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ASSESSMENT OF THE IMPACT OF DEPOPULATION ON SOIL EROSION: CASE STUDY – REPUBLIKA SRPSKA (BOSNIA AND HERZEGOVINA)

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Abstract: Soil erosion is one of the most significant environmental problems in the Republika Srpska / Bosnia and Herzegovina. The 1992-1995 civil war left serious consequences, and together with the depopulation process in the last few decades, it had a significant impact on the intensity of erosion. Depopulation of the Republika Srpska (RS) is evident from the 2013 B&H population and housing census. The results showed that there are 400,846 fewer inhabitants in the RS, and of the total number of settlements, 88.01% are depopulated. The Erosion Potential Method (EPM) was used to map soil erosion and calculate annual gross erosion in the RS. This showed an evident decrease in erosion intensity throughout most of the Entity. This research is an attempt to assess the depopulation impact on soil erosion intensity and gross erosion in the RS using the Erosion Potential Method and statistical analysis. Statistical analysis of 44 municipalities in the RS revealed a significant regression relationship between a decrease in sediment production and a decrease in population. The linear regression coefficient in these municipalities ranged from 0.72 to 0.95, and the coefficient of determination ranged from 0.52 to 0.91. The regression analysis included 1,248 settlements in the RS where there was a change in sediment production and in the population. The Pearson Correlation Coefficient for these settlements is 0.79, while the coefficient of determination for the observed variables is 0.63. This methodological approach represents a good basis for future research, and for all integrated water management projects, soil protection, forest ecosystems and environmental protection, spatial planning, agriculture and other human activities.

Keywords: annual gross erosion, depopulation, settlement, Republika Srpska, Bosnia and Herzegovina.

1. INTRODUCTION

Soil erosion is one of the major environmental phenomena in the Republika Srpska (Bosnia and Herzegovina) due its lithology, relief, climate, soil, land use and land cover characteristics (Tošić et al., 2011, 2012, 2013). The influence of climate change and land use/land cover (LULC) on soil erosion has been analysed in a number of studies, but only a few of them consider the influence of population change on the erosion process, that is, depopulation decreases sediment production (Zlatić & Dragović, 1998, Ananda & Herath, 2003, Walling, 2006, Van Rompaey et al., 2007, Bakker et al., 2008, Zorn & Komac, 2009, Zang et al., 2009, Dragićević et al., 2009, Feng et al., 2010, Dragićević & Milevski, 2010, Sharma et al., 2011, Tošić et al., 2012a, Leh et al., 2013, Bhandari & Damsawasdi, 2014, Dragićević et al., 2014, Kostadinov et al., 2014, Ferreira et al., 2016, Zare et al., 2017, Khaledian et al., 2017, Manojlović et al., 2017, 2018).

Demographic and land use changes due to the war had a significant impact on the intensity of soil erosion, gross erosion and sediment yield in the RS/B&H. Generally, during the last 32 years (1981–2013) erosion intensity has decreased throughout most of the RS (Tošić et al., 2012). This tendency called for a thorough analysis of all the important factors in the erosion process. This study particularly analysed the impact of population change on sediment production. The development of the Republika Srpska's Erosion Map in 2013, and its comparison with the 1981 Erosion Map, showed the main trends regarding erosion intensity, but also enabled us to examine the human role in this process. Change in land use is directly related to the reduced agricultural activities arising from a decrease in population (people are leaving rural areas). This is because most land use in the RS is conditioned by the presence of people and their economic (agricultural) activity and most of the areas affected by erosion are in rural regions where agriculture is the main activity. Uncultivated land (forests, meadows, pastures, orchards, etc.) has retained the same use since 1980s.

Many studies used various methods, generally in the GIS framework. This study used one of the most common empirical methods in the former Yugoslavia, the Erosion Potential Method (EPM) also known as the Gavrilović Method (de Vente et al., 2005, Deilami et al., 2012, Barmaki et al., 2012, Tošić et al., 2012, Milanesi et al., 2015, Zarei & Mokarram, 2016). This method was also used in 1981 and 2013 to develop the RS erosion maps in the scale of 1:25000, thus allowing us to analyse the changes in sediment production in the RS in this period (Lazarević, 1985, Tošić et al., 2012).

The results of the B&H population and housing censuses in 1981 and 2013 were the basis for determining the changes in the population in the RS. The 1990s war and other socio-geographical processes caused a strong demographic decrease that was recorded in the first post-war census of 2013.

The main aim of this research is to assess the impact of depopulation on soil erosion in the RS and to determine the relationship between two variables: the decrease in sediment production (erosion intensity) and the decrease in population (depopulation). Regression analysis will produce a regression equation, that is, a mathematical model with the following parameters: correlation coefficient, coefficient of determination, standard error, etc. These will indicate whether, and to what extent, there is a relationship between these variables. The results will be the basis for better understanding of the nature of the erosion process and the significance of the anthropogenic factor (decrease in the population), as well as the basis for numerous soil and water management projects.

2. STUDY AREA

The Republika Srpska is a political and territorial Entity within the state of Bosnia and Herzegovina. The study area is located in south-eastern Europe between 42°33'19'' and 45°16' 34'' N and 16°11'06'' and 19°37'44'' E, with a surface area of 24,641 km^2 (Fig. 1). According to the B&H population and household census of 2013, the population of the RS is 1,170,342. There are 2,745 settlements, organized into 62 municipalities. The average population density is 47 people per km^2 (Results of the 2013 Census, 2017).

The entire RS is a part of three morphologic clusters: Pannonian region, mountain-valley region and Adriatic region. The climate in the north of the RS (Pannonian region) is moderate continental with an average annual temperature above 10°C and rainfall of 700–1,500mm. Mountainous depression areas have mountainous and specific local climates (parish climate) with average annual temperatures <10°C and rainfall varying between 700–1000mm. The southern part of the RS is under the firm influence of a modified Adriatic climate with an average annual temperature of 11–14°C and rainfall of 1400–1,900mm (Tošić et al., 2011, 2012, Trbić et al., 2017).

Figure 1. Location of study area: Republika Srpska – Bosnia and Herzegovina

The RS has extremely heterogeneous soil cover, both in terms of soil types and properties. The dominant soils in the Pannonian region are Planosols-pseudogley, Fluvisols, Gleysols-dystric, eutric and mollic soils. Mountainous and hilly areas have Luvisolschromic luvisols, Cambisols-eutric cambisols, Rendzinas and Vertisols, while mountain-valley regions are dominated by Rendzinas and Regosols. The region of the Outer Dinarides, called Adriatic region, has several different types of soil, the most dominant being Rendzinas, Regosols, Rankers, Cambisols-chromic cambisols, Fluvisols in the river valleys, as well as Gleysols-eutric and mollic soil in the karst poljes (Burlica & Vukorep, 1980, Stefanović et al., 1983).

Of the total surface area of the RS, 12,824 km^2 (52%) is covered by forests, while 9,840 km^2 (40%) is agricultural land. Of the total agricultural land, 8,190 km^2 (83%) is arable land, of which 5,820 km^2 (71%) are ploughed fields and vegetable plots, 530 km^2 (6%) are orchards, and 1,840 km^2 (22%) are meadows. Pastures cover 1,630 km^2, while ponds, reed beds and fishponds cover 2 km^2 (Agriculture Statistical Bulletin, 2014). Based on the official statistical indicators, 45.48% of the total arable land in the RS is not used. Most unused land is abandoned and not available to agricultural producers. It is important to note that part of the abandoned land has been overgrown and has practically lost the status of agricultural land. However, this land is still recorded as agricultural in the land register.

3. DATA AND METHODOLOGY

Soil erosion is determined mainly by four factors: lithological and pedological structure, climate, topography and land use. The anthropogenic impact on erosion can be direct (by carrying out erosion control works and changing the land use) and indirect (decrease in population, reduction of livestock, ceasing to cultivate the land due to economic migrations from rural to urban areas) (Lal, 1990, Clark, 1985, Walling & Webb, 1996, Walling, 1999, Toy et al., 2002, Chen et al., 2002, Morgan, 2005). If we observe the anthropogenic impact on erosion intensity through the change in the population number (P) and its effect on decrease or increase in sediment production (W), it is possible to distinguish several scenarios: (1) an increase in population follows an increase in sediment production (P↑ W↑); (2) an increase in population is accompanied by a decrease in sediment production (P↑ W↓); (3) a decrease in population is accompanied by an increase in sediment production (P↓ W↑); (4) a decrease in population is followed by a decrease in sediment production (P↓ W↓). Since the first three scenarios are very rare in the RS, the aim of this research is the fourth scenario which is dominant. Therefore, for this scenario it is necessary to determine the sediment production in the RS in 1981 and 2013 to define the areas where sediment production was reduced, and to analyse the B&H censuses results of 1981 and 2013 to identify settlements and municipalities which were depopulated.

Lately, there have been numerous methodologies and models for soil erosion mapping and developing erosion maps. Empirical models are frequently used in preference to more complex models. They can be implemented in situations when data and parameter inputs are limited. For these reasons empirical models for soil erosion and sediment yield predictions are still widely used in many countries (Globevnik et al., 2003, Ananda & Herath, 2003, Tangestani, 2005, de Vente et al., 2005, 2006, 2008, Tazioli, 2009, Amini et al., 2010, Bagherzadeh & Daneshvae, 2011, Tošić et al., 2018, Lovrić & Tošić, 2018), including the Republika Srpska/B&H (Tošić et al., 2012).

Gavrilović (1970, 1972) created and developed an empirical Erosion Potential Model (EPM) for the analytical determination of erosion coefficients, quantification of gross erosion and average annual sediment yield. This model is a result of experimental research at a station located in Serbia. Using the work at experimental stations in Serbia, Bosnia and Herzegovina, Croatia, Slovenia and Montenegro, as well as work on erosion mapping in former Yugoslavia, R. Lazarević adjusted Gavrilovic's empirical methodology by changing the tables for determination of Φ, X, and Y coefficients, and the mean value of the erosion coefficient (Z). The B&H Erosion Map (1980–1985) and the RS Erosion Map (2012) were developed using this methodology (Lazarević, 1985, 1985a, Tošić et al., 2012). The EPM method uses scoring for three descriptive variables: soil protection coefficient (X), soil erodibility coefficient (Y), and coefficient of type and extent of erosion (Φ) (Table 1). Catchments with strong spatial variability in these descriptive factors should be divided into smaller and more homogenous sub-catchments (Gavrilović, 1970, 1972).

The basic EPM value of the quantitative erosion intensity is the erosion coefficient (Z). The soil erosion coefficient (Z) for erosion polygon can be estimated using corresponding tables (Table 2) or calculated from the equation:

$$Z = Y \cdot X \cdot \left(\phi + \sqrt{I}\right) \tag{1}$$

In which, Y is the soil erodibility coefficient, X is soil protection coefficient, Φ is coefficient of type and extent of erosion, and I is average slope of the catchment.

The quantitative values of the erosion coefficient (Z) have been used to divide erosion intensity into classes or categories.

According to Gavrilović (1972), the analytical equation for calculation of the average annual gross erosion W ($m^3/year/km^2$):

$$W_{year} = T \cdot H_{year} \cdot \pi \cdot \sqrt{Z^3} \tag{2}$$

where: W_{year} = the total annual erosion ($m^3/year/km^2$); T = the temperature coefficient:

$$T = \sqrt{\frac{t}{10} + 0.1} \tag{3}$$

t = average yearly temperature; H_{year} = the average yearly precipitation (mm); Z = the erosion coefficient.

Depopulation was analysed through population changes per settlement. The decline in demographic potential (depopulation) and changes in the spatial distribution of the population are shown through the comparison of the B&H population and household censuses of 1981 and 2013 for each settlement (2745) and municipality (62), and also through the presentation of changes in the population density in the RS.

The comparison of the censuses required preliminary research to define the RS settlements within the B&H boundaries of 1981. Seventeen municipalities of the RS remained the same since 1981, while forty-six municipalities changed their surface area and thus the structure (number of settlements). It was necessary to map current administrative boundaries of municipalities and settlements in the RS to the situation from 1981. We used a universal pattern to obtain the population of settlements from the 1981 Census in the present administrative boundaries of municipalities and settlements (Majić & Marinković, 2017). In order to do this, it was necessary to know the total population of settlements according to the 1981 Census, the population of those parts of settlements added to the RS, and those joined to Federation of Bosnia and Herzegovina (FB&H) according to the 2013 Census. The following equation was used:

$$P_{RS1981}=\frac{P_{RS2013}}{P_{RS2013}+P_{FB\&H2013}}\cdot P_{B\&H1981} \qquad (4)$$

where: P_{RS1981} = Population number of settlements from 1981 Census which according to present administrative boundaries are in the RS; P_{RS2013} = Population number of settlements in the RS according to 2013 Census; $P_{FB\&H2013}$ = Population number of settlements in the FB&H according to 2013 Census; $P_{B\&H1981}$ = Population number of settlements in the B&H according to 1981 Census.

After the population was defined for each settlement and municipality in the RS, the difference in the number was determined, which was also the basis for defining changes in population. Since the analysis included only depopulated settlements and those where the sediment production decreased (reduced intensity of erosion), a total of 1,248 settlements were identified (or 45.46% of the RS settlements). In addition to this, the change in population of the 62 RS municipalities was analysed and a total of 44 municipalities were identified to be included in the analysis.

Table 1. Descriptive factors used in the EPM model (Lazarević, 1985).

Soil protection coefficient	**X**
Mixed and dense forest	0.05-0.20
Thin forest with grove	0.05-0.20
Coniferous forest with little grove, scarce bushes, bushy prairie	0.20-0.40
Damaged forest and bushes, pasture	0.40-0.60
Damaged pasture and cultivated land	0.60-0.80
Areas without vegetal cover	0.80-1.00
Soil erodibility coefficient	**Y**
Hard rock, erosion resistant	0.1-0.3
Rock with moderate erosion resistance	0.3-0.5
Weak rock, schistose, stabilised	0.5-0.6
Sediments, moraines, clay and other rock with little resistance	0.6-0.8
Fine sediments and soils without erosion resistance	0.8-1.0
Erosion and stream network development coefficient	**ϕ**
Little erosion on watershed	0.1-0.2
Erosion in waterways on 20–50% of the catchment area	0.3-0.5
Erosion in rivers, gullies and alluvial deposits, karstic erosion	0.6-0.7
50–80% of catchment area affected by surface erosion and landslides	0.8-0.9
Whole watershed affected by erosion	1.0

Table 2. EPM erosion qualitative categorization and range of erosion coefficients Z (Lazarević, 1985).

Erosion category	Qualitative name of erosion category	Range of erosion coefficient (Z)
I	Excessive erosion	1.00 - 1.50 > 1.50
II	Intensive erosion	0.71 - 1.00
III	Medium erosion	0.41 - 0.70
IV	Slight erosion	0.21 - 0.40
V	Very slight erosion	0.01 - 0.20

The methodology consisted of several phases shown in the flowchart (Fig. 2): (a) data collection from the B&H Erosion Map from 1981, the RS Erosion Map from 2013, and calculation of gross soil erosion for these two periods; (b) data collection from B&H population and household censuses of 1981 and 2013 for each settlement and municipality in the RS; (c) formation of geodatabases: define layers for sediment production for the situations in 1981 and 2013 using the existing RS erosion maps; define layers for the RS settlements and municipalities with their population number from 1981 and 2013 censuses and their difference; (d) GIS analysis: geospatial overlay for the analysis and visualization of spatial change; (v) statistical analysis – regression analysis: determine the relationship between the changes in sediment production and the population in areas where both were reduced.

Regression analysis, as a set of analytical techniques, was used to analyse the relationship between the variables (sediment production and population). The final result is the regression equation and the output parameters of the regression analysis: correlation coefficient, coefficient of determination, standard error, etc. The other purpose of using this analysis is to predict a value for the dependent variable (sediment production) for a certain value of the independent variable (population).

The study used a linear regression model:

$$Y = bX + a \tag{5}$$

where: Y = the difference in sediment production between 1981 and 2013 for each settlement, expressed in m^3/year; X = the difference in the population between 1981 and 2013 for each settlement where there was a change in sediment production. This value was obtained using the following equation:

$$X = U \cdot (P_{1981} - P_{2013}) \tag{6}$$

where: U = the area of the settlement where change in erosion intensity occurred, which results from the following equation:

$$U = \frac{A_w}{A} \tag{7}$$

where: A_w = the area of the settlement where change in sediment production occurred; A = total area of the settlement; P_{1981} = population of the settlement in 1981; P_{2013} = population of the settlement in 2013; a = expected change in the sediment production when there is no change in the population; b = regression coefficient showing average change in sediment production when the population is increased by one:

$$b = \frac{n\sum xy - \sum x \sum y}{n\sum x^2 - \left(\sum x\right)^2} \tag{8}$$

$$a = \bar{y} - b_1 x \tag{9}$$

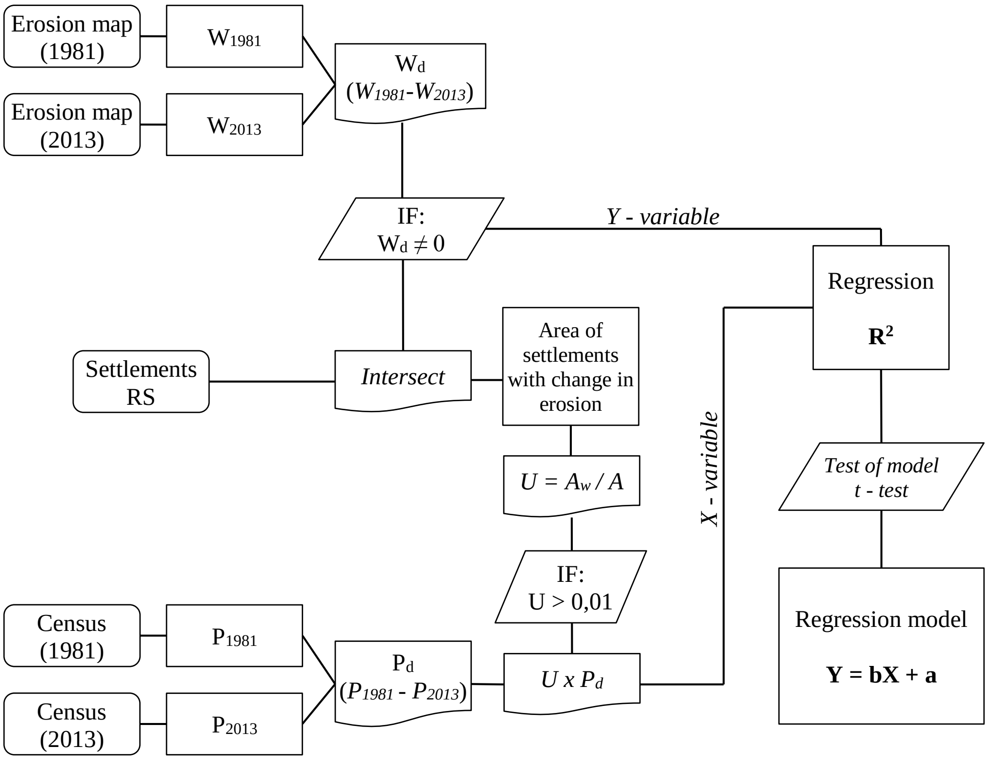

Figure 2. Flowchart of the research - overview of the research structure

The Pearson Correlation Coefficient of linear regression was used to measure the correlation between changes in sediment production on one side and population on the other:

$$r = \frac{n\sum xy - \sum x \sum y}{\sqrt{n\sum x^2 - \left(\sum x\right)^2}\sqrt{n\sum y^2 - \left(\sum y\right)^2}} \tag{10}$$

he significance of the regression coefficient is estimated on the basis of the value t:

$$t = \frac{r}{s_r} \tag{11}$$

$$s_r = \sqrt{\frac{1-r^2}{n-2}} \tag{12}$$

where: n = a number of paired observations, i.e. a number of settlements where a correlation was established between the change in sediment production and the population. The resulting t-values were compared with the critical values of the Student's t-distribution at the significance level of 1% ($p < 0.01$).

In addition to forming and testing the equation of the linear regression model, the coefficient of determination (R^2) was determined and interpreted as the proportion of the variance in the dependent variable (sediment production) that is predictable from the independent variable (population). The standard error, as a measure of the representativeness of the resulting regression model, was calculated as follows:

$$s_y = \sqrt{\frac{\sum\left(y_i - \hat{y}_i\right)^2}{n-2}} \tag{13}$$

The values of these parameters are given in the Summary Output – Regression Statistics and ANOVA table, using Microsoft Office Professional Plus (Microsoft Excel, version 14.0). The data collection and preparation used ArcGIS 10.4 software. All data prepared for the analysis have vector data format. They were reclassified depending on the type of data and their histogram.

4. RESULTS AND DISCUSSION

4.1. Depopulation process in the period 1981–2013

The problem of depopulation in the Republika Srpska has been particularly pronounced during the last decade, as a result of negative natural increase, migration from villages to towns, socio-economic changes, 1990s war, and other socio-geographical processes that marked the last decade of the 20th century. Several authors have analysed this problem. They point out the need for an urgent strategic approach to the planning of demographic development is necessary, as well as for principles that will enable the sustainability of settlements in the RS (Mandić & Živković, 2014, Marinković & Majić, 2014, Mandić, 2015, Majić & Marinković, 2017).

The best way to understand changes in the population, especially per settlement, is by using the results of the B&H population and household censuses. According to the 1981 Census, the settlement geography of the RS counted 2,745 settlements with a population of 1,571,188. The average population density was 63 per km^2, while the average settlement size was 572 (Census of population, 1982). According to the 2013 Census, the settlement geography of the RS counted 2,745 settlements with a population of 1,170,342 (Results of the Census, 2017). The average population density was 47 per km^2, while the average settlement size was 426. A comparative analysis of the data from the censuses shows a decrease of almost 400,846 people, as well as major changes in population distribution, which is clearly evident on the population density maps of the RS (Fig. 3).

The unbalanced demographic size of the eastern and western parts of the RS is evident from the data on population density and number by settlements and municipalities. There is a significant difference in the population between the eastern and western RS (east and west of the Brčko District), which have approximately similar surface areas. 62.78% of the population lives in the western RS, while only 37.22% lives in the east. This undoubtedly points to an unbalanced spatial distribution of the population, and a region with very poor demographic potential and a pronounced depopulation process.

The depopulation process can also be demonstrated by the change in the settlement structure by size. Settlements in the RS are divided into 5 categories: very small, small, medium, large and very large. According to the 2013 Census, of the total number of settlements in the RS, there was a decrease of population in 2,416 (88.01%). There were 1,252 settlements with less than 100 people, and 534 with less than 10. In addition to this, it is important to point out that, according to the 1981 Census, there were 67 settlements without inhabitants in the RS, while according to the 2013 Census that number increased to 218 settlements (Table 3).

Settlements without population are most often divided by the entity line or are in the eastern RS which was exposed to the most powerful demographic destruction in the last war.

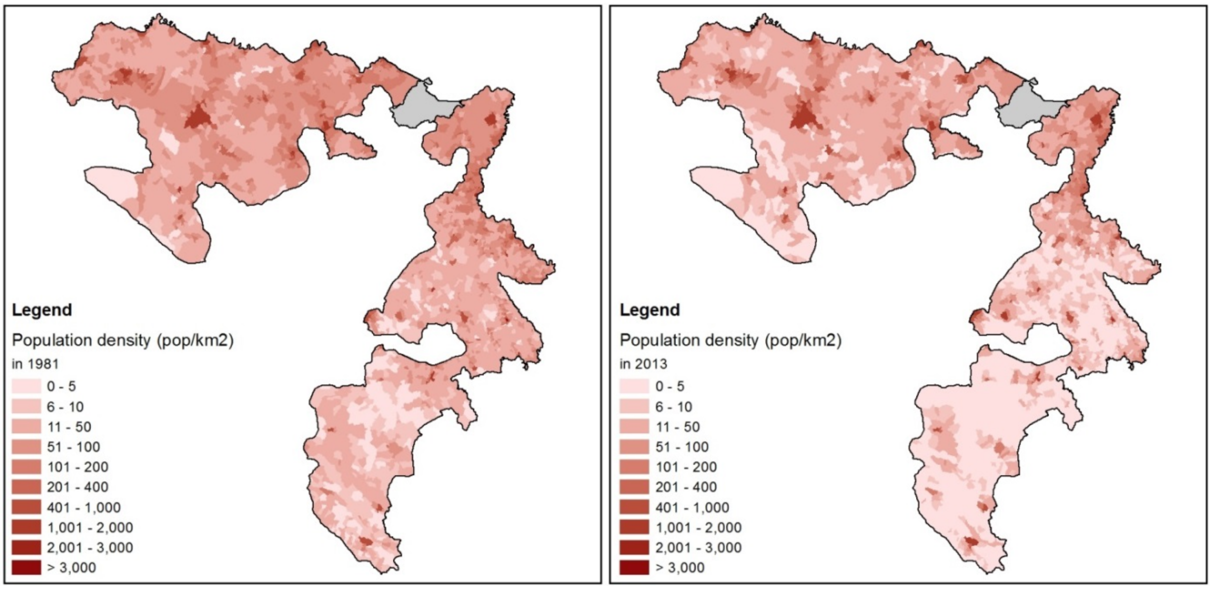

Figure 3. Population density in the RS according to Census data from 1981 and 2013

Table 3. Number of settlements in the Republika Srpska by population size according to 1981 and 2013 censuses

Settlements by population size (people)	**1981 Census**	**2013 Census**
Very small (1 – 100)	662	1,252
Small (100 – 1,000)	1,684	732
Medium (1,000 – 2,000)	236	111
Large (2,000 – 5,000)	71	46
Very large (> 5,000)	25	32

In addition to depopulation as a dominant demographic process, according to the 2013 Census, there was an increase in the population in 263 settlements (9.58%). This increase is the result of migrations during the war, when populations from settlements in the Federation of Bosnia and Herzegovina left their places of residence and most often settled in the suburbs of the regional centres of the Republika Srpska. The number of settlements with more than 5,000 people increased in comparison to 1981. This is a clear indication of the depopulation of rural settlements and the concentration of the population in suburban and urban areas of Banja Luka, Bijeljina, Prijedor, Istočno Sarajevo, Trebinje and others.

The analysis of these results clearly shows that the settlement geography in the RS has experienced great changes, which significantly changed the demographic, infrastructural and functional capacity of a large number of settlements. Loss of demographic potential, i.e. depopulation, caused the formation of a large number of very small and small settlements with small populations, which is essentially a limiting factor for the sustainability of the settlement geography in the Republika Srpska. Depopulation affects 88% of the RS, almost all rural settlements, the area of high mountains (mountain villages), regions along the Entity border, Eastern Herzegovina, upper and middle Podrinje, parts of the western Krajina, and also a large number of municipalities with ethnically heterogeneous population structures.

Currently there is no demographically affluent area in the RS which has positive numbers in all components of the overall population movement. The only positive component is the internal migration, as a result of the depopulation of rural settlements and emigration of population from less prosperous parts to the larger regional centres of the country. On the whole, the problem of depopulation is one of the burning problems affecting all spheres of social life of the Republika Srpska. Therefore, its resolution is the task of the greatest national importance.

4.2. Changes in the intensity of soil erosion in the period 1981–2013

The first quantitative indicators of soil erosion intensity in the Republika Srpska were presented in the B&H Erosion Map from 1981. According to this map, 21,508.07 km^2 (87%) of the total RS was affected by erosion of different intensities, while 3,133.56 km^2 (13%) were affected by alluviation. In that period, the spatial distribution of erosion intensity reflected the dominant land use, population and household number, and the role of primary erosion factors in the development and intensity of erosion processes. According to this map, total average annual gross erosion in the RS was 6,516,230.80 m^3/year, and specific annual gross erosion 298.21 m^3/km^2/year (Fig. 4).

Demographic and land use changes due to the war in the RS had a significant impact on the intensity of soil erosion and gross erosion. Due to changes in erosion intensity, the total average annual gross erosion in the RS in 2013 was 5,242,343.79 m^3/year, and specific annual gross erosion 239.91 m^3/km^2/year (Lazerević, 1985, Tošić et al., 2012). The analysis of the changes in the intensity of erosion compared to 1981 is presented through the change matrix (Table 4). The change matrix indicates a dominant trend of decreasing erosion intensity. An increase was recorded only in an area of 0.07 km^2, which is statistically almost insignificant compared to the total area affected by erosion (Tošić, 2015).

The main reason for these changes is the change in land use, decreasing population, migrations and consequences of the civil war in Bosnia and Herzegovina. During the last 32 years (1981–2013), the erosion intensity is decreasing in most of the Republika Srpska.

4.3. Determination of depopulation impact on soil erosion

Mapping intensity of soil erosion after thirty years, and especially after the war and socio-economic changes, identified and highlighted the influence of anthropogenic factors on the character and tendency of changes of soil erosion in the RS (Tošić et al., 2012). Considering that the decrease in the intensity of erosion is a dominant process in the RS, we selected the fourth scenario for further study, in which a decrease in the population (Fig. 5) is accompanied by a decrease in sediment production (P↓ W↓).

Using the existing erosion data (1981 and 2013 erosion maps), we created a Map of changes (decreases) in specific sediment production in the RS (Fig. 5). Subsequently, this map was overlapped with the RS settlements map to obtain a map of settlements where the change in sediment production occurred (decrease >1%).

This GIS analysis enabled us to identify the settlements in the RS where there was a decrease in the sediment production (>1%). Previously, we collected and processed all the data on population from the 1981 and 2013 censuses, to identify the settlements where the population decreased. Finally, the analysis included the settlements in which there was a decrease in sediment production and a decrease in the population. Further analysis concluded that of the total of 62 municipalities in the RS, 44 showed a significant regression correlation between the decrease in sediment production and the decrease in population.

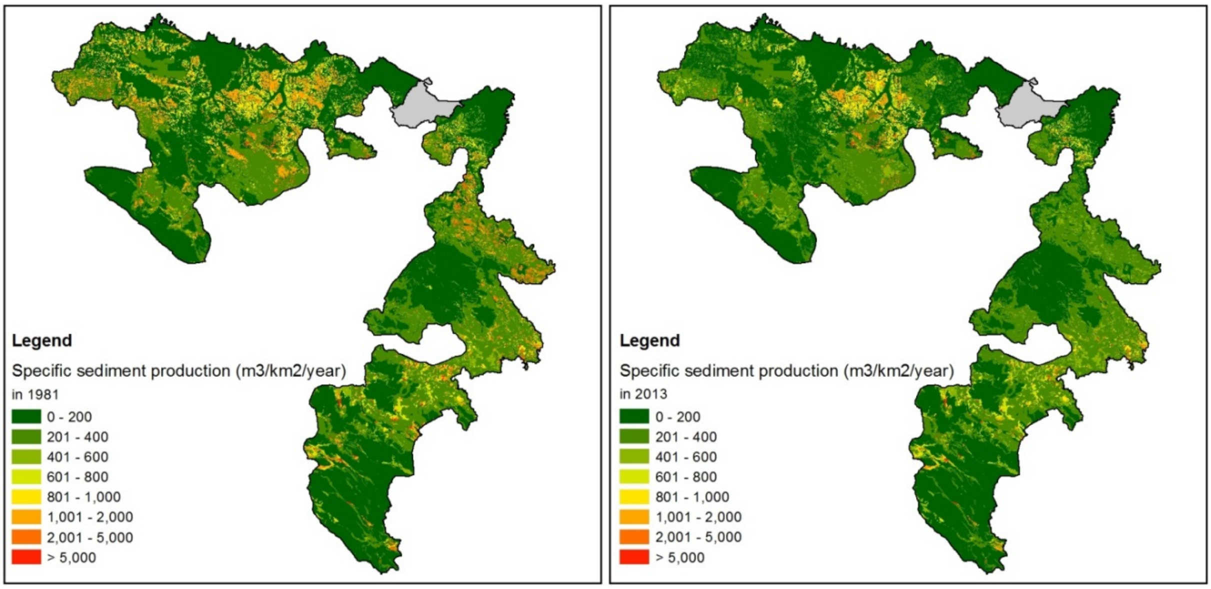

Figure 4. Map of annual gross erosion in the RS from 1981 and 2013

Table 4. Change matrix of erosion categories (I–V) in the Republika Srpska (km^2)

2013 1981	I	II	III	IV	V
I	191.82	0.00	60.41	14.45	0.00
II	0.00	7.27	118.29	266.83	0.00
III	0.00	0.00	931.40	1,432.96	0.48
IV	0.07	0.00	0.00	1,954.99	0.00
V	0.00	0.00	0.00	0.00	16,529.09

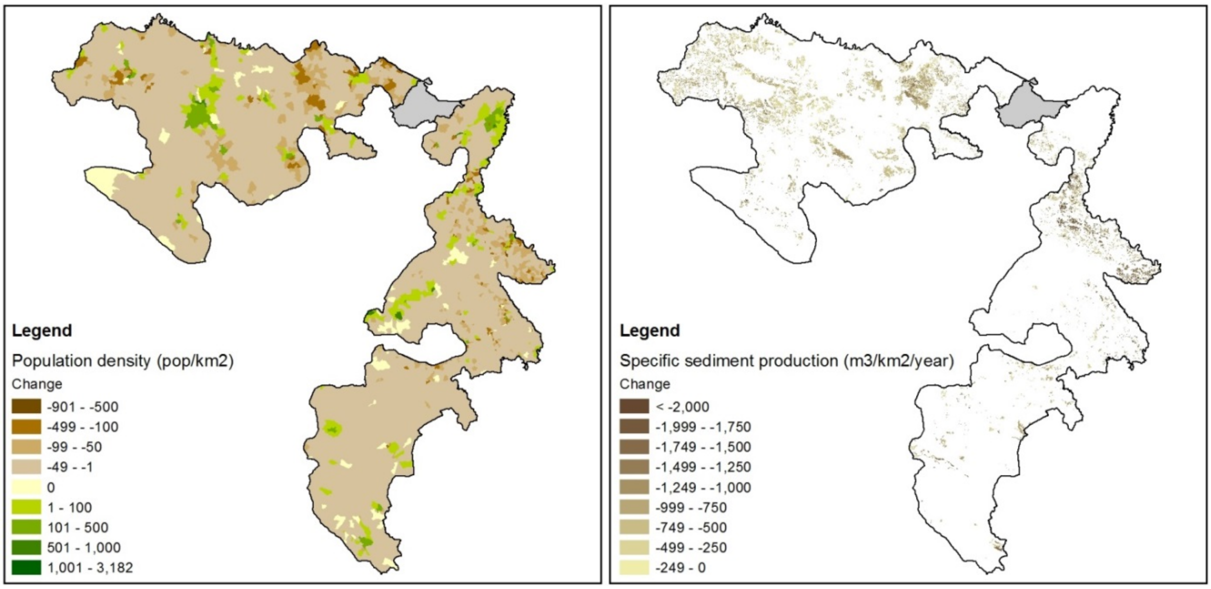

Figure 5. Map of change in population density and map of change in the specific sediment production in the RS

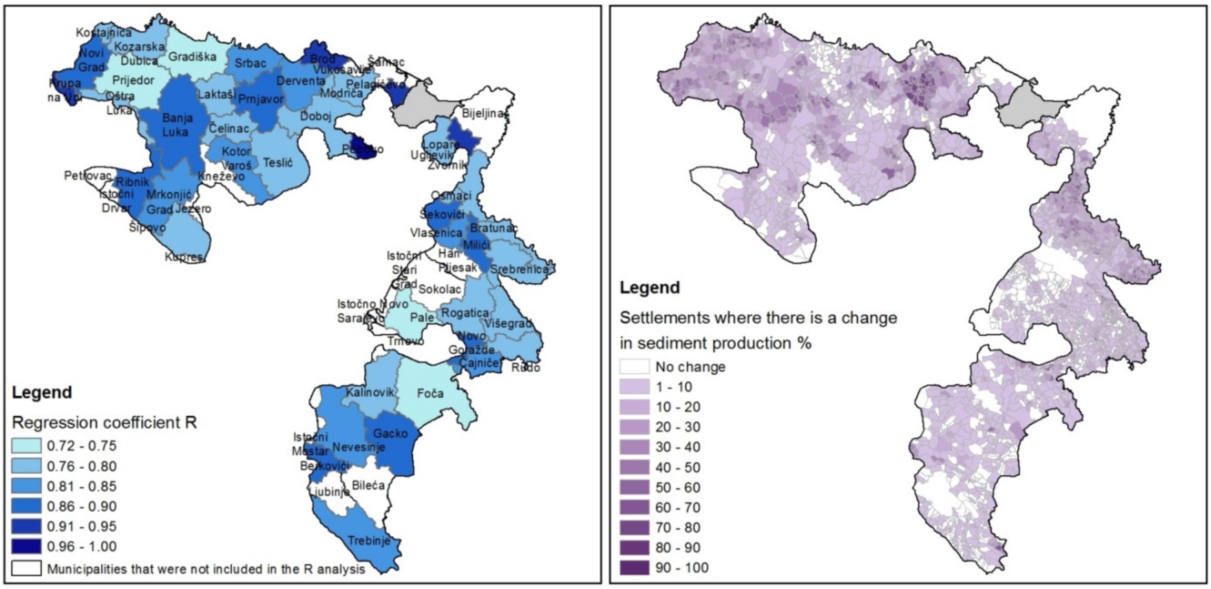

Figure 6. Map of the regression correlation coefficients for changes in sediment production and population by the RS municipalities and map of the RS settlements that were included in the analysis and their share in the change in sediment production

Table 5. Regression analysis parameters

Regression Statistics	
Multiple R	0.79
R Square	0.63
Adjusted R Square	0.63
Standard Error	924.69
Observations	1248.00

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	1783950072	1783950072	2086.36	0.00
Residual	1246	1065396372	855053.27		
Total	1247	2849346444			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-441.43	30.74	-14.36	0.00	-501.74	-381.12	-501.74	-381.12
X Variable 1	15.26	0.33	45.68	0.00	14.60	15.91	14.60	15.91

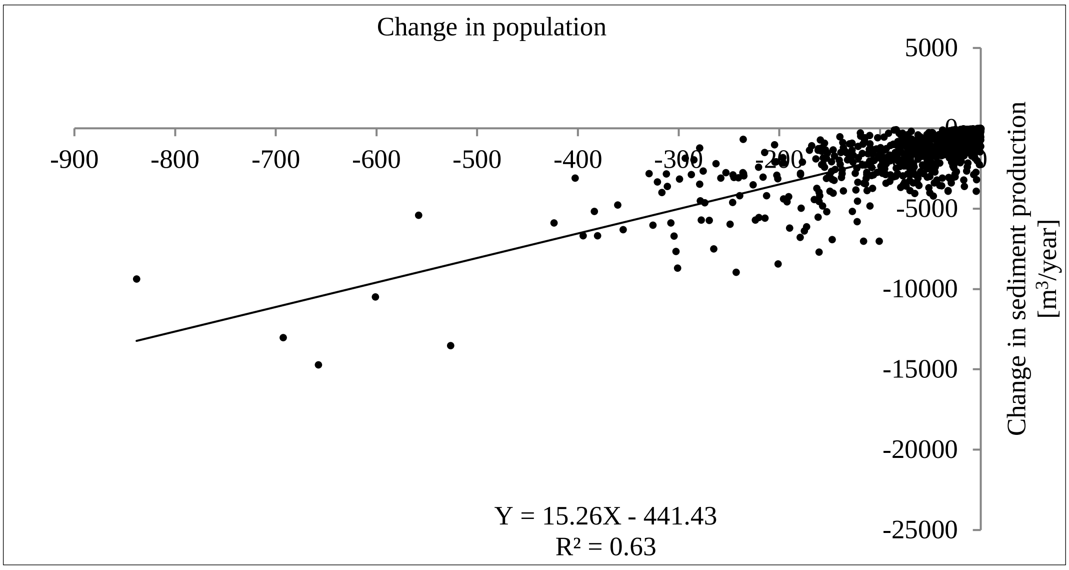

Figure 7. Regression correlation of changes (decrease) in the sediment production and changes (decrease) of population in the RS

The linear regression coefficient ranged from 0.72 to 0.95, and the coefficient of determination ranged from 0.52 to 0.91 (Fig. 6). The largest coefficient of determination (the explanation of the change in the sediment production predictable from the change in population) is present in border municipalities and major regional centres with a pronounced process of deagrarianization**,** de-ruralisation, depopulation and migration caused by the 1992–1995 war, and also contemporary demographic trends (natural increase, migration and population ageing). Of the total of 2,745 settlements in the RS, the regression analysis included 1,248 in which there was a change in sediment production and population (Fig. 6).

The Pearson Correlation Coefficient is 0.79, which is in the range of medium-strong correlation, i.e. 79% of the variance of annual changes in sediment production is explained by the change in population (Fig. 7). Based on the low P-value of 0.00, and due to an extremely large number of samples at the risk level $p<0.01$, it can be concluded that there is a statistically significant correlation between the decrease in sediment production and the decrease in population in the RS settlements (Table 5). The coefficient of determination is 0.63, which means that a 63% decrease in sediment production of a settlement can be explained by the linear regression model:

$$Y = 15.26X – 441.43$$

Therefore, if the population of a settlement (where it is possible to expect a decrease in sediment production and depopulation) remained unchanged, the expected annual sediment production would be smaller by 441.43 m^3, and for each population decrease by one, a decrease of annual sediment production by 15.26 m^3 is expected.

The results of this study indicate a clear correlation between the anthropogenic factor expressed through the depopulation process and the change in erosion intensity expressed through the decrease in sediment production. Depopulation, which also caused changes in land use, significantly influenced the changes in erosion intensity, especially in mountainous areas of the country. These areas are mostly affected by depopulation processes, partly because of the 1992–1995 war, and partly because of the migration and other demographic processes that followed in the post-war period. In most of the world, the decrease in soil erosion is the result of the planned action of humans (Erskine et al., 2002, Walling & Fang, 2003, Putnam & Pope, 2003, Vericat & Batalla, 2006, Desir & Marin, 2007, Heimann et al., 2011), but in the RS it is different.

The above-mentioned socio-geographical processes have left a mark on the strength and intensity of erosion processes. Our research in the RS showed that, to a large extent, humans have unintentionally and indirectly decreased erosion intensity. Depopulation, migration, warfare and massive migration from mountainous areas, led to changes in land use over time, which resulted in decreased erosion intensity and sediment production. Numerous studies have pointed to the fact that the anthropogenic impact on erosion intensity is mostly reflected through land use. Using different erosion methodologies, researchers have identified land use as the dominant factor affecting intensity of erosion and sediment production (Zeleke & Hurni, 2001, Pruski & Nearing, 2002, Erskine et al., 2002, Walling, 2006, Sharma et al., 2011, Tošić et al., 2012, Manojlović et al., 2017, 2018). However, we should not forget that this change is directly dependent on the presence of people and their economic activity. In the last few decades, due to depopulation, the decrease of agricultural activities and other demographic processes, many previously used areas in the RS became covered by natural vegetation. Agricultural production is still present in northern parts but at a low rate. This had a considerable impact on soil erosion intensity and gross erosion.

5. CONCLUSIONS

In a continuously globalizing world human activities have an important impact on the environment. Soil erosion is an example of a geomorphological process that is strongly related to human activities. Various agricultural activities and demographic changes have an important impact on soil erosion. Due to unfavourable trends in demographic process, the depopulation is intensifying in the Republika Srpska, especially in rural areas. According to the 2013 B&H Census, the population of the RS decreased by 400,846 compared to 1981. The analysis of the changes in the population of the RS settlements established that in 88.01% of the settlements there was a decrease in the population, and that the number of settlements without population is significantly increased. Therefore, the data and analyses carried out in this study clearly indicate that the RS settlement geography has experienced great changes, which also affected other processes.

This research shows that the depopulation is a highly significant factor in changes of erosion intensity and rates of gross erosion in the RS. The statistical analysis of 44 RS municipalities revealed a significant regression correlation between the decrease in sediment production and the decrease in population. The linear regression coefficient in these municipalities ranged from 0.72 to 0.95, and the coefficient of determination ranged from 0.52 to 0.91. In addition, the regression analysis included 1,248 RS settlements where there was a change in sediment production and population. The Pearson Correlation Coefficient for these settlements is 0.79, and the coefficient of determination of the observed variables is 0.63. Based on the analysis of statistical significance at both levels, it can be concluded that there is statistically significant correlation between the decrease in sediment production and the decrease in population in the RS settlements.

Finally, we hope that the results of this research will be considered in planning renewable natural resource projects, in protection of soil and forest ecosystems, water management projects, environmental protection, and spatial planning in the Republika Srpska.

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