost 40% of the country's territory (971,769 ha). Cambisols are spread over higher altitudes, mostly under forest vegetation. Cambisols are usually deep soils with a well-developed cambic horizon. On inclined terrains, when the vegetative cover is destroyed for various reasons (clear cut, forest fires, etc.), these soils are very prone to intensive processes of soil erosion. Fluvisols are fertile soils spread over river sediments in the lowest parts of the valleys or over diluvial sediments eroded from the upper relief forms and deposited in foothills. In general, Fluvisols are the main agricultural soils with high production potential due to their favorable chemical and physical characteristics and proximity to sufficient irrigation water sources. However, these soils are under prominent and constant human pressure, causing fundamental changes in their properties. Regosols occupy a huge area of the country (98,410 ha), especially in dry regions on inclined relief forms and moderate vegetation cover. Regosols have a very limited production potential and are usually sown with annual crops, mostly cereals. Chromic Cambisols on saprolite, Vertisols and Humic Calcaric Regosols, in addition to Fluvisols and Regosols, are the most important agricultural soils covering more than 202,623 ha. All three soils are very fertile and, due to their location and production characteristics, are the perfect environment for establishing perennial plantations of orchards and vineyards (Vidojevic *et al.*, 2022). A description of the dominant soils at LUCAS points is provided according to (Filipovski, 2016). Most LUCAS Soil points in North Macedonia occur where Leptosols and Regosols tend to predominate, followed by Cambisols and Fluvisols.

- **Leptosols** includes a wide variety of soils in North Macedonia.

  Nudilithic Leptosols are undeveloped shallow soils up to 25 cm. over hard rock from different origins. These soils are distributed in mountainous regions over a steep slope (<30%).

  Geology: over compact basic, intermediate, and basic ultrabasic and carbonate rock. Distribution is in all climate and vegetation regions. Its chemical and physical properties are directly dependent on the characteristics of the geological substrate. Although the geology is the dominant factor of its properties, the formation of Leptosols is strongly related to the relief conditions and vegetation cover.

  Leptosols are soil with the lowest production capability among the other soils in a mountainous zone and they are not used in agricultural production.

  Rendzic Leptosols (Calcomelanosol) are formed over continuous compact or over „in situ“ fragmented pure limestones or dolomites. The soil profile is hollow, up to 30 cm. Rendzic Lepotols are non-carbonate with the presence of lime fragments, rich with organic matter that decreases with the depth of the soil profile. Distribution is on a flat or sloppy karstic relief.

  Geology: limestones (massive, platy, blocky), calcite marble, dolomite, dolomitic marble, and calcite dolomite marble. Rendzic Leptosols are formed in all climatic and vegetation zones. However, the climax stadium of the development of this soil type can reach in the alpine and subalpine climate zones.

  Rendzic Leptosols can achieve its typical properties under grassland at the high mountains which produce a high amount of biomass. With the development of the solum, the vegetation cover develops as well, so on small areas some associations of forests can appear.

Soil cover with Rendzic Leptososl is usually not continuous. The solum is non-carbonate, and sharply passes into the solid rock surface. The production capability of these soils is very low due to its shallow soil profile and inaccessibility. Rendzic Leptosols can be used as a summer pasture with high precaution measures from overgrazing.

Photo 11 Rendzic Leptosols (Location: Mavrovo, North Macedonia)

Source: Dusko Mukaetov

— **Regosols** are weakly developed soils. Distribution is on steep mountainous terrains and on hilly terrains in valleys over clastic sediments.

Geology is dominant for their genesis and properties. Mountainous Regosols are formed over residual regolith of acid, intermediate, basic and ultrabasic rocks, while in the hilly part Regosols are formed over clastic sediments. They are formed in various climate conditions. For its genesis, the parent material plays a key role, while soil erosion is the most important process of pedogenesis. Before World War II much of our Regosols were under xerophytic hill pastures for winter grazing. Today, a large part of them is arable land. Some of them still have remnants of degraded forests and bushes.

Colluvic Regosols are soils formed over eroded and sedimented materials (soil, regolith of compact rock and resedimented sediments). The eroded material for the higher terrains is sedimented at the foothill forming the so-called deluvial cones. Regosols, Colluvic soils are formed over this type of relief form. The process of pedogenesis is in the initial stages.

Geology: Regosols, Colluvic soils are formed over various soil and geological material depending to the origin of the eroded material.

Regosols, Colluvic soils are under different vegetation cover depending to the actual climate conditions. In almost all cases the natural vegetation is either degraded or destroyed. Hydrographic conditions are much more important in the process of forming of Regosols, Colluic soils, since the quantities and stratification of the eroded material depends to the intensity and the torrential character of surface water. In some cases, at the lowest part of the colluvic cone, the influence of shallow ground water on soil forming processes is possible.

Regosols, Colluvic soils are young soils in its initial stages of formation.

The properties of Regosols, Colluvic soils is highly dependent to the properties of the eroded material that served as material for its formation. The main characteristic of these soil is the presence of undeveloped hor. (A) with a usual depth of 20-30 cm, low stratification of the eroded material with the presence of skeletal particles with sharp edges (short transport of the material) and very diverse texture. Production capabilities are rather heterogenic and depends to the actual properties of Regosols, Colluvic soils which are very diverse. Unlike the Alluvial soils they are bordering with, the productive capabilities of Regosols, Colluvic soils are much lower.

Calcaric Regosols are spread in the geo-tectonic zone of River Vardar, since the geological substrate in the zone is most favorable for its formation. In the valleys Regosols, Calcaric are formed on a hilly and ridged terrains up to a altitude of 600-800 m.a.s.l., while in the mountainous zone can appear at all altitudes depending to the parent material.

Geology: Regosols, Calcaric are lithogenic soils, meaning that substrate plays a key role in its formation. Regosols, Calcaric in the valleys are formed over clastic or cemented sediments (Mesozoic, Eocene, Miocene, Pliocene, flysch), which can be easily decomposed releasing a certain amount of clay minerals and carbonates. Regosols, Calcaric on highlands are usually formed over impure soft limestones, carbonate shale, carbonate breccia etc. Regosols, Calcaric are not climate-zonal and can be formed in different climatic conditions. Most of the Regosols, Calcaric are cultivated. Small part is under natural vegetation of Carpinus and Quercus association.

Regosols, Calcaric especially those in the lowlands have a high productive capacity. The higher fertility is due to the favorable properties (texture, physical and chemical properties), as well as to the good supply of some nutrients.

— **Fluvisols** are young soils formed over recent river sediments accumulated during the regular floods, that have fluvic soil properties. Fluvisols covers the flat areas along the riverbeds and the lower river terraces. Fluvisols in upstream parts of river are normally represented as narrow strips of land adjacent to the actual riverbed, while in the middle and lower stretches, the flood plain is wider and has the classical arrangement of banks and basins, with coarsely textured Fluvisols on the levees and more finely textured soils in basin areas further away from the river.

Geology: Fluvisols are formed over fluvic sediments from different origin.

Hydromorphic conditions have strong influence on its formations and are influences by the surface water flows and ground water and irrigation. The most part of the Fluvisols are cultivated. Human impact on these soils is very strong, and is emphasized through cultivation, destruction of natural vegetation cover, application of agrotechnical and meliorative measures etc.

The properties of Fluvisols are highly dependent to the properties and the nature of the sediments and length of periods of soil formation after or between flood events. Fluvisols possess a high production potential due to its favorable mechanical composition, good air and water regime and suitability for irrigation. If properly managed and regularly enriched with organic matter and nutrients, Fluvisols can be used for intensive cultivation.

— **Cambisols** occur in silicate mountains and all geotectonic units. These are typical mountain soils, formed under the influence of various plant communities of the forest vegetation. Cambisols are the most widespread soil type in the country. At a lower altitude, they are bordered by Chromic Cambisols and Luvisols, while at a higher altitude, they are bordered by Molic Umbrisols (Rankers).

Geology: Cambisols are usually formed over compact non-carbonate quartz and silicate rocks (acidic, transitional, basic, ultrabasic) or from their regolith, and less often from various non-carbonate sediments.

There are typically mountainous soils that appear on all relief forms and exposition between 800 to 1800 m Cambisols are climate-zonal soils, which means that they are formed under specific climate conditions. In North Macedonia, they are spread over several climate-vegetation zones like cold-continental, subalpine-mountain, etc. Cambisols are formed under various plant communities of the forest vegetation. They are most abundant in the beech region with submontane and mountain beech forests, less in the oak region, and the least in the subalpine belt under communities of subalpine beech, fir, or spruce.

The production properties of these soils are good and depend on: the depth of the profile; its texture, the water, air, and heat regime. The chemical and physical properties of Cambisols are usually favorable.

Chromic Cambisols cover a huge area in many valleys of the country. As a single cartographic unit, they are identified on over 113,000 ha.

Geology: Chromic Cambisols are formed over various substrates. They are mostly formed over clastic sediments (Lake Neogene sediments, and younger Pleistocene sediments), in some cases they are developed over Regosols, Colluvic sediments, or no higher lake terraces.

These soils are mostly formed in the valleys on hilly terrains up to 500 m. Small areas are identified at a higher altitude up to 850 m.

Chromic Cambisols are climate-zonal soils, and climate and vegetation have the dominant role in their pedogenesis. Chromic Cambisols are formed in three of our climate zones (sub-Mediterranean, continental-sub-Mediterranean, and warm-continental). In these climatic zones, the oak forests and their associations with other forest species dominated during their formation. The natural vegetation nowadays is generally destroyed or degraded due to the cultivation of this soil.

The productive capability of this soil is medium due to the eroded surface layer on inclined terrains, low nutrient, and organic matter contents, as well as the unfavorable physical properties of the hor. (B) rich with clay.

Photo 12 Chromic Cambisols (Location: Skopje, Butel, North Macedonia)

Source: Dusko Mukaetov

Republic of Serbia

The largest area of arable soil in Serbia, namely 28% of the entire area, is composed of Cambisols. Cambisols are commonly found in all parts of the Mediterranean, but they are considered endemic in some parts of Central Serbia. In Central Serbia, Cambisols is the dominant type of soil, with a share of about 38%. Cambisols were formed in a complex process of pedogenesis through the interaction of climate, vegetation, and geological background. Before the establishment of agricultural production, they were under deciduous, mostly oak forests, with a significant share of grass communities. Acidic soils with low phosphorus content, Cambisols are suitable for viticulture–fruit production. Chernozem, which covers 18% of Serbian territory, is considered "perfect"for vegetable production, as well as for production under irrigation. This soil type was formed on the geological base of the loess and has a weak alkaline to alkaline pH reaction. It occupies 60% of the area in the Autonomous Province of Vojvodina.

Alluvial soils – Fluvisols - originate from alluvial sediments of rivers and occupy 8% of the area of Serbia. These soils are layered and have a high content of sand and gravel. As the cities were most often founded in the valleys of large rivers, the two largest Serbian cities, Belgrade and Novi Sad have significant areas under this type of soil. Vertisols – heavy, clayey soils mostly formed on lake clays – occupy 8% of the area of Serbia. Vertisols are fertile soils but are difficult to cultivate. The most found uncultivated soils are Leptosols, and they represent the skeletal lands of hilly and mountainous areas, which occupy 16% of the territory of Serbia. These shallow soils (up to 20 cm), somewhere under grassy vegetation, can be used as pastures. Podzols, Phaeozems and Umbrisols are distributed over limited areas in the country, with 3.5% (Vidojevic *et al.*, 2022).

A description of the dominant soils at LUCAS points is provided according to (Skoric *et al.*, 1985; Pavlović *et al.*, 2017). Most LUCAS Soil points in the Republic of Serbia occur where Cambisols tend to predominate, followed by Chernozems, Fluvisols, and Leptosols.

— **Cambisols** in the Republic of Serbia encompass a diverse group of soils:

Eutric Cambisol soils belonging to this class emerge through the continued evolution of soil types within the humus-accumulative class. They are notably distinguished by the presence of a cambic horizon directly beneath the humus horizon. Below this cambic horizon, there might exist either loosely packed substrate or dense rock formations.

In Serbia, Eutric Cambisols are typically developed at elevations ranging from 50 to 900 m, with the majority located below 500 m. These soils are commonly found in regions such as Šumadija, Pomoravlje, and Mačva. They predominantly support climatogenic vegetation dominated by deciduous forests (oak trees).

Eutric Cambisols in Serbia exhibit brown to rusty-reddish hues in their (B)v horizon due to hydrated iron oxide and clay minerals. These soils feature a humus horizon directly above a cambic horizon and form across a wide range of rocks from ultrabasic to slightly acidic compositions, including serpentine, gabbro, diabase, andesite, specific gneiss, amphibolitic schists, limestone, marl, loess, Tertiary lacustrine sediments, and various alluvial deposits. Their physical properties resemble a middle ground between chernozem and Vertisol, while chemically, they show high potential, containing elevated Ca, Mg, and other elements. Slightly acidic to neutral, they maintain a high degree of base saturation (70–80%) and a strong adsorption capacity for base cations, with a favorable C/N ratio in the humus-accumulative horizon.

These soils are deep soil, with high productivity; all crops are grown on them, including high-quality vineyards and orchards. Irrigation is often necessary.

Photo 13 Eutric Cambisol (Location: Ovsište)

Source: Vasin, J., & Živanov, M., 2020

Distric Cambisols are acid-brown soil that is less fertile and shallower compared to Eutric Cambisols. It typically develops on acidic rocks such as sandstone, phyllite, shale, acid eruptive rocks, and other quartz or silicate-based rocks.

In Serbia, these soils are predominantly found in mountainous regions like Goč, Željin, Kopaonik, Kosmaj, Bukulja, Cer, and Majdanpečka Domena. They are associated with vegetation typically comprising beech and beech-fir forests.

These soils in Serbia form a high-altitude belt within mountain massifs, occurring at elevations ranging from 500 to 1100 m. They are inhabited by broadleaved forests and mixed broadleaved/coniferous forests. The climate in these areas is moderately humid, with precipitation ranging from 700 to 1000 mm and average annual temperatures between 5 to 8 °C. This soil develops on quartz-silicate parent material that is low in bases. The primary substrate consists of acidic silicate rocks, which, upon weathering, result in minimal clay content but a higher percentage of sand. Chemically, these soils exhibit acidity (pH in water <5.5) and possess a low cation exchange capacity (CEC <50%). They form on acidic rocks such as sandstone, phyllite, shale, acid eruptive rocks, and other quartz/silicate rocks.

Agricultural productivity on these soils tends to be low. However, with the implementation of ameliorative measures, there's a possibility for cultivating certain fields and industrial crops, albeit with some limitations. The effectiveness of these measures might allow for some level of agricultural activity beyond the traditional forestry use of these areas.

Photo 14 Distric Cambisol (Location: Viteževo)

Source: Vasin, J. 2016

— **Chernozems** are soils with a thick black surface layer, rich in organic matter. Subtypes of this soil according to the classification system used in Serbia, are as follows: chernozem on loess and loess-like sediments; chernozem on calcareous aeolian sand; and chernozem on alluvial deposits.

The primary Chernozem zone in Serbia is located within the Vojvodina region, representing the westernmost extension of the southern European chernozem zone. Additional smaller areas can be found south of the Sava and Danube rivers, specifically between Belgrade and Požarevac, within the River Morava valley. The parent material of Chernozem consists of loess, a type of sediment rich in varying levels of calcium carbonate. During the deposition of loess and subsequent wind activity, different formations emerged, impacting the genesis of this soil type to varying degrees. These formations include loess terraces, and loess plateaus, among others. Chernozems can also form on river terraces, which are alluvial deposits containing lake sediments. The terrain of Chernozem primarily comprises lowland areas such as plains and plateaus, leading to different levels of moisture saturation within the soil profiles. Temperature and moisture are the key factors influencing the formation of chernozem. These soils typically characterize semi-arid steppe regions, featuring a mollic A horizon and a transitional AC horizon. Chernozems develop on calcareous loamy substrates (sedimentary rock loess) and, less commonly, on sandy, loose substrates.

Chernozems, highly fertile soils, support cereal crops due to deep, uniform layers, ideal composition, and stable structure, fostering excellent conditions for plant growth through optimal water, air, and temperature. They also offer beneficial chemistry and robust microbial activity, enhancing agricultural suitability.

Photo 15 Calcic Chernozem (Location: Novi Sad, R. Šančevi)

Source: Vasin, J. 2022

— **Fluvisols** are commonly found in the valleys of major rivers such as the Danube, Sava, Morava, Tisa, and their tributaries. In Serbia, these soils cover approximately 7.9% of the total land area.

The genesis of Fluvisols is heavily influenced by the hydrological patterns of the river and the nature of the accumulating material. The profile morphology typically comprises layers of varying textures denoted by Roman numerals (I, II, III, etc.), with the surface layer marked as the youngest. Fluvisols are primarily sandy in composition, occasionally sandy loam, influencing their air-water properties, and typically lack structured formations. Most Fluvisols in Serbia are calcareous, containing 5–30% carbonates; however, their distribution within the profile lacks consistency. These soils contain a small amount of humus, approximately 1–2%.

Despite being underdeveloped soils, Fluvisols are generally highly fertile and are often populated by mixed forests of poplar and willow, along with grassy vegetation. They generally exhibit favorable physical and chemical properties, with exceptions found in gravelly deposits and pure sand. If utilized for vegetable cultivation, alongside irrigation and fertilization, flood defense measures become essential due to their location in flood-prone areas.

Photo 16 Fluvisol (Location: Futog)

Source: Vasin, J., & Živanov, M. 2021

— **Leptosols** represent the most extensive soil group globally, incorporating soils classified within the order of automorphic soils and falling into the category of undeveloped soils. In national classifications, these soils may be referred to as limestone-dolomite rocky areas or Kamenjar-Litosol. They also encompass different types of Rendzinas, various types of Rankers, calkomelanosols etc.

These soils are predominantly found in mountainous regions where low temperatures play a crucial role in rock disintegration. They typically develop on slopes within hilly and mountainous areas, encompassing various geological substrates. Additionally, these soils can be found on both level and partly sloping terrain, as well as on the gentle slopes of rocky massifs.

Leptosols are soils that represent the initial stage of development on solid rock. These undeveloped soils consist mainly of a decayed skeletal (lithos-rock) layer with a depth of no more than 20 cm, which gradually transitions into compact or slightly crushed rock. They are typically found on slopes in hilly and mountainous regions, as well as on flattened landforms or slopes of hard rock massifs.

These soils feature an (A) horizon characterized by the fragmented accumulation of humus in individual large pores, with occasional 'humus' nests found at greater depths. The depth of these soils can vary, with mechanical elements dominating larger than 2 mm. Additionally, there are smaller mechanical elements smaller than 2 mm that represent the initial phase (A) of the horizon. Humic compounds accumulate in this zone. They do not retain water, and their surface horizon is nutrient-poor, lacking an adsorptive complex. Those soils are low productive soils. These are arid habitats typically used as pastures of low quality or forest.

Photo 17 : Leptosol (Divčibare)

Source: Ćirić, V., & Belić, M., 2019

4 Conclusions

Over half of LUCAS Soil points (67.4%) are found in continental climate (Dfa, Dfb and Dsb), while just 3.9% of soil samples reflect Arid conditions (BSk). An analysis of land cover data shows that Western Balkans is a very rich and diverse region. Most Western Balkans LUCAS Soil points occur in agricultural areas (52%) followed by forest and semi-natural areas (46.9%). Within agricultural areas, most of the points belong to the class of Non-irrigated arable land (26.8%). Within forest and semi-natural areas, most of the points belong to the class of Broad-leaved Forest (24%).

In terms of biogeographical regions, most of LUCAS soil points fall to the Continental region followed by the Alpine region. Most of the soil points that fall into the Continental region belongs to Serbia, followed by Bosnia and Herzegovina. The distribution of LUCAS soil points per biogeographical regions and elevation shows that the highest number of points occur in the Continental region with elevation <500 m (29.2%) followed by the Pannonian region with elevation <500 m (14.5%). Serbia has the highest number of LUCAS soil points and half of them (51.7%) are below 200 m elevation. There are 86 soil points within the Emerald Network sites. Most LUCAS soil points occur where Cambisols tend to predominate, followed by Leptosols. Cambisols are soils that show only limited soil profile development and are often considered as 'young' soils that are still in the processes of development and are widespread in the region.

The Western Balkans countries are relying on obsolete soil data for soil assessments and monitoring. This has created a considerable gap between the knowledge on the status of soil health in the region when compared with EU countries. Therefore, there is an urgent need to embark in a soil monitoring system that must be robust and able to provide reliable data for updating soil policies, which are also required by the Sofia Declaration for the Western Balkans. Reliable data must be generated to depict spatially explicit policy-relevant indicators for developing harmonization procedures, and for enhancing the region-wide use of harmonized indicators.

This report represents a significant first step towards supporting the publication of an updated soil database for the Western Balkan region based on the LUCAS 2015 Soil Module. Despite data are not yet available for laboratory analyses soils of the drier climates are expected to have the highest salt content while the wetter ones are less affected by salinity reflecting greater soil leaching. This process is very typical for Albania having the largest concentration of saline soils. Furthermore, it is anticipated that soil organic carbon values are the highest in humid areas, especially in those covered by forests, as in the case of Bosnia and Herzegovina, which have a large extension of forest areas. By incorporating a wide range of environmental data, the updated database will provide a more comprehensive and accurate representation of soil conditions in the area. This enhanced database will be instrumental for policymakers, researchers, and land managers in making informed decisions related to agriculture, environmental protection, and sustainable land use in the Western Balkans. The insights gained from this report and the subsequent database will contribute to improved soil management practices and the overall ecological health of the region.

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List of abbreviations and definitions

Abbreviations	Definitions
CEC	Cation exchange capacity
CLC	CORINE Land Cover
EEA	European Environment Agency
EGD	European Green Deal
ESDAC	European Soil Data Centre
EU	European Union
ha	Hectares
JRC	Joint Research Centre
LUCAS	Land Use and Coverage Area frame Survey
MMU	Minimum Mapping Unit
MMW	Minimum Mapping Width

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