Case study

ANALYSIS OF THE DISAPPEARANCE AND LOSS OF SOIL IN THE EUROPEAN UNION CAUSED BY ELEMENTS OF ANTHROPOGENIC AND NATURAL INFLUENCES

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Abstract: *Soil is often mistakenly considered a renewable resource, but due to the very long-time span of the formation and regeneration processes, it is in fact a non-renewable and limited resource. Poor soil management and the loss of its fertility jeopardies not only current production capacities, but also those of future generations. Only 2-3 centimetres of soil are created in 1000 years, and 33% of the soil on our planet is currently affected by degradation processes which, according to the FAO, fall into the category of severe degradation. Worldwide, 50,000 km² of soil is lost every year. The landscape in many areas also indicates that the interaction of climate, topography, soil characteristics and human activities has led to unsustainable development in the short and medium term. The main factors affecting the rate of soil erosion by water are precipitation, soil type, topography, land use and land management. The following data is used to estimate soil loss: erosivity of precipitation, erodibility of soil, land management and topography. Using this universal formula, it was determined that the average rate of soil loss in erosion-prone soils in the European Union (agricultural, forestry and semi-natural areas) is 2.46 tonnes per hectare per year, resulting in a total soil loss of 970 megatons per year. The highest annual soil loss rates were observed in the Mediterranean regions, while lower values are predicted for Scandinavia and the Baltic states. The highest average annual soil loss rate (at country level) is recorded in Italy (8.46 tonnes/ha), followed by Slovenia (7.43 tonnes/ha) and Austria (7.19 tonnes/ha), which is due to the combination of high erosive precipitation and steep topography (steep and long slopes). The average soil loss rates in other Mediterranean countries (Spain, Greece, Malta and Cyprus) are also higher than the European average. The lowest average annual soil loss rates were found in Finland (0.06 tonnes/ha), Estonia (0.21 tonnes/ha) and the Netherlands (0.27 tonnes/ha). The Republic of Croatia has an annual soil loss rate of 3.16 t/ha. Soil loss due to water erosion is expected to increase by 13–22.5 % in the EU by 2050. Changes in future soil erosion rates will be determined by climatic conditions, land use patterns, socio-economic development, farmers' decisions and agro-ecological policies. According to some climate change scenarios, soil loss could affect 84% of the area and erosion rates could reach 45%.*
The paper provides a detailed analysis of the indicators and causes of degradation and the potential consequences for humanity.

Keywords: *soil, erosion, losses, anthropogenic and natural impacts*

1. INTRODUCTION

Soil is a biologically active and porous medium that was formed during the geological development of the earth in the uppermost layer of the earth's crust (Škorić, 1992). It is a loose natural formation created by the action of pedogenic factors: initial substrate, climate, organisms, relief, and time in the processes of pedogenesis: wear of minerals, formation of secondary minerals, decomposition of organic matter and formation of humus, formation of organo-mineral compounds, migration and specific processes (Geochemical Atlas of the Republic Croatia, 2009).
Of the most important components of soil, the parent substrate is the most important for its formation, as almost the entire mineral content of the soil, which accounts for 86-99% of the total mass, comes from rocks (Geochemical Atlas of the Republic Croatia, 2009).

The role of soil is diverse, but for the purposes of this thesis it is a water and nutrient reservoir and an essential element for food production, carbon cycle and other nutrients in ecosystems (Britannica, 2024).

Accordingly, soil is a very important factor for life on earth, as it is the basis for food production, a source of raw materials and plays a regulating role in natural cycles
(Geochemical Atlas of the Republic Croatia, 2009):

- acts as a natural filter for pollutants and as a regulator of nitrogen and phosphorus
- protects groundwater from pollution
- contributes to controlling the amount of CO_2 in the atmosphere
- regulates surface water runoff with a direct effect on the occurrence of floods and landslides
- maintains biodiversity
- provides biomass that affects the entire food chain.

Soil is often mistakenly regarded as a renewable resource, but due to the very long duration of the formation and regeneration process, it is de facto a non-renewable and limited resource. Poor soil management and the loss of its fertility jeopardise not only current production capacities, but also those of future generations.

Only 2-3 centimetres of soil are created in 1,000 years, and 33% of the soil on our planet is currently affected by this degradation process. Soil erosion caused by water, wind and human activities is the biggest threat to soil, and several factors lead to soil erosion: soil erodibility, climatic erosivity, terrain and land cover (JRC, 2015). Soil erosion is a global problem, and it is a challenge for most countries to implement effective solutions. It is generally defined as the destruction of soil by natural phenomena such as water, wind and snow, as well as man-made factors such as intensive and extensive agriculture, urbanisation, road construction, etc. (Zachar, 1982). Erosion is categorised as a natural process that takes place over millions of years and creates new soils. Soil erosion is considerably accelerated by human activities. The best known of these is the uncontrolled clearing of forests without establishing new plantations or rehabilitating the soil. In this cases soil loss is much greater than its creation. It is important to point out that erosion has a negative impact on agricultural production, source water quality and ecosystems (Fayas, 2019).

According to estimates by the Food and Agriculture Organisation of the United Nations, up to a third of the world's soils are moderately or severely degraded. This means that there is less and less arable land. Worldwide, 50,000 square kilometres of soil are lost every year - roughly equivalent to the area of Costa Rica. At European level, around 11 hectares of soil are covered with asphalt or concrete every hour, which is equivalent to the area of 14 football pitches (2015 data). In Italy, 100 square metres of fertile soil are lost every minute due to housing construction (Fayas, 2019).

Since the second half of the 19th century, erosion has been recognised as one of the biggest environmental problems worldwide (Bakker et al., 2007), especially in areas with seasonal climates and significant human impact on the surface. Soil erosion caused by water, wind and human activities is not only a threat to the soil, but also to the ecosystems that are connected to the soil.
Soil science is one of the land-related disciplines and has an essential link to several SDGs (Keessatra et al., 2016). The prospects for the future are not rosy. To ensure sufficient food for the growing local population, it is highly likely that the condition of the soil will deteriorate even further than it is now. To achieve the SDGs in the areas of food, health, water and climate, an increase in pressure on soil is very likely.

2. METHODS

The method of reviewing the available literature and statistical indicators was used to write the paper.
The sources of information were databases Web of Science (WoS) and Scopus. WoS is a database covering more than 250 disciplines such as environmental sciences, social sciences, biotechnology, etc. with more than 30,000 journals. Scopus is a database provided by Elsevier covering more than 25 disciplines. An advanced search has been used which makes it possible to find related results related to erosion.

3. DESCRIPTION OF SOIL AND EROSION IN THE TERRITORY OF THE EU COUNTRIES

3.1. A brief description of the soil in the Republic of Croatia

According to EU sources, the distribution of land in the Republic of Croatia is as follows (EEA, 2024):

- Artificial land – 2,169 km^2
- Cultivated land - 22,462 km^2

- Forests and similar areas – 31,196 km^2
- Wetlands – 203 km^2
- Water areas (inland waters) – 561 km^2.

According to the Geochemical Atlas, the territory of the Republic of Croatia belongs to the geotectonic systems of the Dinarides and Alpides and the Pannonian area. Geologically, the area is divided into the Pannonian and Dinaric coastal areas. The border between them runs from the southern part of Žumberek to the Una River and south of Trgovska gora (Figure 1). These two areas differ considerably in their geological structure, which is also reflected in the spatial distribution of many chemical elements in the soil (Halamić and Miko, 2009).

Figure 1: Geological map of the Republic of Croatia (Halamić and Miko, 2009)

The physical and chemical erosion of the parent rock and thus the process of pedogenesis begins as a result of external factors. The circulating water transports ions that are released from the crystal lattice during the decomposition of minerals and brings other ions with it. In this way, a new geochemical environment is created in which secondary minerals are formed that are stable under surface conditions (Halamić and Miko, 2009). The development of the soil (pedogenesis) is stimulated both by the circulation between the atmosphere, the organisms and the soil and by the exchange processes within the soil (Halamić and Miko, 2009).
Due to the heterogeneity of geological and lithological composition, climate and relief, most European soil types are represented in Croatia (Halamić and Miko, 2009).
On the basis of natural diversity, the territory of Croatia is divided into three natural geographic units (Halamić and Miko, 2009):

- Lowland or Pannonian natural area (covers 46.3 % of the territory and about 60 % of the population)
- Mountainous region (covers 24.5 % of the territory and 3 % of the population).

- Coastal or Adriatic natural area (covers 29.2 % of the territory and about 30 % of the population).

3.2. Soil erosion in Europe - assessment methods and status

The EU has established a universal equation (RUSLE2015) for estimating soil losses that considers the following: erosivity of rainfall, erodibility of soil, land cover management and topography. The average rate of soil loss in erosion-prone soils in the European Union is 2.46 tonnes per hectare per year, resulting in a total soil loss of 970 megatons per year. The European erosion equation includes multiplication of:

- E: average annual soil loss
- R: Erosion factor of precipitation
- K: erodibility factor of the soil
- C: Soil management factor
- LS: Factor for slope length and slope steepness
- P: Factor for support measures.

Over the last ten years, policy measures have reduced soil loss in Europe by an average of 9.5 % and by 20 % for arable land. Particular attention is paid to the 4 million hectares of arable land that are currently experiencing unsustainable soil loss of more than 5 tonnes and should be targeted by policy measures.
Precipitation, soil type, topography, land use and land management are the main factors influencing the rate of soil erosion. The highest annual soil loss rates were observed in the Mediterranean regions, while lower values are predicted for Scandinavia and the Baltic states (Pangos et all., 2015). The combination of high precipitation erosivity and relatively steep slopes also leads to increased soil loss rates in the Alpine regions, the Apennines, the Pyrenees, western Greece, west Wales and Scotland (Pangos et all., 2015)
The effects of low vegetation cover are most pronounced in southern Spain and eastern Romania. The effects of soil erodibility are particularly pronounced in the loess belt (Belgium, southern Germany and southern Poland), (Pangos et all., 2015).

Table 1. shows that the highest mean annual soil loss rate (at country level) is recorded in Italy, Slovenia and Austria. The average soil loss rates in other Mediterranean countries (Spain, Greece, Malta and Cyprus) are also higher than the pan-European average. The lowest mean annual soil loss rates were found in Finland, Estonia and the Netherlands. All Scandinavian and Baltic countries have average annual soil loss rates of less than 0.52 tonnes/ha.

Table 1. Average soil loss rate (E-value) by country (all land, arable land), impact of good agricultural environmental status (GAEC) practises and share of soil loss in the EU-28 (Pangos et all., 2015)

	Overall mean E(t ha^{-1} g^{-1}) (%)	**Mean value on arable land** E(t ha−1 g−1) (%)	**Mean value on arable land without GAEC** E(t ha^{-1} g^{-1}) (%)	**GAEC efect** E(t ha^{-1} g^{-1}) (%)	**% of total soil loss in the EU**
Austria	7.19	3.97	5.23	31.8	5.65%
Belgium	1.22	2.06	2.71	31.8	0.30%
Bulgaria	2.05	2.47	3.77	52.5	2.21%
Cypar	2.89	1.85	2.82	52.6	0.25%
Chech Republic	1.65	2.52	3.30	31.0	1.24%
Germany	1.25	1.75	2.51	43.5	4.15%
Denmark	0.50	0.61	0.68	11.4	0.20%
Estonia	0.21	0.70	0.88	25.3	0.09%
Španj	3.94	4.27	5.56	30.3	19.61%
Finland	0.06	0.46	0.64	37.9	0.18%
France	2.25	1.99	2.78	39.5	11.85%
Greece	4.13	2.77	3.63	31.1	5.31%
Croatia	**3.16**	**1.67**	**1.80**	**7.5**	**1.74%**
Hungary	1.62	2.10	2.35	12.0	1.42%
Irland	0.96	1.32	1.52	15.7	0.55%
Italy	8.46	8.38	9.80	16.9	24.13%
Litva	0.52	0.95	1.02	7.5	0.32%
Luxemburg	2.07	4.54	6.19	36.3	0.05%
Latvia	0.32	1.01	1.11	10.1	0.20%
Malta	6.02	15.93	18.72	17.5	0.01%
Netherland	0.27	0.54	0.68	24.7	0.08%
Poland	0.96	1.61	1.79	11.2	2.92%
Portugal	2.31	2.94	3.55	20.6	2.01%
Romania	2.84	3.39	3.88	14.3	6.31%
Sweeden	0.41	1.12	1.31	16.6	1.57%
Slovenia	7.43	4.63	5.33	15.0	1.49%
Slovakia	2.18	3.54	4.09	15.6	1.03%
UK	2.38	1.04	1.49	43.2	5.14%

According to Pangos et all., from 2015 the estimated total soil loss in the eight Mediterranean EU Member States (Italy, Spain, France, Greece, Portugal, Croatia, Slovenia and Cyprus) amounts to 67% of the total soil loss in the European Union (28 countries - including the UK).

The European Commission's Thematic Strategy on Soils identified soil erosion as an important issue for the European Union and proposed an approach to monitoring soil erosion because of its impact on food production, drinking water quality, ecosystems, mudflows, eutrophication, biodiversity and the reduction of carbon stocks (Boardman, 2006).

3.2.Future scenarios

The European Union contributes 1.3 % of the total annual soil loss according to Pangos et all., 2015.

Soil erosion is one of the agri-environmental indicators developed by the European Commission's agricultural and environmental policy monitoring services. One example of such indicators is the annual rate of soil loss on arable land at NUTS3 (Nomenclature of Territorial Units for Statistical Level 3).

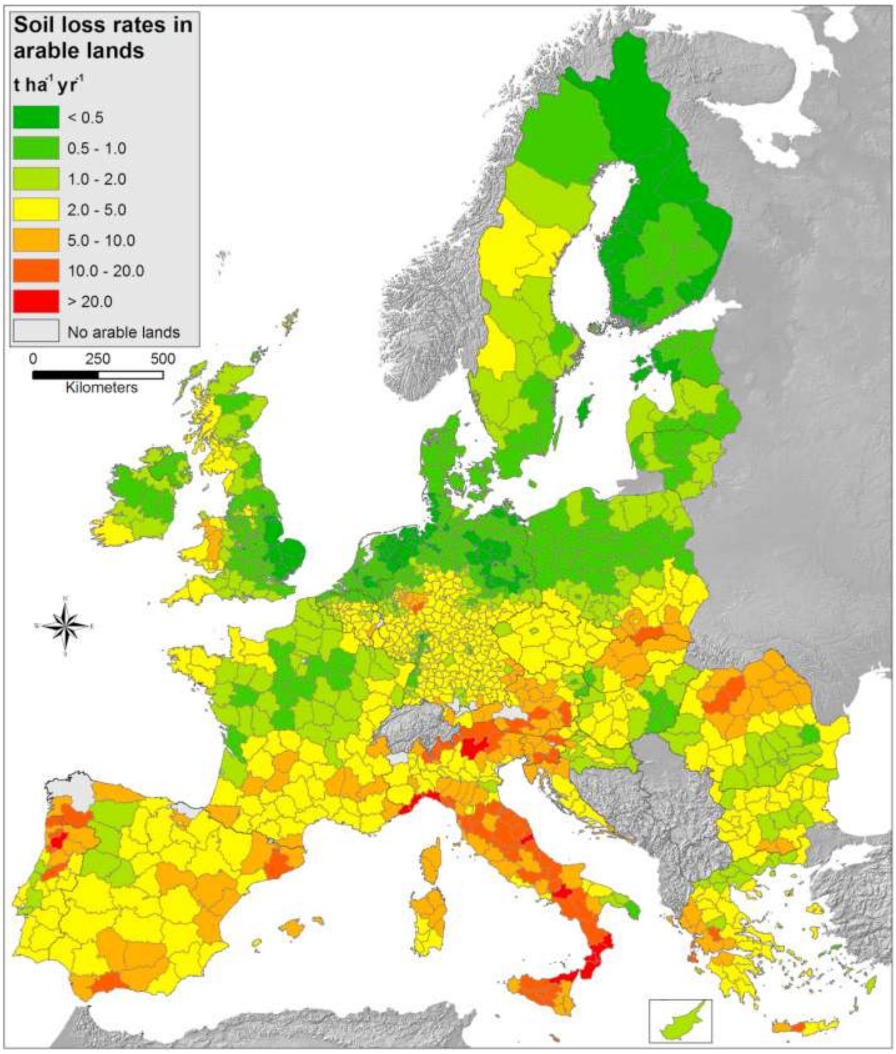

Figure 4: Mean rates of soil loss at provincial level (NUTS3) for arable land in the EU (Pangos et all., 2015)

The average rate of soil loss in the EU exceeds the average rate of soil formation by a factor of 1.6. The highest soil losses are recorded in the Italy, Portugal, Alpine regions and western Austria. The cause is due to a combination of high precipitation erosivity and steep topography (Figure 4). The highest soil losses are recorded in areas with sparse vegetation. Particular attention has been paid to arable land, where management practises and support measures implemented under the Common Agricultural Policy have reduced the rate of soil loss by 20%.

These measures have helped to reduce overall soil loss in the EU by a total of 9.5 % over the last ten years (Pangos et all., 2015).

Soil loss due to water erosion is expected to increase by 13–22.5 % in the EU and the UK by 2050, mainly due to increasing rainfall intensity. This soil loss is expected to be highest in central and northern Europe, where losses could be as high as 100% in some areas. Soil erosion in southern Europe will remain largely unchanged due to lower precipitation (European Soil Data Centre, 2024.).
Changes in future soil erosion rates will be determined by climatic conditions, land use patterns, socio-economic development, farmers' decisions and agro-ecological policies. It is the major changes in climate (increase in precipitation) that will lead to a significant increase in soil erosion. According to some climate change scenarios, soil loss could affect 84% of the surface and the erosion rate could reach 45%. In the Mediterranean region, the increase is lower, mainly due to the different impacts of climate change on the erosivity of precipitation in this region (European Soil Data Centre, 2024).

Currently, agri-environmental policy in the EU is the only mechanism to mitigate the future negative trend of soil loss in the EU. The application of soil protection measures such as cover cropping and reduced tillage should cover at least 50% of the vulnerable areas to neutralise the future impact of climate change on water erosion (Figure 5).

Total soil loss [Mt]	553	596 (+8%)	595 (+8%)	645 (+17%)
Mean soil loss [t ha^{-1} yr^{-1}]	3.07	3.47 (+13%)	3.46 (+13%)	3.76 (+22.5%)
% of land in severe erosion	6.6	7.8	7.7	8.6
% of land with increased erosion (Future vs. Baseline)	-	74	76	84

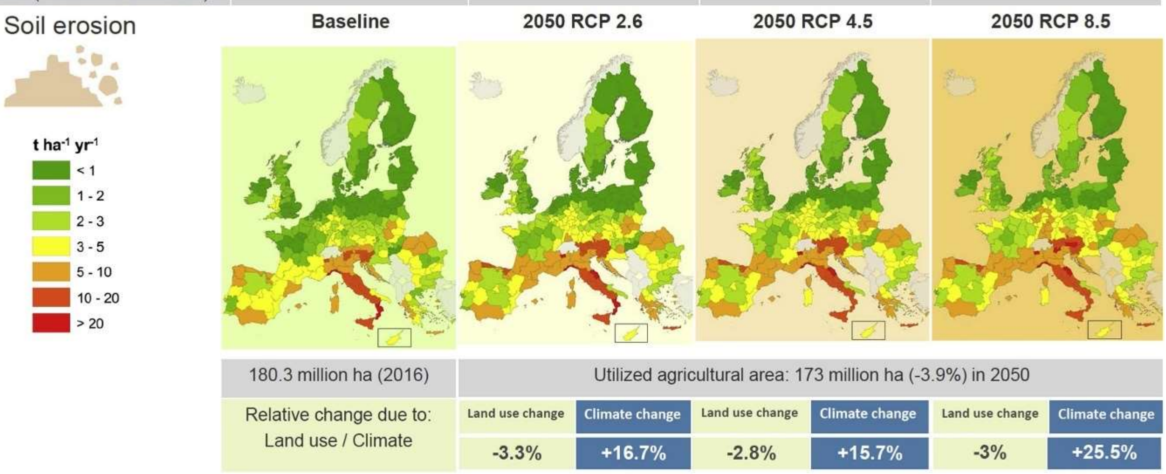

Figure 5: Summary of the main indicators of soil loss due to water erosion on agricultural soils in the EU by 2050 (European Soil Data Centre, 2024)

3.3. The importance of reducing soil erosion for realising the Sustainable Development Goals in the context of climate change

The increasing global temperatures are causing issues that are becoming more evident in the 21st century. The rise in temperature has an impact on sea level rise, acidification, the emergence of ever larger drylands, but also on erosion (Petrini, 2013). The Paris Agreement on climate change commits all countries to take action to reduce greenhouse gas emissions to limit the rise in temperature and to take measures to adapt to existing and future climate change in order to minimise harmful impacts. The potential opportunities if the trend of rising temperatures continues, i.e. the likelihood of a 1.5°C increase in global warming in the period between 2030 and 2052, may have significant consequences (Pufiak, 2014).
The European Environment Agency (EEA) report categorises the Republic of Croatia as one of the European countries with the highest cumulative proportion of damage caused by extreme weather and climate events (Nižić and all., 2022.).

Warming is also occurring on the territory of the Republic of Croatia, with temperatures rising more in coastal areas than inland. Climate change has an impact on the whole world and the way of life (Jackson, 2021).
Before the industrial revolution, the average global temperature was 15 degrees, and after the industrial revolution, the temperature is rising due to increasing human activity. At the same time, the emission of aerosols into the atmosphere is having the opposite effect, namely a decrease in temperature. Numerous scientific, technical and socio-economic studies have focussed on climate change, the possible consequences and preventive measures, as well as ways to mitigate climate change (Latif, 2010). The rise in temperature causes changes in the life cycle of plants and animals, which can lead to an increase in pests and invasive species as well as an increase in infectious diseases. Rising temperatures lead to an increase in water evaporation, and insufficient rainfall increases the risk of droughts (Jackson, 2021). Climate change also has a negative impact on soil quality. Erosion problems may increase, as well as a decrease in organic matter, salinisation, a decrease in biodiversity, the occurrence of landslides, an increase in flooding and desertification (Jackson, 2021).

4. CONCLUSION

Soil erosion is being accelerated by human activity, whether directly or indirectly, through the effects of climate change, the reduction of biodiversity, unsustainable agriculture or construction. All these factors are significantly changing the picture of Europe in which we live. Although the public usually thinks of the threats and conditions caused by extreme droughts, fires or floods in terms of restoring current conditions, soil erosion is a major problem for the future in the long term. Changes in future soil erosion rates will be determined by climatic conditions, land use patterns, socio-economic development, farmers' decisions and agro-ecological policies. According to some climate change scenarios, soil loss could affect 84% of the area and erosion rates could reach 45%. According to Joint Research Centre research reduced land productivity due to soil erosion leads to increased demand for land, which also raises the per capita footprint. Also, the soil erosion losses will provoke an increase in land used for food consumption to 167,000 km2, and increased demand for water supply of 10 billion m3. By analysing the available parameters presented in this paper, it is necessary to know all these activities have a negative impact on the soil, which is primarily necessary for food production and therefore for the survival of the community. In this sense, it is necessary to take the following measures: Analysis of the state of the soil from the point of view of erosion at the level of the regions of the Republic of Croatia, creation of and participation in programmes for the prevention of soil erosion, education of all actors in the system about the importance of soil protection.

On the end the realisation of the Sustainable Development Goals (SDGs) is the responsibility of all countries.

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