Soil Erosion and TOrrential Flood Prevention: Curriculum Development at the Universities of Western Balkan Countries

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WP1

# Analysis of soil erosion state and torrential floods in Western Balkan Countries

Lead Organisations of WP1**: UNSCM; UB**

**Participating Organisation:** UNS; UNI; UBL; UNSA; INSZASUM; BOKU; UNIRC; FRI-BAS

Deliverable 1.1

Title : **Analysis state of soil degradation/soil erosion in WBC**

**Participating Organisation:** UNSCM; UB; UNS; UNI; UBL; UNSA; INSZASUM ; FRI-BAS

Project number: 598403-EPP-1-2018-1-RS-EPPKA2-CBHE-JP (2018 – 2579 / 001 – 001)
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## PROJECT INFO

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# Contents



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# Introduction

The Republic of Macedonia having an area of 25713 $km^2$ is land-locked country situated in the central part of the Balkan Peninsula. It extends between 40°50' and 42°20' north latitude, and 20°27'30" and 23°05' east longitude. .Large and high mountainous massifs with emphasized vertical (dividedness) characterize the country's topography. Mountainous and hilly mountain region encompasses almost 3/4, whilst valleys only 1/4 of its territory The average elevation is 829 m above sea level and vary from 40 m asl near Greece border up to 2 764 m asl (peak Golem Korab situated on the Albanian border). Mountains in the Western part are continuation of Alps-Dinarides range while mountains in the eastern continue to Rila-Rhodpes massif. Geology and soil pattern are very heterogeneous. The mountainous region is generally composed of compact (solid) rocks which are of eruptive or metamorphic origin and only a small part of mountains consists of clastic sediments. The valleys consist mainly of clastic mechanical sediments and only a very small part of the valleys consists of recent compact stones (vulcanite). The climate varies from sub-Mediterranean, moderate continental/ sub-Mediterranean to continental and alpine on the highest mountains. The mean annual precipitation is also quite diverse and it vary from 450 mm (central part) up to 1200 mm (mountains in the western part). Mean annual temperature vary from 4,8 – 14,2 $^{o}$C. The total annual precipitation on the territory is 19.5 x $10^9$ $m^3$, with the external inflow being 1,014 x $10^9$ $m^3$. The total actual outflow is 6,322 x $10^9$ $m^3$. The total water resources are estimated at 6.37 billion $m^3$ in a normal year and 4.80 billion $m^3$ in a dry year, out of which 72.19% are carried in the Vardar basin, 25,74% in Crn Drim basin and 2,07% in Strumica basin. There are 4,414 springs with a total yield of 991,9 million m3/year. Three natural lakes, Ohrid,Prespa (and Dojran Lakes have also great significance for the hydrographic characteristics of the country. There are 22 larger dams and reservoirs and over 100 smaller reservoirs. ). There are 44 wetlands (including lakes) in the country, having an area of 57,422 ha or 2.23 % of the total area of Macedonia. 66% of the waters are used for irrigation purposes. State owned forests (89%) are managed dominantly by PE "Macedonian forests" (81%) and other public institutions as National parks, reserves and communal enterprises (8%). Private owners manage 11 % of forests. Waters are managed by SSC "Macedonian water management" (reservoirs for dominant irrigation purposes), SSC "Macedonian Power Plants" (water for energy production), and numerous smaller concessioners. Agricultural land is dominantly private, while state owned agricultural land after collapse of former big agro-industrial enterprises, is a subject of privatization and concessions. Pastures are managed by PE "Macedonian Pastures" and is a subject of concessions. Mineral resources are subject of concessions. Various climatic influences and relief are present forms on a relatively small territory and it influence the richness of biodiversity that is illustrated by the outstanding number of over 16,000 floral, faunal and fungal species, out of which more than 850 are endemics and through the large variety of ecosystems hosting more than 260 plant communities. many different relict and recent ecosystems are registered. There are total 86 protected items that cover 230,083 ha.

The last census was conducted in 2002 and has approximately 2 million inhabitants, of which 56.7% live in urban environments and 43.3% in rural areas.. The GDP was worth 11.34 billion US dollars in 2017. The unemployment rate in 2018 decreased to 19.4%. Poverty rate at national poverty line decrease from 27,9 (2010) to 21.9 % (2016) . In the recent 20 years, the country has faced a number of economic and political challenges that have strongly influenced the national economy and many people emigrated abroad. According to the latest UN report on migrant stock, 534,720 people from the country are living overseas (NAP LDD, 2017).

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# Status of soil data

Soil survey and soil mapping in the Republic of Macedonia started soon after the World War II in 1947. This process started with the survey of soils of Strumica valley, i.e soil survey study, including a soil map of this valley in a scale of 1:50 000. (Filipovski Gj., 2016). This process continue up to the finalization in 2015. For soil mapping during the time were used various methods (Rozov, Stebut and Gracanin, Gracanin, but dominantly classification by Skoric, Ciric and Filipovski from 1973 – 2012 used on the whole former SFRJ. In the period 2012-2015 was launched FAO-financed project for finalization of the soil maps of the Republic of Macedonia. All previous collected data and maps were reclassified, according to the WRB (The World Reference Base that is the international standard for soil classification system endorsed by the International union of soil scientists). Then, all paper maps were scanned, digitized and was prepared attribute database so a Soil Information System was produced. Soil type items are polygonal, while profiles are dots with added all physical, mechanical , chemical characteristics. Later 62 over the topographic elements of the topo- graphic maps in a scale of 1:50 000 maps were published (in printed and digital form) and one for the entire territory of the Republic of Macedonia in a scale of 1 : 200 000. In addition, 11 soil studies have been published: 10 studies for particular regions and one for the whole territory of the country comprising 1028 pages in total. (Filipovski Gj.2016)

As digital output additionally were created the following thematic maps: Maps on spatial distribution of: pH, CaCO, organic matters, clay, dust and sand and Initial maps on soil suitability for cultivation. All this database could be used for of quantifying different risk for soil and impact to the agricultural production and environment etc.

Soil information system is partially free (depend on a level of access) for usage (https://www.google.com/search?client=firefox-b-d&q=masis)

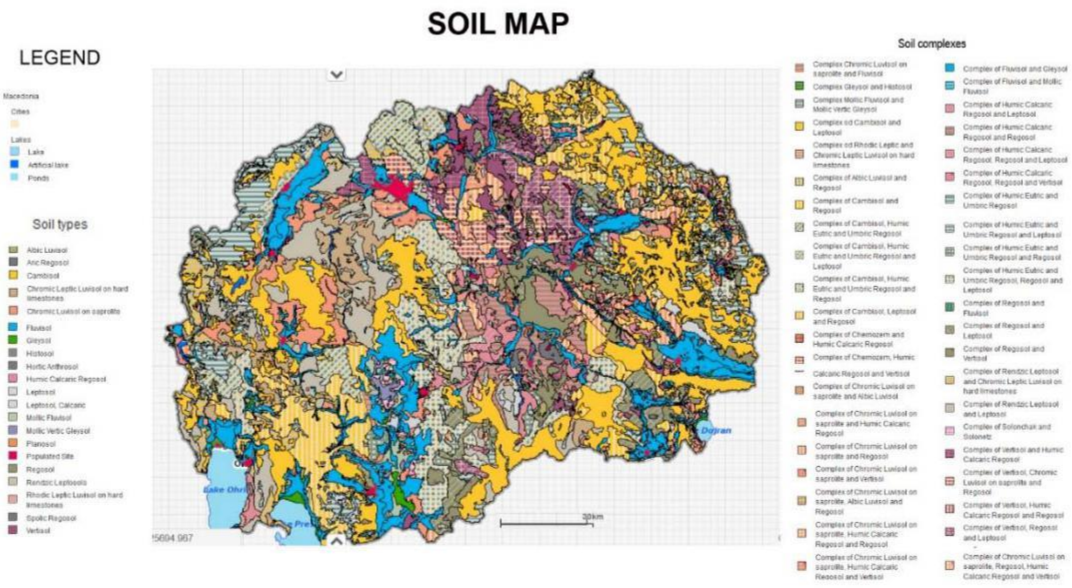


Figure 1 – Soil Map

Legend of soil map consist of 21 soil type and 42 soil complexes.

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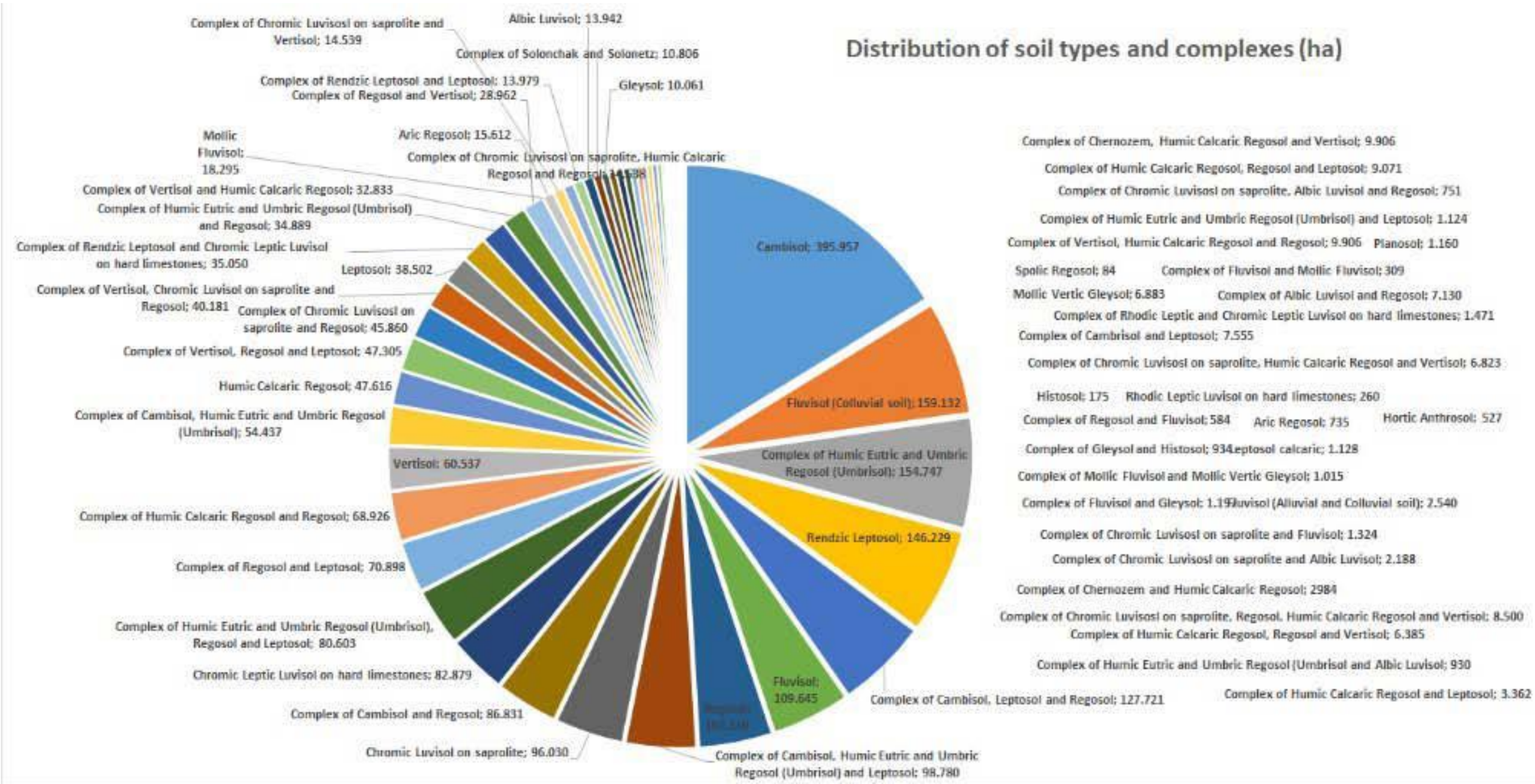


Figure 2- Distribution of soil types and complexes

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The most dominant soil types are as follow: Forest cambisols (15.87%), Proluvium (7.25%), Calcomelanososls (5.93%), Ranker (5.68%), and Fluviatile soil (5.45%). On the part of the territory dominant are soil complexes, forest cambisols and rankers, leptosols, regosols (15.07%) and complex of vertisol + rednzina leptosols (5.33%)

In the *mountain relief* dominate Cambisols (brown forest soils) , leptosols, regosols and umbrisols. Cambisols that are distributed only in the on the mountain cover 771 000 ha (30,8% of the whole country territory), out of 395 957 ha (15,8) as unit soil type and 375 000 ha (15%) as a part of soil complex with other soil types. These are typical forest soils. Leptsols also cover significant area in the mountain relief (23%) Leptosols correlate with the 'Lithosols' taxa of classification systems by Skoric Ciric and Filipovski and with 'Lithic' subgroups of other soils groupings. In many systems, Leptosols on calcareous rock are denoted 'Rendzinas'; those on acid rock are also called 'Rankers'. They are very shallow soils over hard rock or highlycalcareous material, but also deeper soils that are extremely gravelly and/or stony. They are rich in coarse fragments (average 21%). Umbrisols (humic and umbric regosols) can be found on 17% of the territory of the country as clear or in the complex with, leptosols or cambisols. They acoomodate soils in which organic matter of low base saturation has accumulated at the surface to the extent that it significantly affects the behaviour and utilization of the soil.

On the *rolling relief and lake terraces* the following soil can be found: regosols including humic calcaric regosols, aric and spolic regosoos, leptosols, vertisols and flluvisols. Regosols occur in basins, mainly on rolling relief and lake terraces, over paleogenic, neogenic and diluvial sediments. Depending on the substratum over which they are formed, these soils are very heterogeneous in mechanical composition. Clear regosols cover 6% of the territory of the country while in complexes with other osil types cover 16% of the territory of the country. various complexes . Leptosols are registered at registered everywhere because they are not azonal soil type. These are undeveloped soils with profile (A) -R. They have a poorly developed humus horizon below which has a base wall and are at a depth of 25 cm to personal contact They are widespread in a wide range of 750 to 2500 pm. They are found as independent or in complexes with: runkers, with brown forest soil and ranger, with regosol, with limestone dolomite blackness. *Eluvial-illuvial soils (luvisols)* have the following characteristics: the skeletal content is fairly low (9%), the sand fraction dominates and accounts for 2/3 of the particle-size fraction; physical clay dominates in the Bt horizon, where it accounts for 54%; the clay content in the A horizon averages 15%, and in the Bt 36%. The microaggregates show high stability. *Vertisols* are identified as intrazonal, lithogenic topogenic soils. They are found together with other types of soil; depending on the parent material, with regosols, rendzinas, chernozems and cinnamonic forest soils, and on basic compact rock with lithosols and vertic rankers. The texture of vertisols is characterised by the following features: low coarse fraction (4% on average); the clay fraction dominates (clay + silt = 60%); clay is the dominant soil separate (40%) in the fine earth; there is little coarse sand in the vertisols (9%), more silt (21%) and fine sand (30%); clay textures prevail and there is no texture differentiation. They are used for agriculture production.

On the sloppy and flat relief dominate fluvisols. Fluvisols under sloppy relief are assigned as colluvial (old classification) while on the flat terrains as alluvial soils. Fluvisols cover 271 317 ha (10,85%), out of them Fluvisols (colluvial soils) 159 132 ha (6,37%) and fluvisol (alluvial soils ) 112185 ha (4,49%). Fluvisols (alluvial soils) cover approximately two-thirds of the flood plain surface and are among the best-known soils in these parts. They are characterized by their highly heterogeneous texture. Other soil types that can be founds are: gleysoils, planosol, histosol, solonetz, solonchak, hortic anthrosoils etc.

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Systems for the monitoring of soils have not been established yet. This is the result of insufficient financial support for this complex and expensive work.

# Land and Soil degradation

Land degradation and soil degradation are very similar terms. Land degradation is lowering of the productive capacity of land. It thus covers various forms of soil degradation, adverse human impacts on water resources, deforestation, and lowering of the productive capacity of rangelands. Soil degradation is defined as a change in the soil health status resulting in a diminished capacity of the ecosystem to provide goods and services for its beneficiaries. Degraded soils have a health status such, that they do not provide the normal goods and services of the particular soil in its ecosystem. Several FAO publications define that soil degradation "includes soil erosion by water and wind, deterioration in soil physical, chemical and biological properties, waterlogging, and the build-up of toxicities, particularly salts, in the soil.

There are five basic **land-use categories**, which can be matched up with the land cover classes described before and which are subject to land degradation: Cropland; Grazing land (used for animal production) – pastures and meadows,; Forest; Mixed land use (mainly agroforestry, agro-pastoralism, silvo-pastoralism, transitional woodland); non-vegetated artificial land use (mining, human settlements, communication, energy and water infrastructure). These different land uses are subject to specific forms of land degradation. (Blinkov and Mukaetov 2017)

The land use distribution Is presented on the figure bellow.

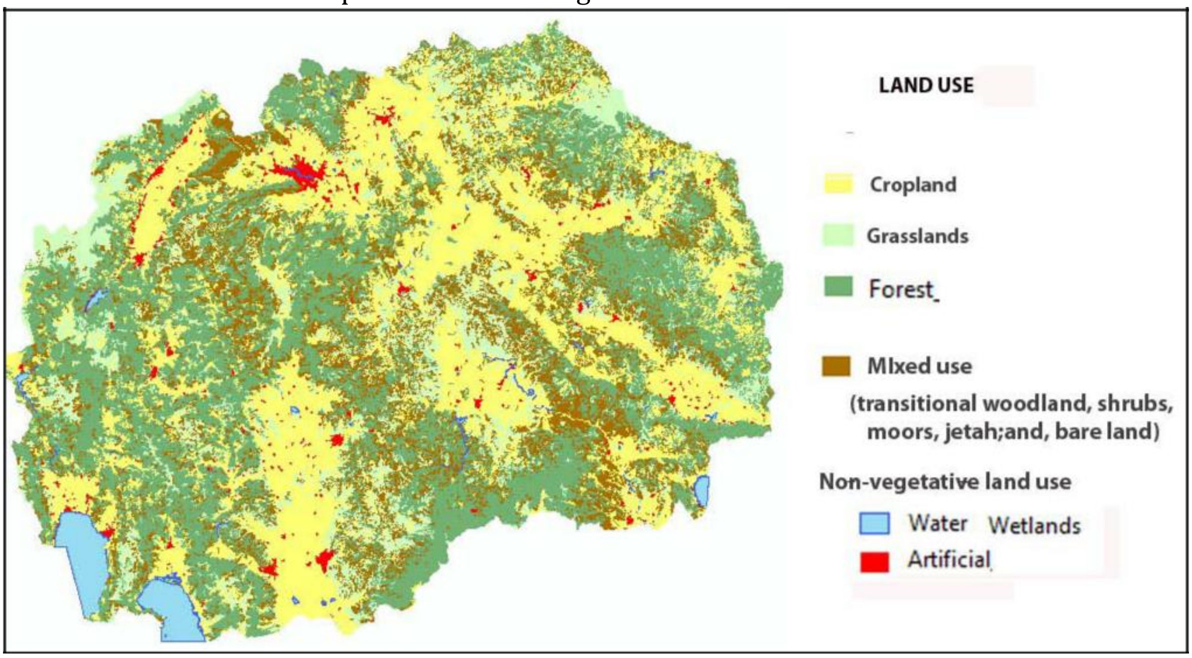


Figure 3 - **- Land use**

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## Land degradation

Land degradation neutrality (LDN) is defined as a "state whereby the amount and quality of land resources necessary to support ecosystem functions and services and enhance food security remain stable or increase within specified temporal and spatial scales and ecosystems". The baseline is expressed as the initial ($t_0$) estimated value of each of the three indicators used as proxies of land-based natural capital and the ecosystem services that flow from that land base: land cover/land use change, land productivity status and trends, soil organic carbon status and trends. The baseline of LDN indicators was calculated with estimation of the average values across the 10 years baseline period of the following indicators: Land Cover/Land Cover change (LC/LCC), Land Productivity Dynamics (LPD) and Soil Organic Carbon (SOC). Data by ESA-CCA global data service and CORINE LCU has significant differences. (Blinkov and Mukaetov 2017a)

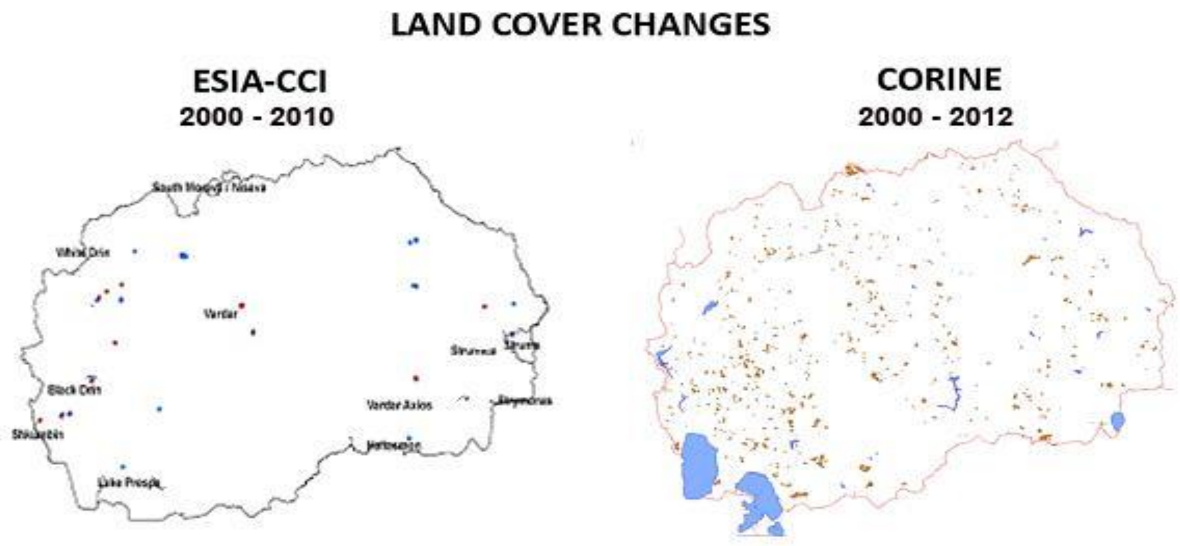


Figure 4 - **Land Cover changes by ESIA-CCI and CORINE LCU**

Table 1 - Area under different categories of LC of CORINE Land Cover Data base (LDN TSP 2017)

| LC categories | ESA-CCI, in km2 | | | CORINE Land cover in km2 | | |
|---|---|---|---|---|---|---|
| | 2000 | 2010 | Net area change | 2000 | 2012 | Net area change |
| Forest (F) | 11.159 | 11.152 | -6,50 | 8.608,5 | 8.242,7 | -365,8 |
| Shrubs, grassland and sparsely vegetated areas (SG&Sva) | 2.631 | 2.635 | 3,90 | 4.388,6 | 4.722,8 | 334,2 |
| Cropland © | 10.345 | 10.347 | 2,6 | 11.256,6 | 11.228,9 | -27.7 |
| Wetland and water bodies (W&Wb) | 497 | 497 | 0,00 | 723,1 | 698,3 | -24,2 |

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| | | | | | | |
|---|---|---|---|---|---|---|
| Artificial areas (Aa) | 713 | 713 | 0,00 | 387,2 | 428,4 | 41,2 |
| Bare land and other areas (Bl&Oa) | 4 | 4 | 0,00 | 74,3 | 113,5 | 39,2 |
| Total | 25.349 | 25.349 | | 25.438,3 | 25.434,7 | |

Comparison of data from both dataset is very difficult. In the following text will be comment results by CORINE. The reasons of these **LCU changes** are result of forest fires in 2007 when almost 40 000 ha were burned. After fire, the land is bare and in the next period the self-restoration usually starts, firstly as a ground flora: grass and bushes and later in most cases forest species. For decoding and calculation of LC changes in 2010 aerial images from the period 2008/9 were used when significant land areas were affected with forest fires due to what in most cases forest areas were classified in the category of SG&Sva. There is also a notable increasing of the categories of bare-land (39, 28 km$_2$) and artificial land (41, 25 km$_2$) which is most probably result of urban expansion and conversion of fertile cropland and pastures. Of particular interest is the decreasing of the area classified as wetlands& water bodies. There are several reasons for this: errors during the photointerpretation, drought that cause decrease of water level and surface area of the Prespa Lake and other wetlands, and perhaps different period of the year of the images because of variations of the water level and lake surface area of the reservoirs because of usage of water for irrigation. Most significant differences are notable among the first two categories forest and shrubs, grassland and sparsely vegetated areas.

The ESA-CCI data base recognizes a total loss of 6, 5 sq. km, out of which 3, 9 km are converted to shrubs, grassland and sparsely vegetated areas and 2, 9 to cropland. (Mukaetov and Blinkov 2017)

According to the calculations, total area of **land productivity dynamic** for the period 2000-2010 (according to the Global data) defined as unacceptable are only 2,35% of the territory of the country and it seems as to be very small area, but in reality there are 58 500 ha with negative land productivity dynamic.

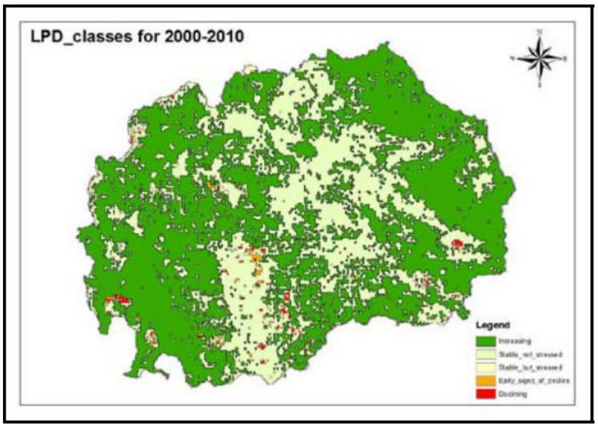


Figure 5 - LPD for the period 2000-2010

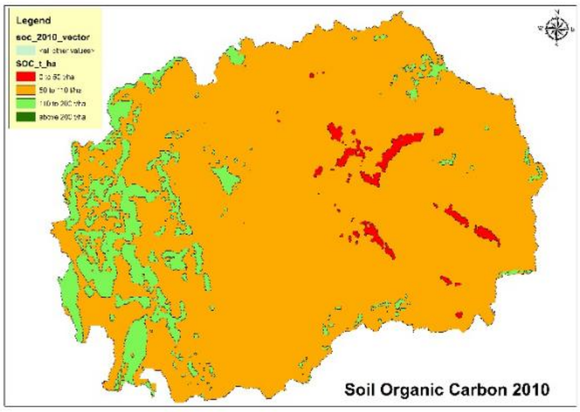


Figure 6- SOC - staus 2010

The available global data sets gives a modeled SOC levels for the period 2000-2010. According these data, the total loss of SOC in our country is estimated on 3951 ***t***. (Blinkov and Mukaetov 2017).

According to the ESA CCI data, the total degraded area is 588, 6 km (LPD – 585 km$_2$ and SOC loss – 2, 6 km$_2$). Total degraded area (negative status in dynamic of LPD +SOC) in the country cover 589 km$_2$ out of which 585 km$_2$ from LPD and 3,5 km$_2$ with SOC losses.

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## Soil degradation

Soil degradation has 2 aspects i.e. degradation of soil physical, chemical, and biological characteristics (local and diffuse contamination, soil acidification, alkalization, salinization, depletion of organic matter and nutrients, physical deterioration) and loss of soil (soil sealing, soil erosion, large scale land movement. ).

Due to climatic conditions and other factors related to **soil acidification**, this type of soil degradation is insignificant in Macedonia. The irrigation activities especially in dry areas accompanied with improper water portions and low quality irrigation water, lead to **salinization**. There are 11 000 ha. of naturally salty soils located in the driest region in Macedonia (Ovce Pole). Unfortunately, due to the absence of monitoring or any research, it could be mentioned that it might be a problem but its intensity, dimension, and state in Macedonia cannot be exactly defined. **Alkalization** is another soil degradation process which can dramatically increase drought but there is no data **Depletion of organic matter and nutrients** are additional types of soil degradation which are just described and their present identified in practice but no further broad investigations or monitoring has been performed whatsoever. Some scattered data can be found in various reports and elaborates for different regions but the global and updated picture of the status and area affected do not exist. In dry areas, like Macedonia, depletion of OM can be rapid, because the processes of decomposition are accelerated at high temperatures. The soils under intensive agriculture production on sloping terrain with heavy texture and shallow soil profile are the most vulnerable soils particularly the soils on hilly relief (lithosol, rendzinas, chromic cambisols, vertisols and the soils on colluvial forms). **Loss and worsening of the soil structure** is another soil degradation process caused by different types of activities mainly in agriculture. This situation is provoked mainly with performing *bad agricultural practices*: absence of crop rotation and improper plowing and *unfavorable economical* situation of farmers which exploit the soils above its natural performance with almost no inputs. (Blinkov et al., 2014)

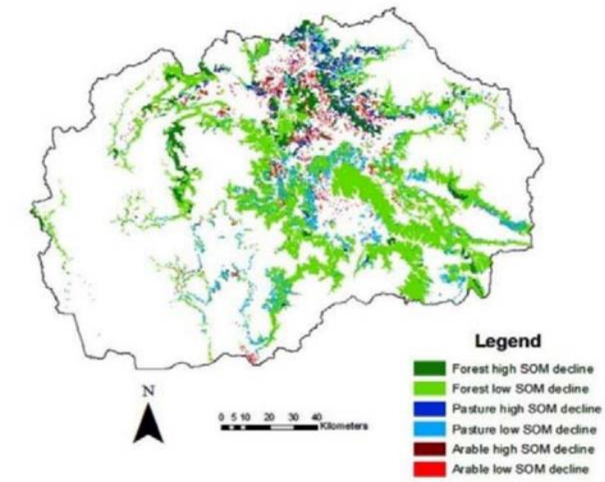


Figure 7 Area vulnerable to SOM decline

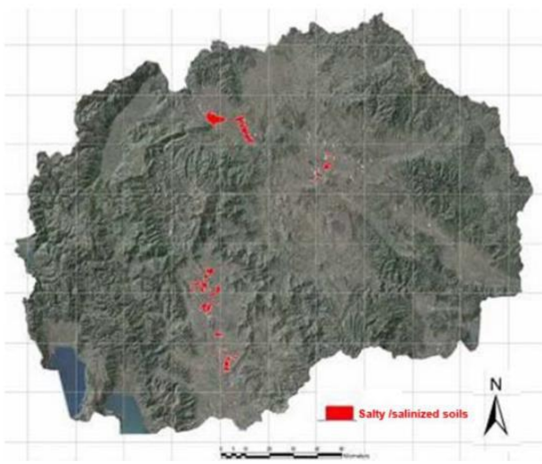


Figure 8 - Area with salty or salinized soils

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There is **soil pollution** with nitrates, phosphates, sulphates, pesticides, organic pollutants, heavy metals, oil. There is no regular and long-term monitoring system. Some incidental measurements of soil pollution around certain industrial complexes have been conducted, and these results are relevant only for those localities. Till the end of seventies fast development of industry brought big changes in socio-economic structure of the population in the economy and also in spatial structure as well in the environment. In general, people are not aware of waste problems and the potential risks of hazardous waste, or of the adverse effects on their health and living/natural environment. The total amount of generated waste, inclusive of waste from mining, can be estimated app.26 million t/year. The main waste fractions arise from mineral excavation and ore processing (app. 17,3 million t/year). However, the group of waste from mineral extraction and processing contains a significant amount of hazardous constituents and improper landfills and managing of technological processes cause the most evident impacts on the environment. At present, the main impact on the environment is observed as the consequence of the abandoned landfills of hazardous constituents in disposed residues, the so-called hot spots. Out of the total production of solid waste, waste arising from exploration, mining, quarrying, physical and chemical treatment of minerals (17.246.000 t/y), waste from agriculture and food processing (5610000 t/y) and municipal waste (680000 t/ha), yields 90.5 % from the total solid waste production. The total amount from different sources of hazardouse waste is aprox. 77126 t/y. Reliable statistical information on waste generation from agriculture is absent. Estimations based on a field survey including the larger crop and feedstock farms in Macedonia indicate the following situation: agriculture waste is a waste group consisting of app. 5 million. t/year of animal excreta, app. 5600 t/year of carcasses and of app. 6000 t/year of animal by-products from slaughterhouses, and app. 500.000 t/years of the plant residues. There is also present app. 3800 t of waste plastics generated by early vegetable production under plastic covers and from silage production, and app. 3400-5000 t of agrochemical waste containing dangerous substances. The group of agriculture waste represents the second biggest waste fraction, mainly addressed as by-products, i.e. these types of waste shall represent "recyclable" fractions in agricultural activities. The management of animal by-products from slaughterhouses and dead animals on breeding farms is far from the requirements of EU regulations. Regarding quantities of manure, only app. 3,6 million. t of animal manure per year (pigs, cattle and poultry manure) is applied on arable land and grassland, in vineyards and in orchards, However, storage of manure on farms and the application of manure on agricultural land is generally very questionable with respect to the pollution of soil and groundwater, and waste generated in commercial pig, poultry and cattle farms in Macedonia form a real threat to the environment. Actions should be taken to strengthen the knowledge and capacity of farmers to manage this type of waste in an environmentally sound manner, in particular in direction of anaerobic/aerobic stabilization and preparation of humus and artificial soils. Municipal solid waste is one of the main fractions of totally generated waste (app. 570.000 t/year for the years 2004/2005). Only 60 -70% of the population is involved in the public municipal waste collection system, which is performed by public enterprises, but only 10% of habitants in rural settlements receive regular municipal solid waste collection services. Most of the MSW and other collected wastes are deposited at municipal dumpsites or at wild dump sites without any pre-treatment. There are app. 54 active municipal dumps used by communal enterprises and a huge number of non-legal dumpsites created by population that do not receive a waste collection service. The solid waste generated in Macedonia is mostly disposed of on landfills. Existing waste disposal practices do not comply with any technical and/or environmental standards; landfills represent risks for the pollution of air, soil, surface water and groundwater, as well as potential risks for biodiversity, agricultural land and human health due to deposition of mixed hazardous and non-hazardous waste. An additional environmental problem is represented by the traditional burning on open-air fires of municipal waste, plant tissue waste and plastics originating from greenhouses or silage coverage. Most of the existing municipal dumpsites need to be closed since the site conditions and environmental impact do not allow them to be upgraded economically, to be harmonized with the EU standards. Active municipal waste landfills are categorized according to the assessment of their environmental risk. 16 landfills are ranked with high risk, 16 with medium risk, and 19 with low environmental risk. Four high-risk landfills are classified as special cases and need to be closed and/or remediated immediately. The *hazardous waste* generated by Macedonian mining and processing industries faced severe problems during the transition period and many have stopped their activities, with no chance of being restarted in the near future. Their on-site process waste dumps were abandoned as well, and little or no information is available on the history of these dumpsites. Apart from the larger industrial dumpsites, being considered as “hot spots” exhibiting higher risk to the environment, there are smaller dumpsites where both processing waste and HZ waste are and/or has been disposed on site but in lower quantities than 1000 t of non-hazardous waste /year; only “MTZ Foundry” generates app. 2500 t of casting sand and core (BLinkov et al, 2014).

**Soil sealing** is a type of soil degradation which become more important with the process of industrialization, expanding of settlements and traffic network. An accelerated increase of built-up areas can be recorded as a consequence of the political and economic changes during the late 1970s and 80s. Rural populations migrated to the cities and new settlements were developed. The concentration of urban population had reached the level of 60% of the whole population. In the last decade migration has been slowed down and the daily migration movements are expanding especially in the areas of gravitation around the economy centers and bigger cities such as Skopje, Kumanovo, Tetovo, Gostivar and Veles. Soil sealing in the Republic of Macedonia hasn’t been defined yet. According to the Trpcevska Angelkovic (2014) intensity of soil sealing in the Skopje region for the period 1965-2010 is 0,14%/anm. This is mostly in the suburban area of the city and is result of illegal ban but also as inappropriate planning. Soil sealing affects fertile agricultural land, puts biodiversity at risk, increases water scarcity and contributes to global warming but together with inappropriate and ‘wild’ urbanization, it significantly contributes to the risk of flooding and damage from flooding. This was one of the reasons for the latest flood, and the damage it subsequently caused, in the vicinity of Skopje in August 2016. (Blinkov. 2016)

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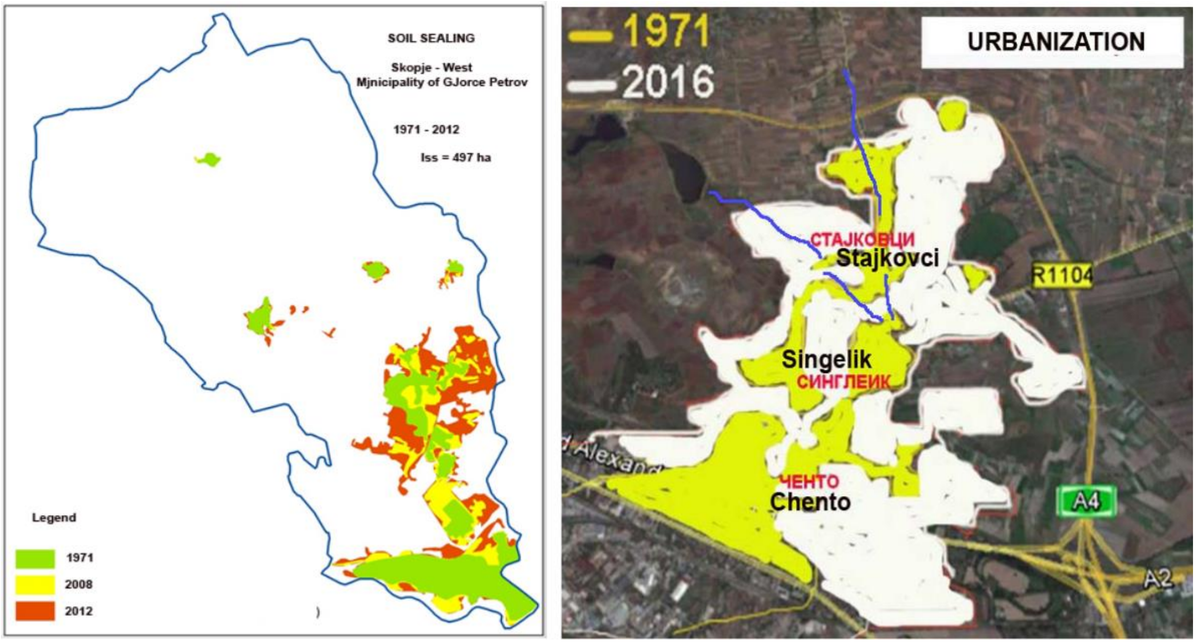


Figure 9- Soil Sealing of suburban area of Skopje – left - western part) and right - eastern part (where happened flood catastrophe in 2016)

## Desertification

Desertification is a new recognized natural hazard in the country. Drylands cover central part of the country and wide to the eastern part. Climate conditions are the main reason for desertification, IN the central part of the country, Mean annual sum of precipitations is bellow 500 mm, while mean annual temeprature is higher then 11₀C. Water deficit is high. The last two decades of the XX century were very arid and in this region mean annual sum were bellow 300 mm even sevral times bellow 250 mm.

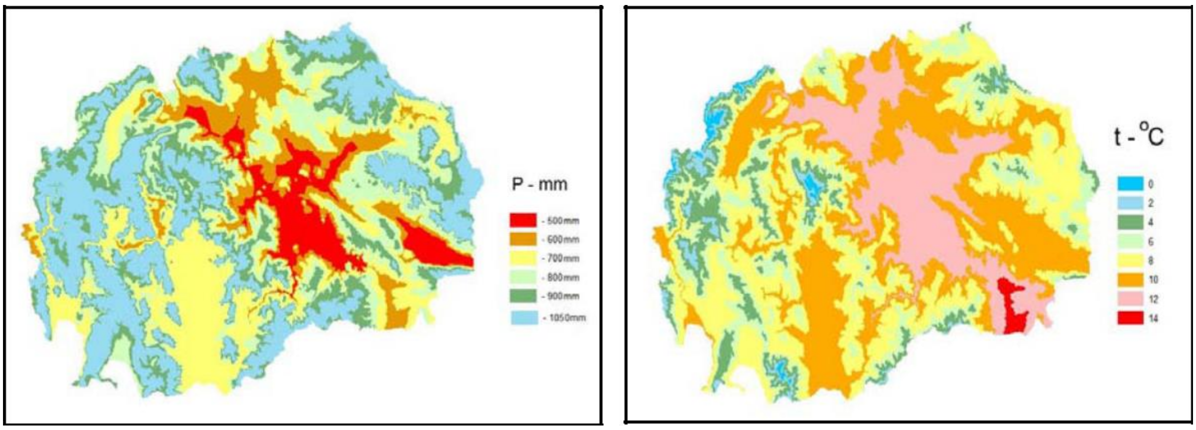


Figure 10 - **Isohyet and Isothermal maps**

Based on the above data was calculated aridity index (AI) and on several climatological stations the AI was bellow and near 0,65. It reflex appearance of natural vegetation.

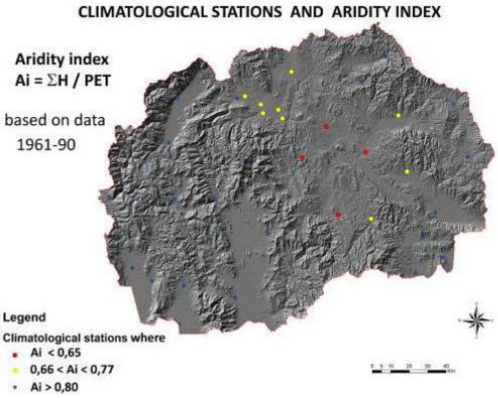


Figure 11- Aridity index

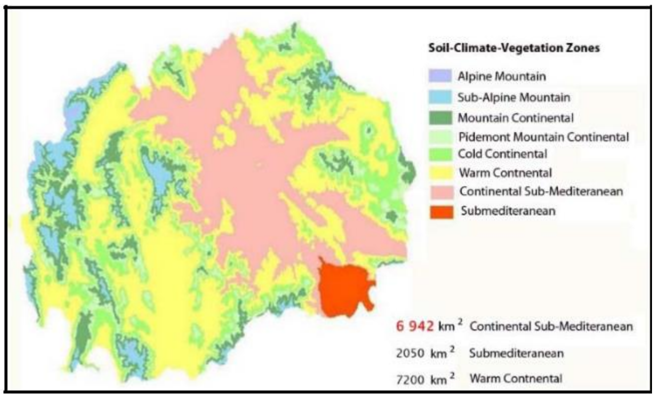


Figure 12 - Soil-climate-vegetation zones

In the lower part of the central zone, existed natural vegetation expressed with grasslands and bushes and transitional woodland is adopted on extreme climate conditions. Barelands are typical for this area. Greater part of the area is abandon.

# Institutional set-up concerning soil management, legal and policy governance

## Organization of soil management

The main Governmental institutions responsible for various issues related to soil are the Ministry of Environment and Physical Planning (MOEPP) and the Ministry of Agriculture, Forestry and Water Management (MAFWE). The following governmental agencies are involved in soil and land related issues: the National Extension Agency (NEA), Agency for Financial Support of Agriculture and Rural Development (AFSARD), Agency for Real Estate cadastre (AREC), and Spatial Planning Agency (SPA).

Soil, as environmental medium, is treated within the Ministry of Environment and Physical Planning (MOEPP). Within the Environmental Administration of the Ministry a unit for Soil exists, but it has insufficient capacity. Within the Ministry of Agriculture, Forestry and Water Economy (MAFWE) there is no any organizational unit that is dealing only with soil related issues, although soil is covered in various sectors, such as land policy, general agriculture etc. The soil information system is developed through a project coordinated by this ministry. On the other hand, the land management is well institutionalised and organized. Land related issues are predominantly dealt by the MAFWE and its cadastre of agricultural land.

The Ministry of Environment and Physical Planning, through its Department of Spatial Planning, is mandated to manage and implement the policies and monitor the processes of physical planning in the Republic of Macedonia. Spatial Plans are developed by the Space Planning Agency established by the Government of the Republic of Macedonia, upon order by the Ministry of Environment and Physical Planning. The National Extension Agency (NEA) is responsible for providing high quality consulting services for individual farms in order to improve the quality and quantity of agricultural production in the rural areas, as well as to assist in improving other agricultural practices for soil protection. Operative protection from soil erosion is the responsibility of the local municipality's administration and the Joint Venture Water Economy (AD Vodostopanstvo).

## Legal framework

No specific legislation for soil exists to date in Macedonia. However the Law on Waters contains some articles that refer to erosion (here also soil erosion).

Soil protection in the Republic of Macedonia is regulated by several laws, including those covering the matters of nature protection.

According to Article 2 of the Law on Environment (Official Gazette of the Republic of Macedonia No. 53/05 and amendments Official Gazette of the Republic of Macedonia No. 81/05), the scope of the law includes protection and improvement of the quality and the state of environmental media, including the soil. The same Law, in its Article 9, stipulates the implementation of the polluter pays principle, and Article 13 provides for the precautionary principle, that would help to avoid local contamination of soil in future. The Law on Nature Protection (Official Gazette of the Republic of Macedonia No. 67/04), Article 11, restricts the change in land use, and Article 12 prohibits nature use in a manner that leads to soil degradation and loss of its fertility.

Within the Law on agricultural land forbidden activities that address soils indirectly are described the following: e.g. protection against pollution and infection, the prohibition of ploughing land with a steepness gradient over 15%, etc. The same Article stipulates that the Ministry of Agriculture, Forestry and Water Economy specifies matters that are harmful to agricultural land, determines their maximum permissible concentration . in soil and measures to be undertaken on agricultural land of higher concentration of harmful matters in order to reduce them below the permissible levels. Within the forestry law sustainable forest management is addressed as a main principle. This can also be interpreted as indirectly referring to soil protection.

The Law on Spatial and Urban Planning of 1996 determines several types of spatial plans: General urban plan (setting the overall organization of cities, including zoning and land use aspects), Detailed urban plan (spatial arrangement of land plots up to 30 ha, containing details of land use) and Urban documentation (plan for rural settlements).

Law on water regulate mater related to water erosion in the chapter for Adverse impact of water. According to article 135 each municipality, the city of Skopje and the water management enterprises are obliged to proclaim boundaries of actual and potential erosive areas and due to this to carry out appropriate non-structural and structural erosion control measures. UP to now only 1 municipality (GAzi Baba) adopted this document although for the Skopje region that consist of 10 municipalities as a part of the City of Skopje and 9 other in the region was defined and proposed actual and potential erosive risk areas.

The most relevant document for soil protection are:

• National Action Plan to Combat Land Degradation and Desertification 2017-2023

Specific measures have been developed according to the outcomes in 5 operational objectives (Advocacy, awareness raising and education; Policy framework; Science, technology and knowledge; Capacity-building; Financing and technology transfer) set within UNCCD 10-years strategy 2008-2018, as well as 1 additional objective (.

- Land Degradation Neutrality Target Setting Programme (up to 2030)

Both documents are in phase of approval.

The other relevant national strategies/action plans are:

- The National strategy for Sustainable Development of the Republic of Macedonia 2009 - 2030;
- The National Water Strategy, 2011 - 2041;
- The National Rural Programme, 2014 - 2020;
- The National Strategy for Land Consolidation of Agricultural land;
- The Third national communication on climate change – 2014;
- Spatial Plan of the Republic of Macedonia, 2002 - 2020.
- The National Strategy for Sustainable Forestry Development (NSSFD), 2006 - 2026;
- The National Strategy for Biodiversity Protection and Action Plan (2018-2023);
- Waste Management Strategy of Republic of Macedonia (2008 - 2020).

## Financial instruments for soil protection

As far as instruments for soil protection are concerned, it should be underlined that there are no specific funds, charges or other allowances to be used specifically to cover the costs related to soil and land protection. The only current mechanism in the country related to decrease soil degradation are subsidiaries for farmers for good agricultural practices. Some mechanisms or activities in related sectors, contribute to protection of soil as follow: programme for extended reproduction in forestry, permanent forest fires management activities according to the relevant legislation, improvement of irrigation techniques etc.

Options in this context include resources from the Central or local Budget, capital grants and long-term loans intended for environment protection or good agricultural practices, financing on bilateral bases and capital investments from the European Union Instrument for Structural Policies Pre Accession. Within the NAP LDD are defined various measures within the operative objective 5 (Financing and transfer of technologies) as folloe: Mapping of possible DLDD financial sources (domestic and international) ; Creation of mechanisms for linking available domestic and international financial sources for DLDD; Integration of DLDD issues in the annual operational financial planning at the central and local level; Ensuring regular allocation from the central and local budgets for DLDD issues; Increasing the capacity at the national and local level to apply for and use the available international Programmes for DLDD; Matching domestic with international financial support by co-financing and other mechanisms; Promotion of the public-private partnerships for treating DLDD issues; Promotion of inter-municipal cooperation in the area of DLDD; As a part of the NAP LDD is annexed financial strategy.

# Soil Erosion

## Erosion intensity

Natural conditions in the country (climate conditions; topography characteristic; vegetation cover; geology ...) contribute to high erosion processes. Also Poor arable farming, grazing management, and deforestation in past and wild fires have contributed to erosion, a problem spread all over the country.

` The Erosion Map of the Republic of Macedonia was prepared by the team from Water Development Institute of the Republic of Macedonia led by Gorgević M. in the period 1981 – 1993. Erosion potential method (EPM) by Gavrilović was used with direct on-field mapping. Team was firstly trained for subjective assessment of processes during on-field mapping. Team used m maps in a scale 1: 50000. A summarized report was produced in 1993. Later, in 2002, the working maps were scanned, georeferenced and vectorized.

Additional researches (modelling in a GIS environment using EPM and on-field validation) in the last 15 years were done by Blinkov, Trendafilov, and Mincev for some parts of the country, Additionally few researchers created maps using EPM or RUSLE for parts of the territory even for the whole country but without on-field verification. For the Skopje Region (one of 8 NUT III regions in the country) in 2017 were prepared several maps as follow: map of erosion intensity, map of hot-spots, map of actual and potential erosion risk . For all these maps/models was developed separate approach and method while the basic methodology was EPM. All developed models were validated through on-field works.

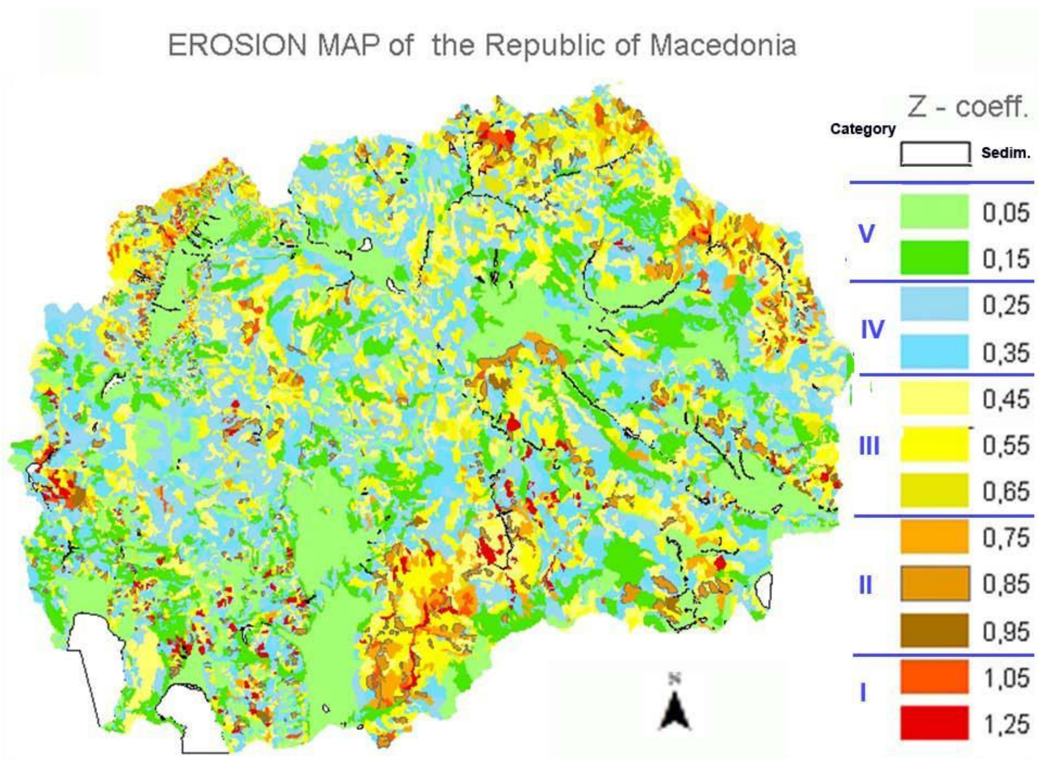


Figure 13- Erosion Map ( Z – coefficient of erosion}

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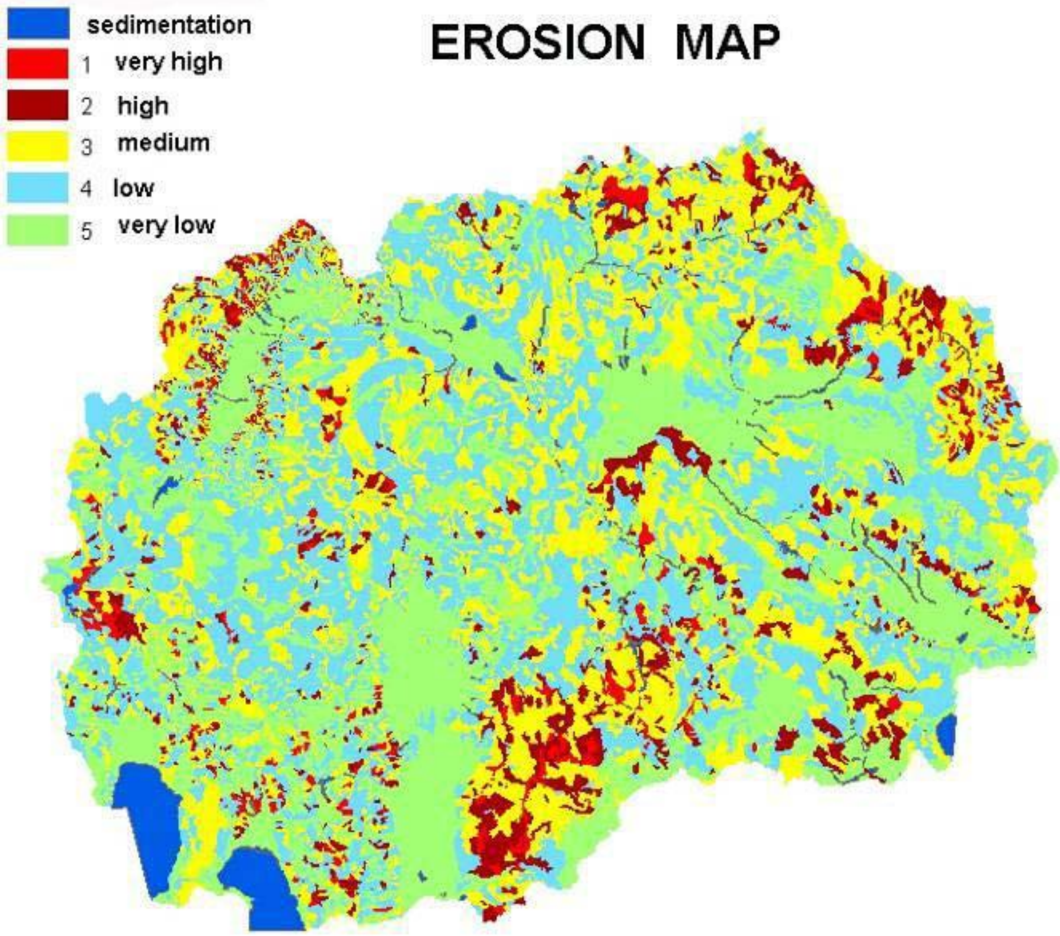


Figure 14- Erosion Map by category of destruction

According to the Erosion map of Macedonia (figure 14 and table 3) , 96,53% of the total area is affected by erosion. An area of 9,423 $km_2$ or 36.65% of the total state area was is under unacceptable - highest erosion intensity categories , from moderate to excessive soil erosion

Table 2 -- Erosion distribution in Macedonia (Gorgevic *et al.*, 1993)

| Degradation category | Erosion process intensity | Erosion intensity | Area endangered | |
|---|---|---|---|---|
| | | $(m^3 km^2 yr^{-1})$ | $km^2$ | % |
| I | Excessive | > 3000 | 698 | 2,71 |
| II | High | 1500 – 3000 | 1832 | 7,12 |
| III | Moderate | 1000 – 1500 | 6893 | 26,81 |
| IV | Weak | 500 – 1000 | 7936 | 30,86 |
| V | Very weak | 70 – 500 | 7463 | 29,02 |
| sedimentation | | | 891 | 3,47 |
| | Total | | 25 713 | 100.00 |

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The total annual erosion in Macedonia is about 17x10$_6$ m$_3$yr$_{-1}$ or 685 m$_3$km$_{-2}$yr$_{-1}$, with about 7.5x10$_6$ m$_3$yr$_{-1}$ or 303 m$_3$km$_{-2}$yr$_{-1}$ of the sediment load. A significant part of these deposits within Macedonia, about 3x10$_6$m$_3$yr$_{-1}$, is not carried downstream for the rivers, but is deposited in natural lakes and reservoirs inside of the country.

According to the calculation of Gorgević *et al. (1993)*, based on the erosion map, the rates of annual sediment yield in the biggest reservoirs in Macedonia were: Tikveš (1.3x10$_6$m$_3$ or 497 m$_3$km$_{-2}$), Kalimanci (0.42x10$_6$ m$_3$ or 970 m$_3$km$_{-2}$).

Through the years , various researchers in the country (Popovski B., Jovanovski S., Djorgevic M., Gasevski M., Trendafilov A., Blinkov I., Mukaetov D., ..) carried out research on erosion intensity, soil losses, losses of organic mater and nutrients, on experimental plots.

Researches by Jovanovski and Blinkov (1992-1998), on experimental plots with slope from 11 – 27%, with pentagonal form an area of 100 m$_2$, where sediment is collected at the downstream edge, to be later analyzed in a laboratory, showed strong correlation between soil losses and slope of the terrain. i.e. *Y = 329.1 x – 3884.5* *($R^2$ = 0.91) where y – annual soil losses in [t] , x – slope of the terrain.* Soil losses vary from 0.04 -4.773 t/ha, losses of $K_2O$ (0.021-1.598 kg/ha) , losses of $P_2O_5$ (0.008-0,737 kg/ha), losses of N (0.082-2,704 kg/ha), losses of humus (1,929 – 33,546 kg/ha), Those plots covered with vegetation (grass and bushes) show minimum runoff with no silt in the collectors.

Gesovski M. (1979) researched irrigation erosion on vineyards (furrow irrigation) and measured annual soil losses of 36.69 t ha$_{-1}$.yr$_{-1}$ (on slope 3.67%) and 126, 91 t ha$_{-1}$.yr$_{-1}$ (on slope 10,1%). It is estimated that irrigation erosion at the state level is 3*10$_6$ m$_3$ yr$_{-1}$.

Sedimentation of the reservoirs is a problem taking in consideration that the most of the reservoirs are primary used for irrigation purposes necessary for agricultural production that is a pillar of country economy. Measuring depose sediments started in 1969 but frequency is not satisfied. Only for 2 reservoirs there are more measuring that are enough to calculate trends. Two periods can be deduced from measuring, 1969-1985 and 1985-2013. In the period 1969-1985, the average annual deposition in the reservoir is 467,686 m$^3$ yr$_{-1}$, and in the period 1985-2013 the average annual deposition in the reservoir is 214,325 m3 yr$_{-1}$. In the first period the filling is more than double than in the second period. When comparing the modeled erosion intensity from the Erosion map (mapped in the mid of 80's) and mapped/modeled in 2013 show significant decrease of erosion intensity. In the erosion map Z = 0.54, while current value is Z = 0.36. Several factors affects this phenomenon i.e. slightly decreased precipitations, huge migration processes from the hilly-mountain region and abandon agricultural land that cause positive land cover changes, effects of mas erosion control works in the region. Finally, the consolidation and compaction of the deposed material into the reservoir storage contribute to the total volume of the sediment. Beside it in few long reservoirs was defined negative effect i.e. deposition of sediments in the "useful" storage and consolidation there.

## Description of erosion processes

Due to the natural conditions as well as human activities, various type of erosion processes can be defined in the country as follow: water erosion (dominantly), wind erosion (mostly in central part), karstic and glacial erosion on the high mountains). By type are presented sheet erosion, rills, shallow and deep gullies, streambank erosion, mass movement erosion (landslides and landfalls). Rock weathering are significant in the mountain region and are significant contributors of sediment.

The most characteristics erosive processes will be elaborated per 3 different high erosive zones in the country: western part – Shara – Korab massif, central part of the country along the river Vardar and southeast part of the country near Kalimanci reservoir.

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The main mountain range in the **western part of the country** is continuous of are the Dinaric Alps, the Shara-Korab - Jablanica massif which spreads along the border between Albania and Macedonia. It is generally composed of Palaeozoic metamorphic complex, with volcanic and sedimentary formations in the lower parts, and carbonaceous formation on top. The creation of this massif, as we know it today, probably originated from Eocene about 40 million years ago, and throughout that period, the mountain significantly changed its appearance. These mountains usually has narrow, sharp ridges and peaks and deeply incised valleys. The highest peaks are Korab (2764 m asl) and Titov Vrv (2747 m asl). There are 17 peaks wth height more then 2600 m asl. Slopes are very steep (ina some parts even mean slopes of torrent beds achieve more then 20%). The terrain is rough. Drainage net is very dense. Various erosion processes by type and intensity can be seen. Erosion intensity in the region is at least 2 times higher then the average value for the country.

Figure 15- Glacial forms and talus cones (high mountain region) , deep gullies, landslides (mid mountain region), sediments by torrents and rivers (on the foot of the mountains)

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**Central part of the country** (along the river Vardar and lowest parts of its tributaries Bregalnica and Crna Reka) on the altitude < 450 m asl., characterize with semiarid climate. Geologically dominate various Paleogene and Neogene sediments. River Vardar is the main river in Macedonia and the main communications pass along this river always. Mouth of the Vardar into the Aegean Sea is near Thessaloniki in Greece, big port, and west trade center of the Ottoman Empire. According to Turkey chronicle E. Cheleby (XVII AC) this area was cover with dense woodland and forest. Later was proclaimed "res nullius" for the forests that means nobody is owner and everybody can cut free. Forest along the river was cut and transported throw the river to Thessaloniki. After clear-cut, erosion processes did other. Today on that territory, part of Vardar left side in Central Macedonia is decertified (Krivolak). Low education level, insufficient of consciousness, social structure and low financial level in past, were reasons for large forest destroying around the settlements too. Although sum of precipitations is low, rare sudden high intensity precipitations caused intensive erosion processes on the slopes forming even deep gullies. Beside typical sheet, rill and gully erosion, taking in consideration the lithological structure, in this area has appearance of landslides and the Mokliste landfall is the biggest in the country (10-15 million $m^3$ earth material fell in the valley and barrage the river Lud Mara forming a lake. )

Figure 16- Typical processes in t central part of the country – sheet erosion, decertified area, gullies and a lot of sediments, mass movement erosion

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The **eastern region** i.e. in the Kalimanci reservoir catchment the erosion processes are various. These mountains belong to Serbo-Macedonian Massif that's characterize by the domination of very old Precambrian and Rifey-Cambrian lithological complexes: gneisses, mica-schists, amphibolite, green-schists that are high erodible. Intensive volcanic activity contribute to the landscape. Mountains are with subdued relief, rounded ridges and peaks, and less deeply incised valleys. Lower parts of the mountains consist of sediment rocks sandstones that are highly erodible. Precipitations are higher then country average values. Depp gullies U and W type and pyramidal forms are characteristic and intensity of erosion is extremely high. Natural conditions combined with human influence contribute to high erosion processes. In the XIII-XIV century German miners (we call them Sasi), arrived to Macedonia and started with mines activities especially in the East and Northeast part of Macedonia. They cut forests in that territory and use like fuel wood or mining wood. This area (Kamenicka river catchment) is still one of the most erosive part in the country besides huge erosion control works.

Figure 17- Eastern mountains (deep gullies, pyramidla forms on sandstones highly erodible) all type Kamenicka river catchmnet (sheet erosion, gullies, sediment cones) , huge sedimentation of the Kalimanci reservoir

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