Soil Erosion Risk Assessments in Bulgaria

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Abstract

Soil erosion is recognized as one of the most serious soil degradation processes on the territory of Bulgaria. This paper aims at presenting a brief review of work done on soil erosion assessment in Bulgaria and it will focus on the main results from a recently developed geographic database for soil erosion risk assessment.

For the time being, soil erosion assessments in Bulgaria have been based mostly on the USLE approach. It was used in the 1970-ies for developing a National Long-term Program to combat soil erosion. Much work has been done on evaluation of the USLE factors for diverse climate, soil and management conditions and empirical equations for soil erosion assessments have been developed.

Geographic database for soil erosion risk assessment on the country's territory was developed recently at a scale of 1: 100,000 using the USLE approach integrated with GIS (ArcView 3.1.). The inputs included maps of (i) rainfall erosivity; (ii) soil erodibility; (iii) agro-ecological regions; (iv) soils; (v) topography and (vi) permanent land cover, and values of the C-factor of the main agricultural crops and vegetation cover, and the soil loss tolerance.

The topography maps were used to develop a map of the slope-length factor. The map of rainfall erosivity was developed on the basis of data from 84 weather stations across the country's territory with long-term observations. The soil erodibility map was based on the soil maps of Bulgaria at scales of 1: 400,000 and 1: 25,000 and soil survey data on soil texture, organic matter content, soil structural class and profile permeability class for about 1,800 soil profiles. Values of mean monthly canopy cover, effective plant height, average acute angle of leaves and/or branches to the plant stem, maximum volume of the interception store, fall velocity of the drops dripping from the vegetation on the ground were set for wheat, maize, sunflower, potatoes, tobacco, beats, alfalfa, vineyards and orchards in accordance with data from measurements presented in different literature sources. Respective C-factor values were then calculated with respect to rainfall erosivity monthly distributions for each of the 47 agro-ecological regions distinguished on the country's territory using a quasi-deterministic approach (model) for estimating the cover and management factor.

The system enables either graphical or tabular outputs for the potential and the actual soil erosion risk. The graphical outputs can be thematic maps or layers and the tabular outputs can contain 29 fields with the whole available information ore be more generalized. The results showed that the potential erosion risk for 61.6 % of the country's territory exceeded 10 t/ ha/ y and for 29.9 % it was higher than 40 t/ ha/ y.

***Keywords**: soil erosion, risk assessment, potential erosion, actual erosion, mapping, Bulgaria*

Introduction

Soil erosion is recognized as one of the most serious soil degradation processes on the territory of Bulgaria. Information on soil erosion at diverse soil, climate, topography, cover and management conditions is essential for better understanding the soil erosion processes and developing reliable predictive models – a basis for planning effective conservation measures. This paper aims at presenting a brief review of the work done on soil erosion assessment in Bulgaria and it focuses on a recently developed geographic database for soil erosion risk assessment.

The natural conditions and the land use and management in Bulgaria set patterns for intensive soil erosion processes. As a result of the land collectivisation in the 1950-ies accompanied by unwise land management, soil erosion started inflicting serious damages to the national economy and in the early 1970-ies it was recognized as a national problem of a primary significance. Establishment of Soil Erosion Department at the Institute of Soil Science together with 3 experimental fields for soil erosion studies marked the orderly research in the field of soil erosion in Bulgaria in 1956. For the time being, studies have been carried out aiming at evaluation of the soil erosion processes and factors; design, validation and use of models predicting the soil loss due to water erosion; soil conservation planning and optimisation of measures for soil erosion control. National Long-term Erosion Control Programme (NLECP) was elaborated (Agropromproekt, 1980) that recommended erosion prevention measures based on estimated average annual soil loss rates and land capability evaluation. The NLECP made provisions for design of erosion control measures at three levels – catchment, administrative territorial unit and co-operative farm. The methodology for developing the NLECP (Biolchev et al., 1977) was based on the Universal Soil Loss

Equation (Wischmeier and Smith, 1978) modified for Bulgarian conditions considering the available information by that time (Onchev, 1977; 1983).
According to the NLECP (Agropromproekt, 1980), 79.2 % of the area of the agricultural lands and 78.3 % of the arable lands were with potential soil erosion risk. The average annual soil loss rate from agricultural lands by 1978-1980 was estimated as 22.9 t ha^{-1} y^{-1}. The highest erosion rate was estimated at the area covered by perennials – 65.6 t ha^{-1} y^{-1}, followed by the croplands – 30.8 t ha^{-1} y^{-1} and the pasturelands – 18.9 t ha^{-1} y^{-1}. The average annual soil loss was estimated to 135.9 Mt, 68 % of which was formed from the croplands representing 34.6 % of the agricultural lands.
Much work has been done on evaluation of the USLE factors for diverse climate, soil and management conditions during the 1980-ies and the 1990-ies. Empirical equations for predicting average annual soil erosion and the soil loss from single rainfall event have also been developed (Daskalov, 1994a; 1994б; 1995). Databank on the field plots for soil erosion studies organized the relevant information obtained across Bulgaria since 1958 (Rousseva, 2002a). Considering that new information, Tsvetkova et al. (1999) and Rousseva et al. (1999) evaluated the USLE approach modified in the 1970-ies (Biolchev et al., 1977; Onchev, 1977) and the equations proposed by Daskalov (1994a, 1994b, 1995). They found that (i) the soil losses assessed according to Biolchev et al. (1977) and Onchev (1977) were significantly higher than the measured soil erosion rates mostly due to overestimations of the soil erodibility factor and (ii) the empirical equations proposed by Daskalov did not predict adequately the annual erosion rates nor the soil loss from single event because of the limitations of the data set used for developing the equations.

Geographic database for soil erosion risk assessment

Modelling approach

Geographic database for soil erosion risk assessment on the country's territory was developed at a scale of 1:100, 000 using the USLE approach (Wischmeier and Smith, 1978) integrated with GIS (ArcView 3.1.):

$$A = R\ K\ LS\ C\ P, \quad (1)$$

where A is the estimated average annual soil loss, R is the rainfall and runoff factor, K is the soil-erodibility factor, LS is the slope length and steepness factor, C is the cropping-management factor, and P is the erosion-control-supporting-practice factor. The USLE was validated with data from long-term observations from field plots for soil erosion studies (Rousseva, 2002c) found to allow reasonable estimates of the average annual soil loss from bare soil for nine sites across the country (Rousseva, 2002a).
The inputs included maps of (i) rainfall erosivity; (ii) soil erodibility; (iii) agro-ecologica regions; (iv) soils; (v) topography and (vi) permanent land cover, as well as values of the C-factor for the major agricultural crops, and the soil loss tolerance.
The system enables either graphical or tabular outputs for the potential and the actual soil erosion risk. The graphical outputs can be thematic maps or layers and the tabular outputs can contain 29 fields with the whole available information or be more generalized. Potential risk of soil erosion by water is categorised according to predicted average annual soil loss from bare soil in 7classes, namely: 0≥5, 5≥10, 10≥20, 20≥40, 40≥100, 100≥200 and >200 t ha^{-1} y^{-1}. Actual risk of soil erosion by water is categorised according to predicted average annual soil loss considering permanent land cover with respective cropping-management factor in the following 7 classes: ≥T, T≥3, 3≥5, 5≥10, 10≥20, 20≥40, >40 t ha^{-1} y^{-1}.

Rainfall erosivity

The general equation for estimating the erosivity term proposed by Richardson et al. (1983) was modified (Rousseva, 2002) to enable evaluation of the rainfall erosivity factor from the routine outputs of the national meteorological survey. Rainfall erosivity map was developed (Rousseva and Stefanova, 2006) using categorized in 10 classes average annual values of EI_{30} calculated for 84 meteorological stations (1 station per 1,320 km^2) with long-term observations of intensive rainfalls with duration T ≥ 30 min. Obtained rainfall erosivity map showed that about 65 % of the country's territory are characterized by rainfalls of annual erosivity higher than 800 MJ mm/ ha h (Rousseva and Stefanova, 2006).

Soil erodibility

The soil erodibility nomograph (Wischmeier et al., 1971) was adapted (Rousseva, 2002a) to evaluate the soil erodibility of Bulgarian soils using the routine outputs of the national soil survey. Values of the soil erodibility factor (K-factor) were calculated for each of the 67 soil mapping units defined by the soil map of Bulgaria at a scale of 1: 400,000. The assessments were based on data for soil texture, organic matter content, soil structure class and profile permeability class for 1,845 soil profiles (1.7 profiles per 100 km^2) studied by the large-scale soil surveys at scales M 1:10,000 and M 1:25,000 and pedotransfer functions (Rousseva, 2001). The obtained values were then categorized in 6 classes and mapped using ArcView

3.1. Resultant map of soil erodibility showed that 61.5 % of the territory of Bulgaria is covered by soils with erodibility higher than 0.03 t ha h/ha MJ mm (Rousseva and Stefanova, 2006).

Topography (slope length and steepness factor)
Topography maps were used to develop a map of the slope length and steepness factor (LS). The LS factor was calculated after Wischmeier and Smith (1978) for each unit with uniform soil, landuse and slope gradient class assuming the mean value of the slope gradient class and a length of 200 m. Obtained map showed that lands with slope 6-18° cover 49,1% of the territory (Fig. 1).

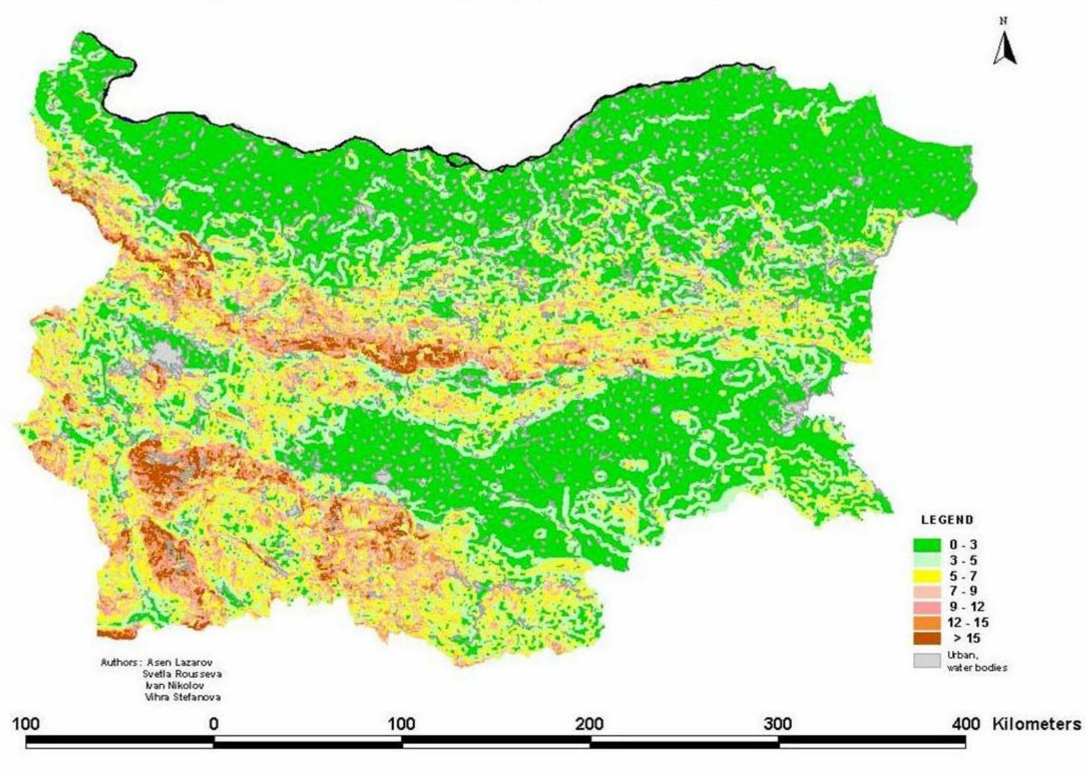

Figure 1. Slope distribution of Bulgarian territory

Soil protection effect of vegetation (cropping-management factor)
The estimates of the soil protection effect of the vegetation were based on the permanent land cover distributions obtained by CORINE (1996) assuming 14 major classes (Rousseva, 2002a). Values of the vegetation index (C-factor) were calculated for wheat, maize, sunflower, potatoes, tobacco, beats, alfalfa, vineyards and orchards using the approach developed by Rousseva (2002b, 2004) with respect to rainfall erosivity monthly distributions for each of the 47 agro-ecological regions distinguished on the country's territory. Values of mean monthly canopy cover, effective plant height, average acute angle of leaves and/or branches to the plant stem, maximum volume of the interception store, fall velocity of the drops dripping from the vegetation on the ground were set for wheat, maize, sunflower, potatoes, tobacco, beats, alfalfa, vineyards and orchards in accordance with data from measurements presented in different literature sources. Means of the obtained C-factor values were calculated for each agroecological region defined by Yolevski at al. (1980). The values of C-factor for cropland were based on crop rotations with specific proportion between cover crops and row crops, representative for each agro-ecological region. The values of the C-factor for grassland, rangeland, abandoned agricultural land and sparse vegetation are based on adaptation of the respective data of Wischmeier and Smith (1978) with respect to the findings of Djingov (1983), Sanh (1986) and Onchev et al. (1988). The C-factor values of burned land are set after Wischmeier and Smith (1978), while these for forestland are based on the data of Wischmeier and Smith (1978) and Mandev (1995).
Data based on satellite images and cartography of the classes of permanent land cover show (Fig. 2) that the agricultural land covers 5 734 854 ha (51.6%), forest and semi-natural areas - 4 721 246 ha (42.4%), and anthropogenic objects – 545 488 ha (4.9%); cropland is 39.8% of total area, grassland and rangeland 11.6%, and perennials 1.9%. The data in Tables 1 and 2 illustrate the value ranges of the C-factor estimates for the major field crops and perennials grown on the territory of Bulgaria.

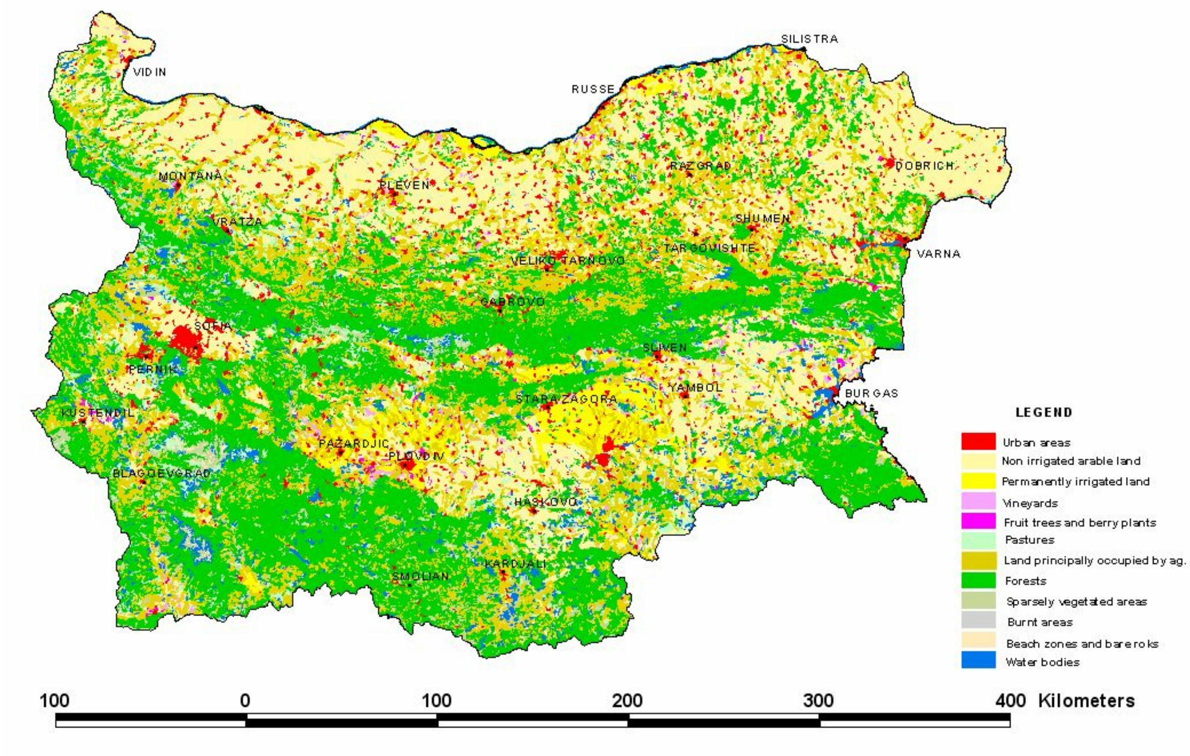

Figure 2. Distribution of the territory of Bulgaria according to classes of permanent land cover

Table 1. Mean, minimal and maximal values and standard deviations of the crop and management factor (C) of the major field crops estimated for 47 agro-ecological regions distinguished on the territory of Bulgaria.

Parameter \ Crop	Wheat	Wheat*	Maize	Maize*	Sunflower	Tobacco	Potatoes	Beats	Alfalfa
Mean	0.22	0.28	0.39	0.50	0.32	0.71	0.69	0.34	0.07
St.Dev.	0.05	0.04	0.06	0.04	0.05	0.08	0.03	0.05	0.02
Minimum	0.12	0.16	0.27	0.42	0.20	0.51	0.62	0.22	0.04
Maximum	0.32	0.34	0.52	0.59	0.44	0.84	0.75	0.44	0.10

* For eroded lands

Table 2. Mean, minimal and maximal values and standard deviations of the crop and management factor (C) of vineyards and orchards estimated for 47 agro-ecological regions distinguished on the territory of Bulgaria.

Parameter \ Canopy	Orchards			Vineyards	
	8x8m c*=0.35	8x8m c=0.60	Palmette	c=0.35	c=0.24
Mean	0.42	0.30	0.39	0.64	0.70
St.Dev.	0.08	0.04	0.06	0.05	0.03
Minimum	0.24	0.21	0.26	0.54	0.62
Maximum	0.58	0.39	0.51	0.74	0.77

* Canopy cover

Soil loss tolerance

Values of the soil loss tolerance (T, t ha^{-1} y^{-1}) have been defined (Rousseva, 2002b) for each soil mapping unit of the soil map of Bulgaria at a scale of M 1: 400 000 based on adaptation of the respective data of Biolchev et al. (1977) and Onchev (1983).

Potential erosion
Obtained estimates for the potential risk of sheet soil erosion show that it exceeds 100 t/ha y for 10.4% of the country's territory; 19.5 % are with a risk from 40 to 100 t/ha y, 31.7 % – from 10 to 40 t/ha y and only 25.9 % have a risk lower than 20 t/ha y (Fig. 3).

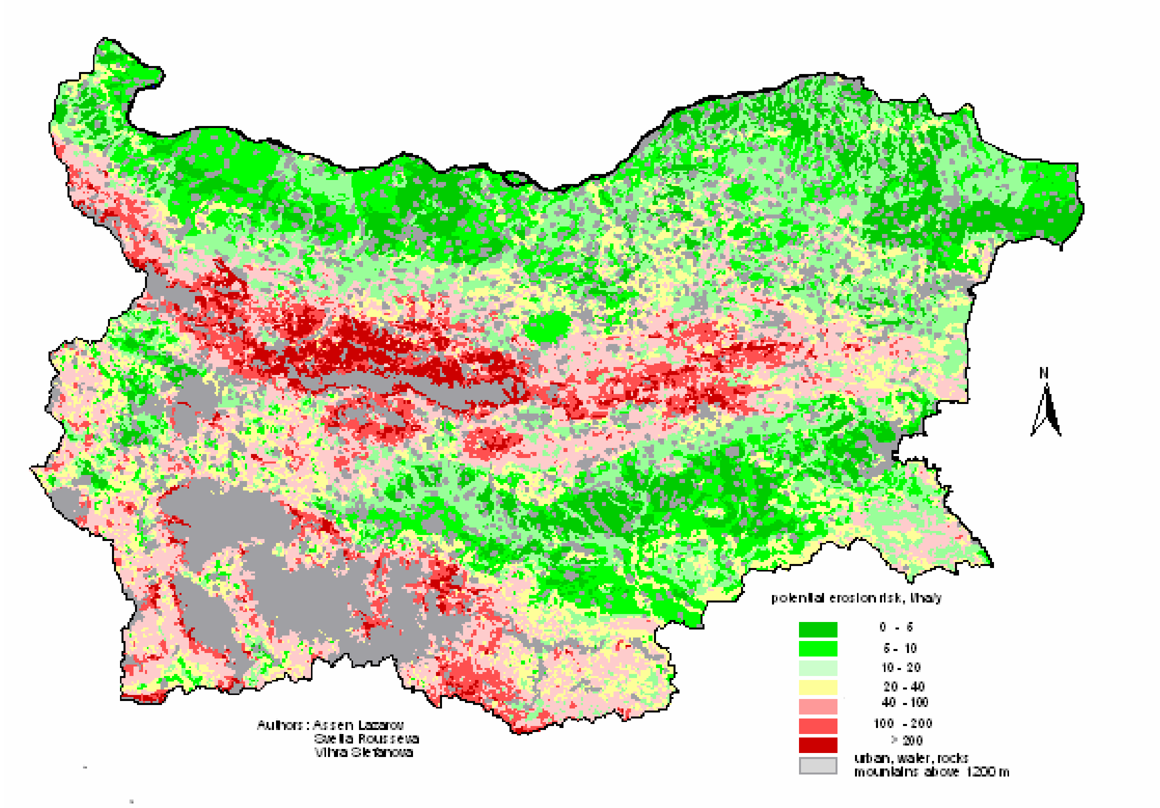

Figure 3. Distribution of the territory of Bulgaria according to the classes of potential soil erosion risk

Actual erosion
Percentage distribution according to the degree of water erosion risk of the area of different types of landuse considering field crop rotations with 50:50 % proportion of row to cover crop shows (Tab. 3) that about 1/3 of the agricultural land, including 65.3% of the area of perennials, 34.9 % of the area of rangeland and 23.3 % of the cropland are with a risk of erosion exceeding 3 t/ha y. The average annual

Table 3. Percentage distribution of the area of different types of landuse according to the classes of soil erosion risk by water. T is soil loss tolerance, specific for each soil unit

Erosion risk (predicted soil loss) t/ha y	Cropland		Perennials		Rangeland		Other agricultural land	
	% of crop-land	% of agricultural land	% of perennials	% of agricultural land	% of range-land	% of agricultural land	% of other agricultural land	% of agricultural land
< T	48,4	29,5	15,8	0,4	6,0	1,5	30,8	3,6
T – 3	28,4	17,3	18,9	0,5	50,0	12,2	31,5	3,7
3 – 5	11,4	7,0	24,3	0,7	27,7	6,8	18,8	2,2
5 – 10	8,7	5,3	21,7	0,6	5,5	1,4	10,1	1,2
10 – 20	2,7	1,6	15,2	0,4	1,0	0,3	3,5	0,4
20 – 40	0,5	0,3	4,1	0,1	0,7	0,2	0,9	0,1

rate of water erosion of soil varies depending on the type of landuse from 2.69 t/ha y for the rangeland and 4.76 t/ha y for the cropland, to 12.65 t/ha y for the perennials.
Average annual soil loss estimate amounts to about 32 Mt, over 2/3 of which are formed from the cropland area (Fig. 4). Over 55 % of the predicted annual soil loss from water erosion are formed in 9 administrative districts: Burgas (11,6%), Dobrich (8,9%), Sofia, Ruse and Razgrad (each 5,6%), Veliko Turnovo (5,3 %), Lovech, Silistra and Haskovo (each 4,6 %).

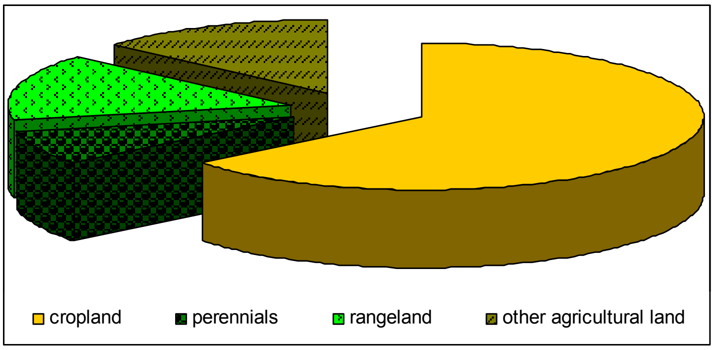

Figure 4. Distribution of predicted average annual soil loss from erosion according to the landuse

Fig. 5 illustrates the distribution of the territory of Bulgaria according to the classes of 'actual' risk of soil erosion by water. The agricultural lands in the administrative regions of Burgas, Razgrad and Ruse are with the highest risk of soil erosion by water – 12 to 15 t/ha y predicted average annual soil loss rate, followed by Dobrich, Silistra, Kardzhlali, Gabrovo, Lovech and Sofia (10 – 12 t/ha y), Sliven, Haskovo, Turgovishte, Veliko Turnovo and Varna (7 – 10 t/ha y) and Blagoevgrad, Pazardjik, Smolyan, Pleven and Yambol (5 – 7 t/ha y).

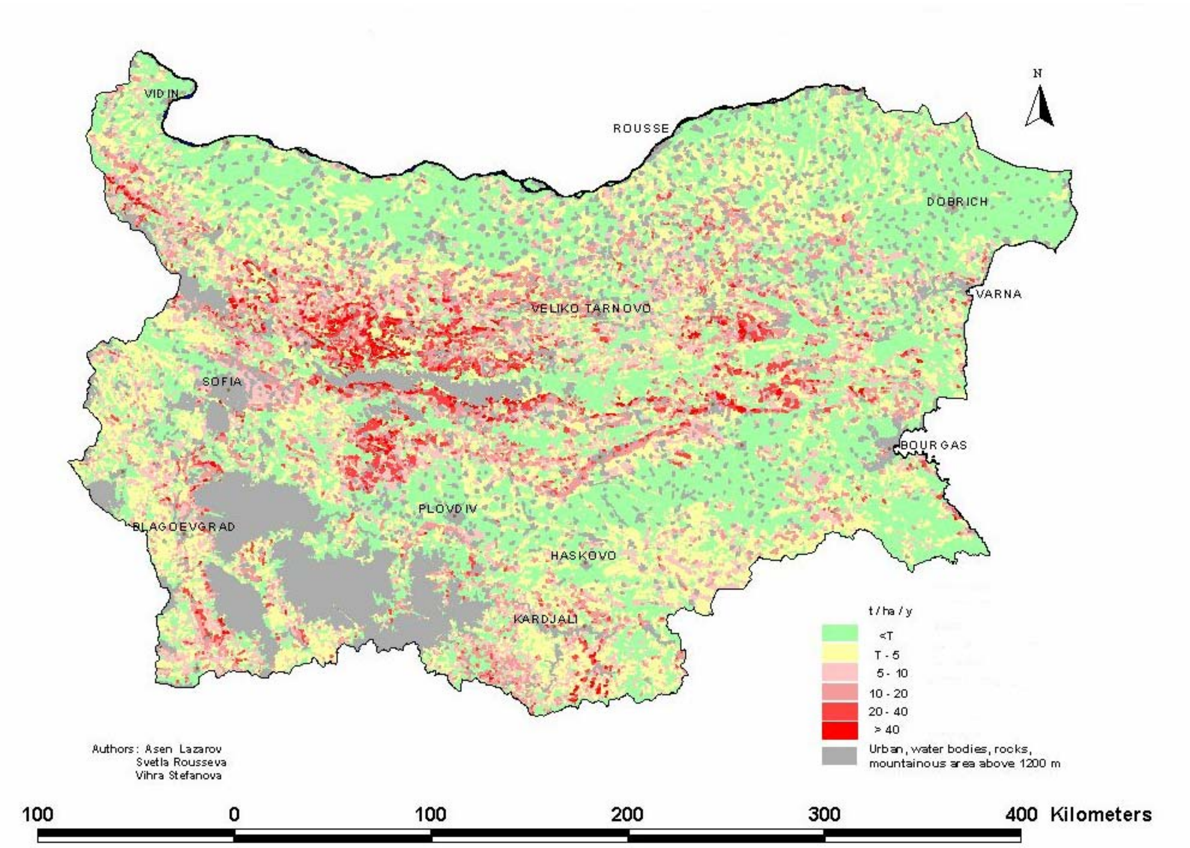

Figure 5. Distribution of the territory of Bulgaria according to the classes of actual soil erosion risk by water

Conclusions

Natural conditions, land management and inefficient application of the policy define a high level of risk for appearance of water and wind erosion in the agricultural lands. The tendencies of erosion processes development depend on annual erosivity of rainfalls and winds, and land management.

The present manner of land management combined with the high probability of increase of the annual erosivity of rainfalls and winds is delineating a tendency toward increase of soil erosion rates in Bulgarian agricultural land.

Development and application of specialized programmes is necessary to control the soil erosion processes in agricultural lands focusing on specific measures for soil protection and surface runoff regulation with respect to the soil, climate and landscape conditions.

Acknowledgements

The present work was supported by the Ministry of Environment and Water through contract No 1108-2556 / 2000.

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