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

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Analysis state of soil degradation/soil erosion in Bulgaria

1. Introduction

Bulgaria is situated in South-eastern Europe and takes the north- eastern part of the Balkan Peninsula. The total area of the country is about 111, 000 sq. km. The geographical location sets very diverse climate and meteorological conditions.

The climate is defined by the influence of the Atlantic Ocean, the Mediterranean Sea and the Black Sea. The cold continental air masses coming to the northwest and northeast and the subtropical air masses of North Africa contribute to the formation of five climatic regions: area of moderate continental climate, transitional-continental area, transitional-Mediterranean, Black Sea climate area (covering an inland area of 20-40 km), and mountain climatic area (regions above 1000 m). There is tendency of winter precipitations increase and summer rainfalls decrease in southern parts of Bulgaria and summer rainfalls increase in the northern (Alexandrov, 2002). During the months from April to October about 70 intensive rainfalls where nearly 14% are erosive, have been recorded (Rousseva, 2002a).

The topography of the country predominantly reaches moderate to hilly elevations (470 m in average). Interesting peculiarity is the alternation from north to south of lands with plane-hilly, mountain- valley, lowland and alpine relief. In terms of relief forms, there are diverse plains, plateaus, hills, mountains, basins, gorges, and deep river valleys.

The soil diversity in Bulgaria is rich (see the section: Status of the soil data). The initial attempts to control soil erosion have been made at the end of the 18th century mainly by afforestation around settlements. The beginning of the organized erosion control was set in 1905 when the first Bureau of torrent stabilisation and afforestation was established. Some very good results have been achieved during the erosion control activities. There are examples very successfully performed complex activities for controlling of torrent watersheds, as well as unique decisions for stabilization of torrent beds and landslides. A significant amount of erosion control activities with very positive results have been performed on the forest's territories and have been studied (Kostov et al. 1995, Zakov, Marinov 2003, Rousseva et al. 2006, Panov 2000, Zuckov 2005, NFB 2005). The soil erosion state in the country has been analysed and presented by Rousseva et al. (2006), Marinov 2009 and Rousseva, Marinov (2019) . The territory of Bulgaria represents 2.5 % of the EU 27 countries area and contributes with 3.8 % to the total soil erosion losses on EU scale (Rousseva 2012).

The river network in Bulgaria is very dense and there are two major catchment basins: the Black Sea, incl. the Danube River catchment (57% of the territory and 42% of the rivers) and the Aegean Sea (43% of the territory and 58% of the rivers) basins. The average annual precipitation in the country is 670 mm. The regions in the north-eastern part are characterized with lower rainfall (450 mm for Dobrudzha), whereas the highest precipitations are typical for the mountain regions (2293 mm in the western parts of Stara Planina Mountain). The water resources are unevenly distributed throughout the country and in terms of renewable

internal freshwater resources per capita, the country is listed in the lower positions among the Balkan countries (The World Bank Database[1]).
Bulgaria has rich and unique biodiversity and as part of the NATURA 2000 network, 34.46% of the territory is protected under the Birds and the Habitats Directives (NATURA 2000 Barometer[2]). That coverage ranks Bulgaria at third place in Europe after Slovenia (37.85%) and Croatia (36.58%). Forestland in Bulgaria cover an area of 4,230,825 ha (38%) (EFA, 2016) and croplands cover area of 4,107,476 ha or 37% of the country's territory (NIR, 2017).

- Status of the soil data (types of soil, monitoring)

The territory of Bulgaria is characterized with great variability of soils (Kolchakov et al. 2005), which distribution is determined by specific topographic and climatic characteristics. The soil map of the country (fig.1) shows more than 20 soils groups out of total 28 FAO soil units (Boyadzhiev 1994; Kotev, Kolev 2009). From this soil types the most widely spread soil group in the country is Chromic Luvisoil with 21.91%. The next soil groups are Chernozems with 20.23, followed by Cambisoils – 15.58%, Haplic Luvisoils with 10.24%, Pseudopodsolic soils (9.75%), Fluvisols (8.97%) and Vertisols (5.37%). Limited spreading has Rendzic Leptosol (2.74%) and Leptosols (1.55%). Least spread soil groups are Solonetz and Solonchaks (0.22%). The rest groups (Regosols, Arenosols, Calcisols and Anthrosols) could be found in association with the other soil groups (Kotev, Kolev 2009).

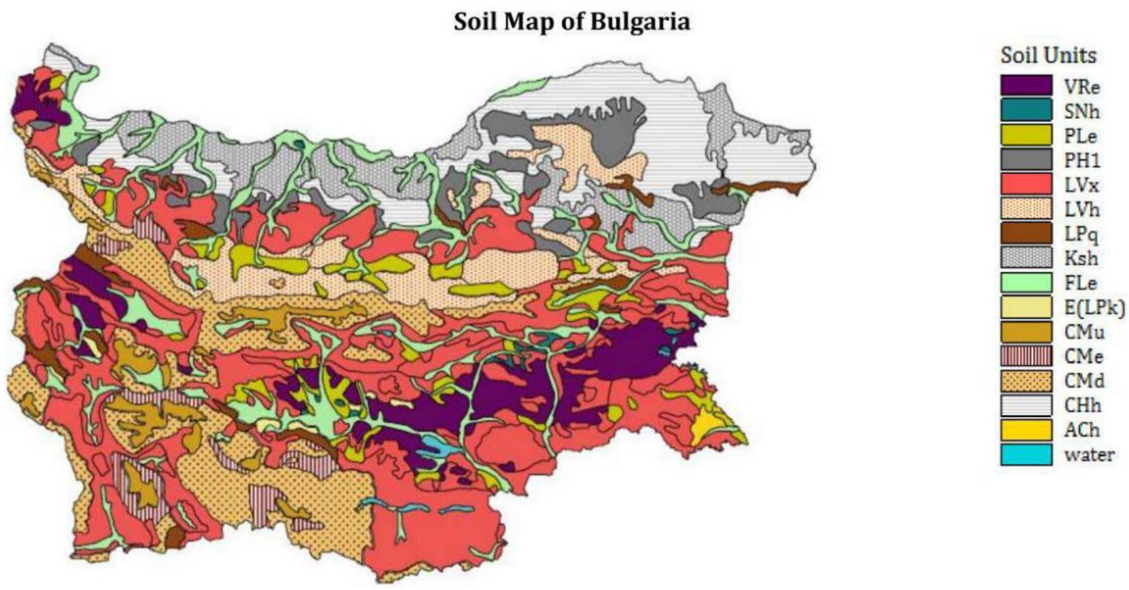

Figure 1. Soil map of Bulgaria (Boyadzhiev, 1994).

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[1] https://data.worldbank.org/indicator/er.h2o.intr.pc?end=2014&name_desc=false&start=2014&type=shaded&view=map
[2] http://ec.europa.eu/environment/nature/natura2000/barometer/index_en.htm

Most of these soils however are under degradation treats. Depend on land use and soil type and soil cover percentage distribution of territories by degrees of erosion risk are presented in table 1.

Table 1

Percentage distribution of territories by degree of erosion risk (*Source:* Executive Environment Agency)

Land use	Low (< 5 t/ha/y)	Moderate (5.01 - 20 t/ha/y)	High (> 20 t/ha/y)
Arable land	65	27	8
Permanent plantation	33	38	29
Pastures	48	32	7
Other agricultural territories	49	35	11

According to the last National report on the status and protection of the environment of Bulgaria (Report, 2018), estimation of the average annual erosion is 72 million tons, and it is appeared in different degrees and intensity. In arable lands depend on land use soil erosion is estimate as 7.1 t/ha/a for pastures, 6.8 t/ha/a in the fields, 22.5 t/ha/a in permanent crops, and in areas occupied with other types of agricultural crops it is 8.1 t/ha/a. The report indicates that the highest intensity of the erosion processes occurred in arable lands is in Sliven region (37 484 ha), the land with perennial crops - 837 ha, pastures - 370 ha. There is also tendency to increase the areas with high and very high erosion risk by 2 961 ha and 3 615 ha respectively. The lowest level of risk of water erosion is the area of Blagoevgrad District - 3 327 ha, of which for agricultural land with permanent crops - 498 ha, pastures - 902 ha.

Soil losses in Bulgarian forests are estimated as 1,211,471 tones. For the areas occupied by deciduous forests the highest intensity of the erosion processes is 15,700 ha and for the coniferous forests respectively 176 ha. Forest areas with the lowest degree of actual risk of water erosion occupy 11,592 ha (Report, 2018).

In Bulgaria, it could be considered that soil monitoring starts with the elaboration of the first soil map for Sofia region in 1913 presented by N. Poushkarov. The following years different researches and maps on various scales are developed. In 2004 The Ministry of Environment and Water develop and implement the state environmental policy including National system of soil monitoring. The soil monitoring aims actual information about the soil vulnerability to different degradation processes, such as erosion, salinization, acidification, heavy metal pollution and groundwater pollution.

The National system of soil monitoring consist 446 points in a network grid 16x16km (Kolev 2007; Zaharinov, Kolev 2010). The monitoring is being conducted during 5 or 10 years and includes 8 criterions. Soil erosion is one of those criterions. Soil monitoring is structured on three levels – basic monitoring, additional monitoring and specialized monitoring. Basic monitoring includes basic information of chemical status and changes in

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time. Additional monitoring includes estimation of about 10% of sampling sites. These sites are referent and are coordinated by European authorities. In this second level of monitoring the aim is to estimate the soil physical degradation, salinization and local soil pollution. The third level is specialized monitoring for soil erosion, loose of land due to construction and hydrogeological risk.

- **Soil degradation (land cover and changes in land use, organic carbon content in the soil, alkalization and salinization, management of contaminated sites etc.)**

Land degradation in Bulgaria is outlined among the most hazardous environmental concerns, where soil undergoes multiple degradation processes. The unsustainable agriculture and forest management practices take the largest share of manmade disturbances to the natural ecosystems. On the other hand, the physical factors and driving forces causing soil degradation and loss of fertile topsoil such as rainfall, surface runoff, floods, wind erosion, tillage, and mass movements can be easily distinguished and are subject of research in many investigations (Malinov, 2003; Marinov et al. 2004; Panagos et. al. 2015, 2017; Stoev et al. 2007). The decline in soil quality results also from agricultural chemical fertilizers, reduction of the soil organic carbon, loss of the biodiversity, salinization and accumulation of exchangeable sodium and contamination with toxic elements. In general, the factors that define soil degradation can be grouped in: biophysical - land use and management, including afforestation, pasture and land cultivation, etc., and socio-economic and political - land property and market, political settings payments for ecosystem services, etc. (Marinov et al., 2005b).

Soil degradation is a process that develops in time, but brings severe consequences on the ecosystem health status, the ecosystem's capacity to provide services and thus to the human well-being. According to the UNDP Bulgaria Review of activities (2007-2008), land degradation affects 50-60% of the country's territory. Therefore, actions to prevent and mitigate that process should be directed into conservation agriculture and forestry, erosion control, as well as improvements in terms of agricultural infrastructure. Special attention from both scientific and practice sectors should be drawn to soil salinization, organic matter decline, alkalization, and reduction of soil organic carbon (SOC) content like problems of great priority for the activities to halt and reverse soil/land degradation.

Land cover and changes in land use. The land cover and land use changes should be taken into account as important elements for comprehensive the soil erosion assessments. The EU Directive 2004/35/EC for establishing a framework for the protection of soil and amending sets the requirement for land users to take precautionary measures as the land use practices and soil treatment can be expected to hamper significantly soil functions. As the aboveground biomass is related to the organic carbon stock in soil (Zhiyanski 2008, 2011), changes in the land use such as in agricultural lands reverted to natural vegetation being or no longer being used for cultivation, soil organic carbon can accumulate. For the sector "Land use, land use changes and forestry" the balance between greenhouse gas (GHG) emissions and sinks shows high rates in favour of the greenhouse gas sinks, such as forests, grasslands and meadows National strategy for development of forest sector 2013–2020 (MoAF 2013). In the last 21 years, the share of GHH emissions in the sector is estimated between 11.35%-19.9% of the total GHG emissions in Bulgaria, where about 94-95% is realized in forest territories.

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Comparing the levels of the organic carbon stock in soils, grasslands and croplands show higher content than forestlands, according to the (NIR, 2017).

The statistic in Bulgaria for land cover and land uses starts in 1965. The balance of the territories includes type of lands (agricultural, forest, waters) is used for the purpose of national programs. The percentage of cultivated (arable) and non-cultivated agricultural lands is used as a main factor of the state of lands. The overall change in land cover compared with other European countries is very low and is getting even lower compared with other periods (Bulgarian land cover 2012). The last data for type of land use showed that about 57.7% are agricultural lands, followed by areas covered by forest - 35.15% (table 2) (Yarlovska 2018). The urbanized territories are about 5% and the territories occupied by water and water bodies - 1.8%, the territories for mineral extraction and transport needs are less than 1%.

Table 2

Change in type of territories in %

Type of territories	Years	
	1998	2015
For transport needs	0.63	0.64
Mining of minerals	0.32	0.23
Areas occupied with waters	1.81	1.80
Urban territories	4.99	4.47
Forest territories	33.1	35.15
Agricultural lands	59.17	57.69
Used agricultural land (UAL)	50.9	45.10
Arable land (% from UAL)	60.10	69.70

There is positive increase in arable lands due to the effect of Bulgaria's accession to the European Union in 2007. With this accession, Bulgarian farmers receive access to financial support of different European mechanisms and frame works. Bulgaria is among the leaders of the European Union (EU) on the growth of arable land and is on average position by the territory of agricultural lands (Yarlovska, 2018).

According to the table forest territories also increased. In this process of restoration the greatest share is the self-afforestation the transformation of coppice plantations into high-stems, afforestation of fires, self-afforestation of untreated territories, revaluation of coniferous crops and low productivity crops and transformation of part of coniferous forests in deciduous (Koleva, Tepeliev 2018). Forest territories (forest fund) in Bulgaria at the end at 2016 according to data from Executive Forest Agency cover 4,230,825 ha which is 38 % of the country area (EFA, 2016). The area of forest territories without forest vegetation is about 366,000 ha.

Organic carbon content in soils. The content of soil organic carbon is a main diagnostic indicator for assessment ecological status of the soils in Bulgaria. For the period 2005-2014, average content of soil organic carbon in arable land is determined from 16.3g/kg to 15.7g/kg for meadows and pastures this values are 20.5g/kg to 20.1g/kg. (Hristova et al. 2016). In some conditions in Bulgaria soil organic carbon could reach about 255 $t.ha.^{-1}$ in a surface

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horizon (Hristov, Filcheva 2017). It is established that in mountain regions, soils are very reach of soil organic carbon (Rousseva, Marinov 2014). In Rila Mountains organic carbon in surface layers under white pine is 8.4t/ha and under spruce is 4.7t/ha (Rousseva, Marinov 2014). In Stara planina Mountains under beech forest this values is 3.8 t.ha (Zhyanski et. al. 2008) . According to Malinova et al. 2011, the total stock of organic carbon in different soil types under forest is determined and is fallow - 76.95 Mt in Luvisols, 67.60 Mt in Cambisols, 12.07 Mt in Regosols, and 10.01 Mt in Leptosols.

Salinization (accumulation in soil of soluble salt). According to UNDP National Action Pan for Sustainable Land Management and Combat with Desertification in Bulgaria for 2014-2020 (UNDP NAP 2014-2020), areas affected by salinization processes count 35,500 ha of the arable lands. These territories are encompassed in Burgas, Varna, Veliko Tarnovo, Pleven, Plovdiv, Sliven, Stara Zagora, and Yambol - some of the largest regions by area and by traditional agricultural production. Moreover, major part of the saline soils overlay with lands abandoned because of the decrease in the soil quality and fertility. The main environmental concern is that the human activities and the anthropogenic pressure on the land may lead to spatial distribution of the saline soils, especially when the saline "patches" are randomly distributed among arable lands. In relation to the content and type of soluble soils, the most common soil groups are the Solonets and the Solonchaks (FAO Soil group).

Soil organic matter decline. This process is related to the loss of topsoil layer due to intensive tillage and aeration of the soil layer, erosion by water or wind, and disturbance in the soil structure (soil compaction). In the context of prerequisites related to the human activities, fires boost soil organic matter decline (dehumification). Despite the legislative restrictions, a widespread practice in Bulgaria is the burning of plant and animal residues (incl. their decomposition products) and shrubs that leads not only to soil fertility loss, but also to loss of biodiversity. The total content of organic carbon has been calculated to 1.3 Gt (Filcheva et al., 2002). The difference between soil organic matter loss in arable and non-arable land ranges between 10-40%, where Cambisols have the biggest contribution to the total organic carbon reserve (Baseline report, 2006).

Alkalization. The soils prone to alkalization take 4,300,000ha of the agricultural territories. For about 1,500,000ha of the arable lands in lowlands and semi-mountain regions and 1,200,000ha of the mountain lands have soil pH lower than 5.0. The undergoing measure to limit the acid fertilizers have favourable effect on the pH balance in the soils. For example, mountain areas from Eastern and Western Stara Planina Mountain, the mountains Osogovo and Kraishte, and the western slopes of Rila and Vitosha mountains are characterized with pH<5.0. The alkalization process is typical for the northern and southern slopes of Sredna Stara Planina Mountain, Rhodope Mountain and the western slopes of Rila Mountain.

Each of the tree abovementioned processes derives one from another and leads to vegetation loss. Thus, the combined effect of the processes increases the exposure to soil erosion. The compaction of soil and contamination from technological sources are other processes that can be outlined as drivers for soil degradation.

Compaction of soil. This negative process causes lower infiltration rates and is mostly present in the arable lands, where farming practices contribute to the problem. Thus, soils are more prone to erosion by water/wind as there is a decrease in soil porosity and an increase in bulk

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density. The degradation of the soil structure is impacted and this process is typical for soils with naturally heavy texture. Soil compaction and decline of soil organic matter are processes directly related to soil fertility and should not be neglected. The aggregate stability of more than 60% of the soils (solid soil sample) show good rates and only 3% - weak. Soil crusting due to the intensive spring and summer precipitations followed by long dry periods impact 12% of the arable lands in Bulgaria (Baseline report, 2006).

Technogenic contamination in soil. The large-scale production and industry (by local inputs) and the use of certain fertilizers (by diffuse inputs) cause consequent changes to the soil quality and composition, and to the nutrient properties of the harvest. In forest areas, the presence of high concentrations of toxic elements and heavy metals impede the ecological balance and functioning of the ecosystems (Broll et al. 2016, Zhiyanski et al. 2008, Zhiyanski 2018). According to the UNDP NAP 2014-2020 report, for the period 2005-2012 the number of sampling points where the measured amounts exceed the maximum of allowable concentrations is 3.02% for agricultural lands (arsenic and copper) and 3.53% for grasslands (nickel and lead). In average, the harmful substances overpass from 1 to 3 times the maximum of allowable rates. Such outcomes have been obtained in the regions Smolyan, Pazardzhik, Sofia, Montana, Kardzhali, Haskovo, Blagoevgrad, and Burgas. As result of the use of sustainable methods in agriculture and the eco-friendly farming there is a positive tendency in mitigation of such technogenic hazards.

- Soil Erosion

- **Mapping/modelling (process of defining erosion intensity, when, who worked, used methodology, used techniques, scale)**

Research methods in the agricultural lands. The studies on soil erosion under different natural and economic conditions carried out by scientists from the Soil erosion department at the Nikola Pushkarov Soil Science Institute. The studies of the erosion processes in the agricultural lands have been made on field/drainage plots in 9 experimental stations. The models of the Universal Soil Loss Equation (USLE) were adapted and validated for use under the conditions of our country. Geographic Information Systems (GIS) for assessing the risk of water erosion of soil have been developed and improved (Rousseva 2002b, Nikolov et al. 2007).

The long-term investigation of the erosion processes in agricultural lands have given the opportunity to synthesize and present the results in two monography books – for North and South Bulgaria (Rousseva et al. 2010a, b).

Research methods in the forestlands. The method for determination of the erosion intensity using the drainage plots is used in the experimental stations. They were set on differently managed areas. The water flow is measured by a system of flow catchers and cauldrons. The solid runoff (eroded soil) is determined by the weight method of an average sample taken after every rainfall. The experimental set-up in the station at the scale in small watersheds is equipped with limnigraphs and sediment sampling systems.

The erosion researches in mountainous permanent experimental stations in Bulgaria began in 1961 at one tributary of the Topolnitsa River – research station Vakarel (Kerenski 1972). The main purpose of the studies was establishment of the restrictive role of the coniferous plantations on the erosion processes at the riverside areas. Nowadays continuous and systematic researches on erosion processes in Bulgarian mountainous regions are carrying out in two experimental stations – "Igralishte" and "Gabra", situated at 850 – 900 m. a.s.l. The experimental station "Igralishte" was established in southwestern Bulgaria, Malashevska Mountain and station "Gabra" - in Sredna Gora Mt.

In the station "Igralishte" are included four small watersheds - oak forest managed through branch-cutting and free for grazing, Scots pine plantations, oak and beech forest managed through branch-cutting. Data collection is at two scales: on small drainage test plots and in small watersheds (7.5 to 64.8 ha). At the plot level different crops and land use types, as well as sun exposure, are tested - fallow, tobacco cultivation, meadow without grazing, Oak forest with grazing, Scots Pine plantation.

In the station "Gabra" we are studying the dynamics of the precipitations, the interception, the surface runoff, and the soil losses on south-facing slope with inclination of 29%. The drainage plots are from 50 to 270 m^2 areas. Different trial variants were applied - pure and mixed plantations (Scots pine (*Pinus sylvestris L.),* Austrian black pine (*Pinus nigra Arn.*), Norway spruce (*Picea abies (L.) Karst*), birch (*Betula sp.),* grass and fallow lands.

Studies in forest ecosystems are also conducted of Forest University in the hydrological experimental station "Bazenika" (the Yundola area) incl. studies on some elements of water balance and eroded soil are carried out (Kitin 1988, Rafailova 2003).

The methodology of the PHARE - MERA Project - Bulgaria - Land Degradation Mapping (Stoev et al. 1997) was used for assessment of the risk of erosion in torrential catchments in the Struma River (Martensson et al. 1998). The methodology is based on the USLE used to obtain an erosion risk assessment database. The methodological approach for classifying the catchment area as a potential and actual risk of erosion is also presented in the publications of Malinov et al. 1998, Martensson et al. 2001, Marinov et al. 2002a, 2002b, Marinov et al. 2005a, Marinov 2009a, Pavlova-Traykova et al. 2017).

A complex methodology for determination of torrents, erosion risk in the forest fund, necessary anti-erosion facilities (dams and thresholds) has been developed and tested (Marinov et al. 2009, Marinov 2009a, Pavlova-Traykova et al. 2017). Assessment of the actual erosion in the forestlands and determination of the necessary erosion control activities in the torrential watersheds, as well as the establishment of the database for them on the regional and national level was the main goal of the methodology. It includes the determination of: torrential watersheds, actual erosion risk for forest lands of the watersheds, anti-erosion forestation, hydro-technical facilities and erosion coefficients. The methodology was developed to be used for the establishing of the National Programme for protecting from erosion and flooding in the forestlands. Monthly and annually dynamics of the precipitations and temperature in the forestlands has been studied and data are used for complex climatic indexes. Precipitation influence on soil erosion development is assessed with rainfall erosivity index (*R* factor). The rainfall erosivity in the regions where the experimental stations are located (Ihtiman Sredna Gora Mountain and Maleshevska Mountain) is studied on the base of many years of research (Marinov, 2004, Marinov, 2009b). A map for area distribution according to *R* factor values were used (Rousseva, Stefanova 2006). Soil index

(*Is*) for forestlands is calculated for each subsection depending on erosion degree and erosion type, defined in forest management plans. For topography factor assessment (slopes gradient), a digital elevation model (DEM) is used, obtained from topography maps in scale 1: 25 000. Slopes gradient is classified in four indexes. For vegetation cover influence assessment, data was used from forest management plans. Vegetation index 1 have plantation and forestation with density above 0.6, these with density 0.3-0.6 - index 2, and open stands not suitable for forest area, barrens, gullies, landslides and landslips- index 3.

Methodological guidelines for remote investigation of soil erosion by means of aerial photographs have been developed (Zakov 2010).

The method of Gavrilovic (1972) for a determination of the intensity of the erosion processes according erosion coefficient was used. The modified Polyakov-Kostadinov's method, based on the newly introduced parameter of "pluvial-erosion index" (Kostadinov 1990, 1993) was used.

The state of soil erosion was studied and erosion control methods suitable for application under our conditions were analysed in the watersheds of many torrential water courses. The formation of sediments behind check dams (post barrage sediments) was studied, as well as the changes in the sediment-bed zone, the anti-erosion function of vegetation and the effects of the technical and correction-and-stabilization activities carried out in the torrent beds (Biolchev et al. 1975, Zakov 1988, Angelov, Marinov 1984, Zakov, Marinov 1995). New technical facilities and technologies of stabilizing torrential water currents have been tested, as well as a new approach for anti- erosion afforestation, of the basic of contemporary concept of the vulnerability and adaptation of forest vegetation in view of the expected global climatic changes.

- **Description of dominant erosion processes by type.**

According to the National Long- term Erosion Control Programme (NLECP) estimations, the average annual soil losses at end of 70th of the last century were 136 million tons (Biolchev et al. 1977). It would take into account that 68 % of which was formed on the croplands, which represent 34.6 % of the agricultural lands of Bulgaria at this period. It was established that erosion processes are developed on 15 % of Bulgarian forestlands. The necessity is existed of carrying out of the erosion control works in the hydrograph network in the total of around 2,300 water flows where the erosion processes are developed.

Soil erosion is one of the major soil degradation treats in Bulgaria. This environmental problem occurs but in recent years the processes has intensified because of the climate changes and related extreme weather events (Advisory Services on a National CCAStrategy and Action Plan, 2018).

According to the Annual report of Ministry of Agriculture, Food and Forestry, the agricultural lands in Bulgaria cover 69.1% from the total territory of the country (Annual Report, 2018). Most of these lands fall under anthropogenic impact (Koutev, Kolev 2009). There are many other threats for quality and quantity of soils, but according to National Action Plan (NAP, 2014-2020), degradation in arable lands in Bulgaria is mainly due to wind erosion, water erosion and irrigation. About 65% of the arable land area is affected by water erosion and about 24% - by wind erosion lands. Potentially endangered from erosion due to irrigation is about 23% of arable land (Popova et al. 1994).

On national level, researches about the erosion factors (precipitations, relief, soil and vegetation), as well as about the potential and actual erosion risk have been conducted by Rousseva, Stefanova 2006, Русева 2002b, Lazarov et al. 2002, Rousseva et al. 2003, Rousseva et al. 2010a, b. Estimations show that more than 62% of the country's territory is characterized with moderately strong, strong and very strong soil vulnerability to erosion (Rousseva, Stefanova 2006) (fig. 2). For 54% of the soils the soil erodibility factor (K) ranges between 0.030 - 0.04%, for 3.3% it is between 0.04-0.05% and 4% of the soils are characterized with K-factor greater than 0.05%.

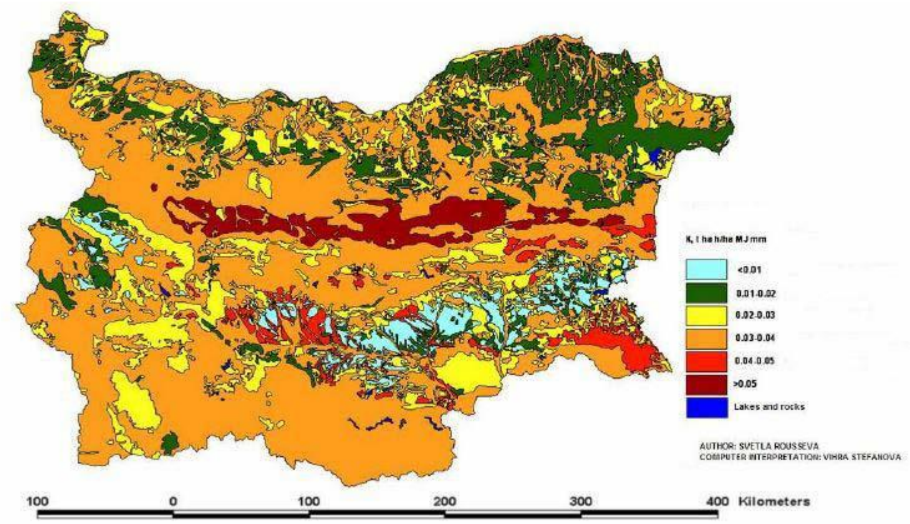

Figure 2. Map of soil erodibility for the territory of Bulgaria (Rousseva, Stefanova 2006)

It was assessed for the beginning of this century, that for 30% of the territory of Bulgaria, the annual potential erosion risk exceeds 40 t/ha, and around 62 % of the entire area, the risk is higher than 10 t/ha. The potential risk of water erosion is assessed to more than 100t/ha/a for 26,4% of the territory of the country, on 16.2% the risk is 40 to 100t/ha/a, 21% are with 10-40t/ha/a and on 33.6% the risk is lower than 20t/ha/a, calculated on specific GIS models (Lazarov et al. 2002, Rousseva 2002b). The estimated "actual" average annual soil loss rates vary from 0.14 t/ha on forest lands to 2.7 t/ha on pastureland and from 4.8 t/ha on cropland to 12.7 t/ha on vineyards, and orchards, resulting in the net average annual soil loss volume, estimated of 32 million tons (290 m^3 /km^2), as over 2/3 of which originates from cropland (Lazarov et al. 2002, Rousseva 2002b, Rousseva et al. 2003) (fig. 3).

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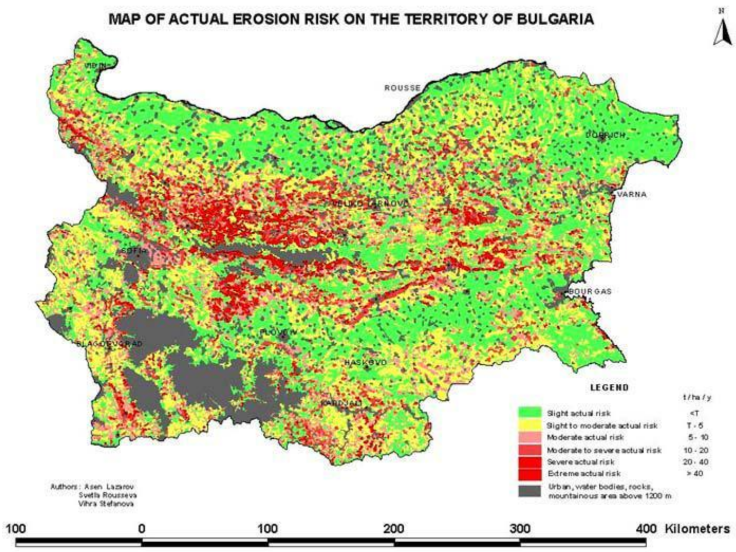

Figure 3. Map of the actual erosion risk on the territory of Bulgaria) (Rousseva et al. 2008)

The Universal Soil Loss Equation (USLE) for assessment of soil erosion processes in arable lands is mainly used (Wischmeier, Smith 1978). This method is well applied in the whole territory of the country and it is already given important results for soil erosion factors and potential risk of erosion in arable lands (Rousseva et al. 2010 a, b).

Bulgaria has specific environmental and climatic condition which create precondition for development of strong erosion processes. Slope gradient (topographic factor) sets condition for appearance of water erosion in many part of the county. The most threatened areas according to this factor are Gabrovo, Lovech regions, Smolyan, Blagoevgrad and Kardzhali (Rousseva et al. 2010 a, b) . The slope gradient in these regions is higher than the average gradient for the country and creates condition for soil erosion processes.

The climatic factor is another major factor for soil erosion. It is represented like the erosive force of the rains, expressed as rainfalls erosivity (*R* factor). This factor has strong influence in the regions Lovech, Sliven and Sofia. The soil factor sets the most serious conditions for water erosion in the regions of Smolyan, Kardzhali and Gabrovo (Rousseva et al, 2010 a, b).

The total amount of predicted potential average annual soil loss from sheet water erosion amounts at 902.5 million tonnes, where 50% result from – Lovech, Gabrovo, Veliko Tarnovo, Sofia, Sliven and Kurdzhali (Rousseva et al, 2010 a, b).

For better management of agriculture lands and in order to decrease the risk of soil erosion specific practices are applied (Atanasov 2010, Malinov et al. 2014). The most effective and easy to develop are contour agriculture, narrow-plowed plowing, furrow-comb plowing, interrupted by interlocking furrows, hoeing, belt cultivation, vertical mulching, minimal and zero soil treatment (Atanasov, 2010).

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Arable lands in Bulgaria are with great productivity potential but significant part of them is under degradation influence. There are many factors with negative impact on soils, but the great threaten for sustainable agriculture remains water erosion. Water erosion causes huge loses and inflict damages in agriculture for million levs every year. The loses in national economy consist- washing out the soil humus horizon, decreasing the soil thickness, destroying the soil structure, deteriorating the water and physical qualities of the soil, loss in soil fertility and rapid decrease in the yield of the grown agricultural crop (Dimitrov, Beloev 2006).

For better management of arable lands, with a view to mitigate influence of climate changes and decrease soil erosion rates it is necessary to be applied appropriate agriculture and soil protection practices.

The entire classified area of the forestlands at the end of year 2004, according to the degree of erosion, was about 292,000 ha which is 7.2% from the entire forestlands (Marinov, Bardarov 2005). It was found that the most widely affected by erosion were territories of the Regional Forestry Boards (RFBs) - Blagoevgrad, Kardjali, Kiustendil, Sofia and Smolyan – which are total between 30,000 and 60,000 ha. The Regional Forestry Boards Kyustendil, Blagoevgrad, Kardzhali, Smolyan present the highest percentage of territory affected by erosion (from 12 to 17 %) (fig. 4). Many of the small rivers in Bulgaria have the characteristics of torrential rivers.

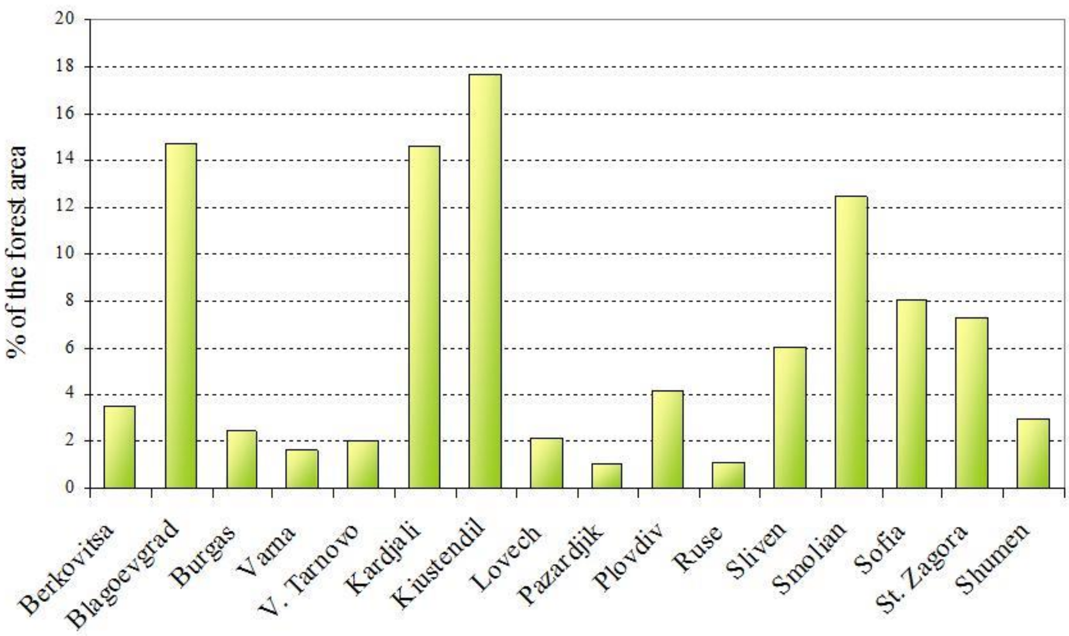

Figure 4. Percent of eroded area to total forest area of the Regional Forestry Boards

It is determined the destroyed areas according of the degree of erosion in the State Forestry Boards (SFBs). To make a comparison for the degree manifestation of erosion in different State Forestry Boards the percent of eroded area (1st to 5th degree of erosion) to total forest area was calculated. It is established that the area affected by erosion is more than 25 % in 11 State Forestry Boards (Parvomai (BL), Gotze Delchev, Sofia, Breznik, Zlatograd, Slaveino,

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Tzaparevo, Kirkovo, Momchilovgrad, Genda, Hova Zagora). By absolute area, 16 SFBs have more than 5,000 ha affected by erosion (Marinov, Bardarov 2005).

It is established the distribution of the territory of our country by Soil Loss Classes (low - <0.5 t/ha per year; slight 0.5-1.0; moderate – 1.01-2; high – 2.01-5; severe – 5.01->) (Özşahin, Eroğlu 2019). According the data for 2015 in the classes “high” and “severe” (> 2.01 t/ha per year) are 11.17 % of the whole territory (12464 sq. km).

The erosion investigations in Bulgaria's forestlands are conducted in different directions (erosion factors, erosion risk assessment, soil erosion determination in stationary studies, sediments, necessary anti-erosion activities, etc.), as well as in various research sites (stationary, separate small torrent watersheds and large catchments (e.g. the Struma River basin)).

Investigations related to the study of soil erosion and determine the necessary anti-erosion activities are conducted in significant number torrential watersheds. This type of research was mainly conducted in the second half of the last century in the regions most affected by erosion - the catchments of Arda River, Struma River, Maritsa River and others, dam catchments of Iskar, Topolnitsa, Studen Kladenets and others.

Studies on soil erosion in one of the largest watersheds in Bulgaria - Struma river watershed find out development of intensive erosion processes in the many of the tributaries (Kerenski et al. 1968, Angelov et al. 1975, Mandev 1984, 1996, Marinov 1984, Martensson et al. 1998, Marinov et al. 2002 a, b, Marinov 2009a, Marinov et al. 2012, Rousseva et al. 2012). The appearance of erosion is a result not only of the human activity in the past, but also of the natural factors of erosion, especially important of which are the topography, climate and bedrocks. The potential and actual risk of erosion for the Struma river basin and of its tributaries – Eleshnitsa river, Sedelska river and Rakovitsa river has been assessed (Martensson et al. 1998, Martensson et al. 2001, Marinov et al. 2005a, Marinov, Lubenov 2007). Watersheds of the main Struma river tributaries of which over 50% of the area will be in degrees ”moderate to strong” and “strong” actual risk after the middle of the XXI century are defined.

Data from stationary studies of hydrological and erosion processes in different managed territories of the Igralishte and Gabra experimental stations were collected and analyzed. They have a duration of more than 30 years and provide an opportunity for assessment the impact of major erosion factors (rain, soils, relief, and vegetation), dependencies of the water runoff and eroded soil from these factors, and the use of obtained results in assessing these processes in geographically similar areas (Mandev 1984, 1996; Marinov 2009a) . The rainfall erosivity in the regions where the experimental stations are located (Ihtiman Sredna gora mountain and Maleshevska mountain) are studied on the base of many years of research (Marinov 2004, Marinov 2009b). Soil erodibility assessment of Ihtimanska Sredna Gora mountain and for different small mountain watersheds is defined (Velizarova, Marinov 2004, Velizarova et al. 2010).

Sediment transport. Gergov et al. (2001) consider the sediments yield in the rivers in Bulgaria as an indicator for soil erosion in the watersheds. It was established that the average annual module of the sediment is 125 t/km^2. The amount of the exported sediments during the flash floods in the torrents depends on many factors, combined in sedimentary coefficient (Zakov

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1988). The methodological approach for the estimation of the sediment transport used in Serbia and Macedonia was applied in Bulgaria in the river Rakovitsa (747.5 ha), representative tributary for the middle part of the Struma river. It was established that the average annual total sediment transport (suspended and bed- load) using Poliakov-Kostadinov's method (Kostadinov 1993) is 340 m^3/km^2 (Marinov et al. 2005). The removal of sediments from tributaries of the Struma river was analyzed by Kenderova et al. (2013).

Erosion control activities. During the period 1905-1944 eroded lands, spread on the area of 170,000 ha have been afforested and 160,000 m^3 stone barrages (check dams) and thresholds (< 2.0 m above torrent bed) have been constructed. National Long-term Erosion Control Programme (NLECP) have been designed and implemented since 1982 and a design of erosion control measures at a level of catchment, administrative territorial unit or the area of the farms was made (Biolchev et al. 1977). About 450, 000 m^3 barrages and thresholds, 380,000 m^3 small stone thresholds and 350, 000 m^2 wattles have been constructed during the period 1945- 1989. This period is also remarkable for comprehensive afforestation of 1.9 million ha of which 760,000 ha (about 40%) are anti- erosion forestation, and development of 20, 000 ha shelterbelts (Zuckov 2005). In this period, the stabilisation of the torrents has been recognized as a substantial part of erosion control activities. So more than 80 large complex erosion control projects have been designed and applied in the dam watersheds. The measures limited significantly the siltation of the dams.

After 1990 the anti-erosion activities mark significant decrease. Considering the erosion control for the agricultural lands, the 1990's are marked as a decade of the complete carelessness. Permanent constructions to control erosion, once completed, have not been maintained after that, so their disintegration has been in progress (Rouseva et al. 2006). During the period 1989- 2004 about 16,000 ha eroded lands has been afforested, 10,000 m^3 barrages and thresholds, 12,000 m^3 small stone thresholds and 7,000 m^2 wattles has been constructed (NFB 2005). A significant reduction of the afforestation rates and in the building of technical facilities was occurred after 1990. In 2014 the afforested territories for erosion and torrent protection cover 542 ha and in 2016 the applied activities cover 580 ha and 108 sq. m of constructed "clayonnage" (wattles) systems (*source:* MoAF - EFA).

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

The national policy for environmental protection is established from the Ministry of Environment and Water. The protection, sustainable management and reclamation of the soil functions are defined by the Environmental protection Law and by the designated acts for soil, water and forest. In order to realize the objectives of the Environmental protection Law, a National strategy for the environment 2014-2020 has been developed.

The Agricultural conservation Law establishes the protection and restoration of agricultural lands and soils in forest territories. The Ministry of Agriculture and Forests supports an informational system for the soil resources in agricultural lands that also includes the risks of contamination, erosion, salinization, alkalization and swamping. Information about programs for the soil quality enhancement and protection is also available in that system.

It is well known that the increase of erosion risk related to climate change will have stronger impact on the southern regions of Europe and on some areas in Bulgaria. A set of measures for adaptation of the forest sector to climate change has been developed in line with the EU Adaptation strategy (EU Adaptation strategy 2013). The “Program of measures for adaptation of forests in Republic of Bulgaria and mitigation of the negative impact of climate change” (Raev et al. 2011) directly refers to limiting the erosion processes in forestlands. In the developed National strategy for development of forest sector 2013–2020 (MoAF 2013) and Strategic plan for development of forest sector 2014–2023 (MoAF 2014) an increase in afforestation on eroded lands is foreseen. Currently, the National Climate Change Adaptation Strategy and Action plan is still in process of development. That strategy covers the main problems related to erosion and the necessary strategic measures for adaptation (Macdona et al. 2017).

The planning and realization of forest protection against erosion, torrential floods and landslides, incl. the design of anti-erosion activities (such as afforestation and construction of facilities) are regulated in the Regulation for protection of the forest territories against erosion and floods and construction of erosion control facilities (Regulation 4/2013).

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