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Agricultural Land Use Changes as a Driving Force of Soil Erosion in the Velika Morava River Basin, Serbia

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Abstract: The erosion potential model was applied to estimate the soil erosion status of rural settlements during the years 1971 and 2011. We used univariate and bivariate local Moran's *I* indices to detect and visualize the spatial clustering of settlements with respect to changes in erosion intensity and agricultural land use, as well as their mutual spatial correlation. The study area was differentiated into four statistically significant clusters using the calculated bivariate local Moran's *I* indices. The statistical analysis examined the two largest clusters, i.e., the high–high and low–low clusters, and the results of the research indicate that the first four principal components explained 70.50% and 73.47% of the total variance, respectively. In the high–high cluster, the low rates of erosion reduction (average Index Z = 98) in the most significant types of rural settlements were determined according to demographic indicators (i.e., the higher population vitality and population density, the smaller share of the old population and the lower average age of the population) and the large proportion of arable land and Neogene sediments. In the low–low cluster, high erosion reduction rates were detected (average index Z = 64). In this cluster, the more statistically significant influence of natural conditions in combination with demographic–agrarian processes (i.e., the larger share of the old population, the higher average age of the population, the lower vitality index and deagrarization) were decisive factors in changing erosion intensity.

Keywords: soil erosion intensity; deagrarization; univariate and bivariate local Moran's *I*; principal component analysis; Serbia

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1. Introduction

Soil is comprehensively considered to be an essential resource for human security. Ever since humankind began to engage in agriculture, the main threat to soils has been soil erosion by wind and water [1,2]. The latest United Nations (UN) report on the status of global soil resources highlighted that soil erosion is still a major environmental and agricultural threat worldwide [3–5]. Additionally, accelerated forms of soil erosion have become a widespread phenomenon that represent a major barrier to achieving the United Nations' sustainable development goals [6]. The study of erosion processes at different spatial and temporal scales is not only of socioeconomic and political importance, but also has the obvious scientific outcome of understanding the processes and general behavior of ecosystem dynamics (e.g., erosion rates in the climate change modeling of carbon dynamics, and the prediction of soil nutrient balance or pollution dissemination) [7–10]. In the early 1990s, it was already estimated that 56% of global land on all continents and under all climatic conditions was degraded and suffered from severe forms of soil erosion by water [11]. The latest research has shown that soil erosion is a global phenomenon [12]. It is widespread in less developed, tropical and subtropical countries, where modeling results have indicated greater exposure to erosive processes [13–20]. It is also widespread in industrialized and highly developed countries [21–27]. One of the leading causes of excessive soil erosion is the conversion of natural vegetation into agricultural land [28,29], which is important considering that almost 40% of the Earth's land is currently used for agricultural production [30]. Despite both the social and economic benefits that are brought about by land use transformation [22], it can cause ecological changes [31], effects on people's health and global climate changes [32,33] and changes in the production, transport and quality of agricultural products [34]. Therefore, the conversion of natural vegetation into agricultural land represents an important factor in the degradation of soil and water quality [14]. For that reason, it is necessary to carry out the spatial–temporal analysis, quantification and identification of the main causes. Yet, in certain regions of Europe, there is also the phenomenon of abandoned agricultural land [35–41].

Serbia's rural spaces are heterogenic and devastated to different extents, which makes the planning of multifunctional development extremely complicated [42]. Until now, study areas in Serbia have mostly been focused in mountainous basins [43] and peripheral rural areas with distinct evidence of depopulation and deagrarization [44,45]. Unlike those areas, the Velika Morava River Basin has a high population density with numerous economic and administrative centers and significant agricultural production. The Velika Morava Basin is a "pivot of development", as well as a part of the pan-European Corridor X. Bearing in mind the geostrategic, transportation, economic and social significance of the Velika Morava River Basin for the whole of Serbia, the estimation of vulnerability to water erosion, as the dominant erosion type in the area, plays an essential role in implementing adequate strategies for sustainable development in Serbia. Since soil erosion is directly linked to agriculture, the subject of this study was primarily a rural area comprising a total of 438 rural settlements.

The main initial hypothesis is based on the view that deagrarization and different demographical processes were essential for understanding the ongoing changes in soil erosion intensity in the Velika Morava River Basin. We have divided the initial hypothesis into two secondary hypotheses: (1) in the areas with deagrarization and depopulation processes, the erosion intensity tends to decrease more; (2) agricultural growth and a higher population concentration are found in the peri-urban areas of the larger urban centres of the Velika Morava River Basin, resulting in a slower decrease in erosion intensity.

The main goals of the study were as follows: (1) the spatio–temporal analysis of changes in erosion intensity; (2) the spatial differentiation of rural settlements, determined by the relationships between agricultural land use changes and changes in soil erosion and the identification of the areas with the most significant changes in erosion intensity caused by changes in agricultural land use; (3) the determination of the influence and order of the dominant factors affecting changes in erosion intensity in the two largest clusters (i.e., the high–high and low–low clusters), based on the most dominant variables controlling sediment and soil erosion (i.e., physical–geographical, agrarian–geographical and demographic variables).

In this study, compared to previous studies, we performed a spatial autocorrelation analysis to determine the relationship between the deagrarization processes and changes in erosion intensity at the rural settlement level. We identified the areas with the most significant changes in soil erosion intensity. The results of this study can be implemented in various projects and national strategies (e.g., rural development, spatial planning, regional development policy, environmental protection, etc.).

2. Materials and Methods

2.1. Study Area

The study area is located in the basin of the Velika Morava River (Figure 1). The basin covers an area of 6734 km^2. The basin is located between the Carpathian–Balkan Mountains to the east and southeast and the Serbian–Macedonian mass occupies the central part of the basin, along the valley sides [46]. The topography of the basin is characterized by a hilly and mountainous relief in the southern part of the basin and a lowland relief in the northern part of the basin. The altitude ranges from 67 m to 1334 m, with an average altitude of 260 m. The geological structure is dominated by Holocene alluvium and Neogene lake sediments [47]. According to the Köppen climate classification, the north part of the basin belongs to the Cfa climate group, while the south part of the basin belongs to the Cfb group [48]. The study area has a continental climate [49], with an average annual temperature of 11 °C and a positive significant trend of average annual temperature across meteorological stations [50,51]. The basin has between 590 mm and 670 mm of annual precipitation and has a semi-humid and humid climate, according to the De Martonne aridity index [52]. Early studies showed similar results (600–650 mm) [53]. The monthly cloudiness values are below average for Serbia [54]. Across the majority of the hydrological stations in the basin, a negative non-significant trend of mean annual discharge has been recorded [55]. However, the basin can experience torrential rain, and 226 floods were registered over 105 years, resulting in 13 casualties [56]. The maximal discharges have a seasonal character (from May to the first half of June) [57]. The study area has a specific runoff that is below the national level ($q < 5$ l/s/km^2) [58]. There are potential flood zones within the valley, while the edges are at risk of seismic movements and landslides [59–61]. According to the WRB classification (World Reference Base), the main soil types in the basin are Eutric Cambisol and Vertisol. Fluvisol and Fluvisol humic are also represented in the alluvial plains of Velika Morava. Leptosol can be found in the highest eastern parts of the basin, while in the mountainous areas to the southwest, Eutric Leptosol is widespread [62].

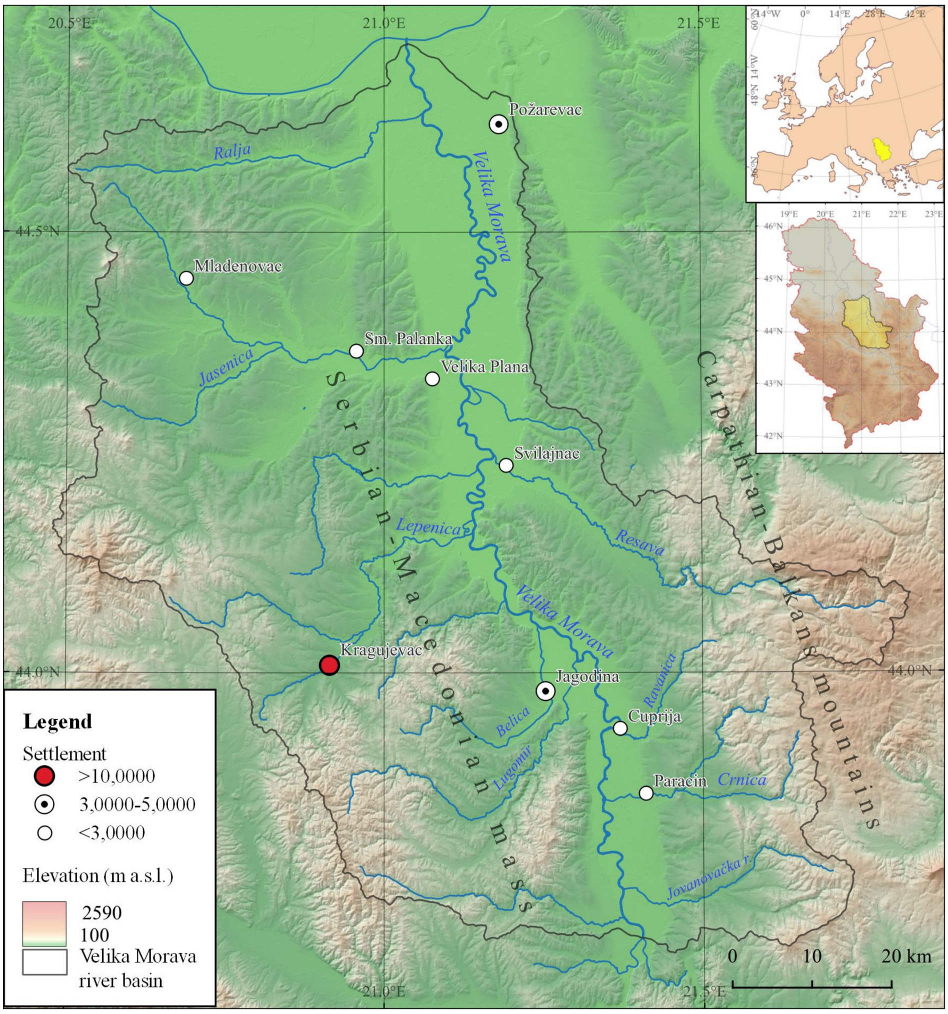

Figure 1. Geographical position of the Velika Morava River Basin.

The population in the Velika Morava River Basin lives in 17 urban and municipal centers and 438 rural settlements. The urban centers are mainly located in the valleys of the Velika Morava River (along the main traffic route, i.e., the pan-European Corridor X) and its larger tributaries. In terms of numbers, small urban settlements prevail: eight settlements have fewer than 10,000 inhabitants and two have between 10,000 and 20,000 inhabitants. There are only six medium-sized towns, with populations ranging between 20,000 and 100,000 inhabitants, while the largest urban center is Kragujevac, with approximately 150,000 inhabitants. The total population has increased from 770,698 people in 1961 to 801,471 people in 2011. However, the total rural population has decreased by 29%, from 559,836 people to 397,730 people [63]. According to the 2012 census, agricultural land covers 286,866 ha in the rural settlements. In terms of the agricultural land, the share of arable land is 79% (227,609 ha). The largest part of arable land is used to grow cereals (68%), with dominant shares of corn (49%) and wheat (38%) and a smaller share of other cereals, e.g., barley, rye and oats (13%) [63].

2.2. Erosion Potential Model

The Gavrilović model, also known as the erosion potential model (EPM), was developed by Slobodan Gavrilović following erosion field research in different catchment areas in Serbia in the middle of the 20th century. Gavrilović proposed an analytical equation for determining the total annual sediment production [64]. In the Balkans, the erosion potential model (EPM) is the preferred method for mapping soil erosion intensity at different scales (i.e., national, regional, local, etc.) [65–71]. According to an evaluation of different methods, the EPM model is the most suitable at the watershed level for engineering purposes and watershed management in southeastern European countries [72]. Research in other countries has shown that the results obtained using this method are in agreement with field observations. Therefore, the method has been widely accepted in regions all over the world [73–78].

The erosion potential model was used to calculate the soil erosion intensity, and is expressed by Equation (1):

$$W = T \cdot H \cdot \pi \cdot \sqrt{Z}^3 \cdot F \tag{1}$$

where W is the total annual gross erosion (m^3/yr), T is the temperature coefficient ($T = \sqrt{(t/10 + 0.1)}$), t is the mean annual air temperature (°C), H is the mean annual precipitation (mm), Z is the erosion coefficient and F is the watershed area (km^2).

The EPM model uses a scoring approach for three descriptive variables to calculate the coefficient of erosion (Table 1): the coefficient of soil resistance (Y), the coefficient of soil protection (X) and the coefficient of the type and extent of erosion (φ). The EPM erosion categorization is shown in Table 2. The erosion coefficient (Z) was calculated using Equation (2):

$$Z = Y \cdot X \cdot (\varphi + \sqrt{I}) \tag{2}$$

where Y is the coefficient of soil resistance, X is the soil protection coefficient, φ is the erosion and stream network development coefficient and I is the average slope (%).

The Y, X and φ coefficients are dimensionless parameters. Y is the coefficient of soil erodibility, which depends on the lithological characteristics of the watershed and indicates the resistance of soil to erosion. The values of this coefficient range between 0.1 and 1; values close to 0.1 indicate low erodibility, whereas values close to 1 represent strong erodibility. In this study, we used basic 1:100.000 geological maps of the study area to evaluate the Y coefficient. X represents the coefficient of soil protection, which is based on vegetation cover and land use within the catchment area. It varies from 0.05 to 1; values close to 0 indicate low soil protection, while values close to 1 indicate high soil protection. φ is a coefficient that depends on active erosion and the degree of extension of linear erosion. It includes the geomorphological features of the terrain and various erosive–accumulative processes. This dimensionless coefficient has values ranging from 0.1 to 1.

Table 1. Values of the descriptive variables (Y, X and φ) used in calculating the erosion coefficient (Z).

Coefficient of Soil Resistance	Y Value
Fine sediments and soils without erosion resistance	0.80–1.00
Sediments, moraines, clay and other rock with little resistance	0.60–0.80
Weak rock, schistose, stabilized	0.50–0.60
Rock with moderate erosion resistance	0.30–0.50
Hard rock, erosion resistant	0.10–0.30
Coefficient of soil protection	**X value**
Areas without vegetal cover	0.08–1.00
Damaged pasture and cultivated land	0.06–0.80
Damaged forest and bushes, pasture	0.04–0.06
Coniferous forest with little grove, scarce bushes, bushy prairie	0.20–0.40
Thin forest with grove	0.05–0.20
Mixed and dense forest	0.05–0.20
Coefficient of type and extent of erosion	**φ value**
Whole watershed affected by erosion	0.90–1.00
50–80% of the catchment area is affected by surface erosion and landslides	0.80–0.90
Erosion in rivers, gullies and alluvial deposits, karstic erosion	0.60–0.70
Erosion in waterways on 20–50% of the catchment area	0.30–0.50
Little erosion on watershed	0.10–0.20

Table 2. EPM erosion categorization and range of the erosion coefficient (Z).

Erosion Category	Erosion Intensity	Range of Z	Average of Z	Range of W ($m^3/km^2/yr$)
I	Excessive erosion	>1.01	1.25	>3000
II	Intensive erosion	0.71–1.00	0.85	1200–3000
III	Medium erosion	0.41–0.70	0.55	800–1200
IV	Weak erosion	0.21–0.40	0.30	400–800
V	Very weak erosion	0.01–0.20	0.10	100–400

Previous studies [44] on the importance of certain variables in the EPM model have shown that climatic parameters (e.g., precipitation and temperature) do not significantly affect soil erosion. Specifically, correlation matrix results at the statistical significance level of $\alpha = 0.05$ for function $W = f(H, T, Z, X, Y, \varphi, I, F)$ showed that the erosion coefficient Z had a major impact on soil erosion intensity ($W = f(Z)$; $r = 0.967$). Out of the four variables that determine erosion, the erosion coefficient Z and the coefficient of soil protection X were found to be the primary controlling factors in erosion intensity. According to mathematical interactions between the different variables, the correlation coefficients for the functions $Z = f(X)$, $Z = f(\varphi)$ and $Z = f(Y)$ are $r = 0.820$, $r = 0.767$ and $r = 0.392$, respectively. Given that results have shown that there were no significant changes in the trend of annual precipitation for the period of 1961–2009 in Serbia [79], the focus of this study was on determining the factors that control soil erosion from the perspective of anthropogenic influences, as well as physical–geographical variables that largely determine erosion intensity and are included in the calculation of the erosion coefficient Z.

2.3. Spatial Autocorrelation Analysis

The effects of land use/land cover changes on soil erosion processes have been documented in many studies [41,80–86]. In our research, we additionally focused on the spatial heterogeneity and spatial distribution of agricultural land use changes, erosion intensity changes and their mutual spatial relationships.

Moran's *I* [87,88] is a commonly used indicator for measuring the spatial patterns of geographical phenomena:

$$I = \frac{n\Sigma_{i=1}^{n}\Sigma_{j=1}^{n} W_{ij}\left(X_i - \overline{X}\right)\left(X_j - \overline{X}\right)}{\Sigma_{i=1}^{n}\Sigma_{j=1}^{n} W_{ij}\,\Sigma_{i=1}^{n}\left(X_i - \overline{X}\right)^2} \quad (3)$$

where n represents the number of spatial units (i.e., settlements in our case) in the study area, X_i and X_j are the measured or calculated values of a certain phenomenon or variable at location i and j, respectively, $\overline{X}$ is the calculated average value and W_{ij} represents a particular element of a spatial weighted matrix, which is calculated according to the spatial proximity between two locations (in our case, this was calculated using the inverse distance method).

In addition, the local indicator of spatial autocorrelation (*LISA*) is commonly used to determine spatial heterogeneity and distinguishing local clusters [86]:

$$I_i = \frac{(n-1)\left(X_i - \overline{X}\right)}{\sum_{j=1, j\neq i}^{n}\left(X_j - \overline{X}\right)^2}\sum\nolimits_{j=1, j\neq i}^{n} W_{ij}\left(X_j - \overline{X}\right) \quad (4)$$

where I_i is the local Moran's I index of a spatial unit in location i, which indicates the correlation between that unit and its neighborhood, thereby offering insights into how the spatial units with high and low attributed values are clustered. A high–high cluster indicates that spatial units with high values of the considered variable are surrounded by other units with high values. On the contrary, a low–low cluster designates that units with low values are surrounded by neighbors with low values.

We used bivariate local Moran's *I* [89], which recognizes whether the values of one variable (X) in a given spatial unit are correlated with the values of a second variable (Y) in the neighboring spatial units. The formula for bivariate local Moran's *I* for the unit k is similar to the univariate version:

$$I_{XY}^{k} = Z_X^k \sum\nolimits_{l=1}^{n} W_{kl} Z_Y^l \quad (5)$$

where I_{XY}^{k} is the standardized value of X at unit k, Z_Y^l is the standardized value of Y at unit l and W_{kl} is the spatial weight between units k and l.

In our study, bivariate spatial autocorrelation analysis was used to determine and visualize the rural areas in the Velika Morava River Basin that have experienced the most significant changes in erosion intensity (Index *Z*) due to changes in agricultural land use (Index *AgL*). Both the univariate and bivariate local Moran's *I* indices were calculated and visualized using open-source GeoDa software that was designed for exploratory spatial data analysis (ESDA) [90].

2.4. Control Variables as Determinants of Changes in Erosion Intensity

After establishing the spatial differentiation of rural settlements using the function Index $Z = f$ (Index *AgL*), the next aim of this research was to determine the influence and order of the dominant factors affecting changes in erosion intensity. In this context, the two largest clusters were analyzed, i.e., the high–high and low–low clusters. This study focused on examining the combined effects of the selected physical–geographical variables and anthropogenic activities as the most dominant factors controlling sediment and soil erosion.

As presented in Table 3, 17 variables that could potentially affect changes in erosion intensity were taken into consideration. The variables were grouped into three classes: physical–geographical, agrarian–geographical and demographic.

Table 3. Controlling variables used in the correlation analysis (CA) and principal component analysis (PCA).

Variables–Abbreviation (Units)	Calculate	
Physical–geographical		
Erosion coefficient in 2011 Z_2 (–)	Equation (2)	X, Z, φ—Table 1
Mean Altitude *Aav* (m)	DEM	DEM—Digital Elevation Model
Terrain slope I (°)	DEM	DEM—Digital Elevation Model
Lithology—sediments of Neogen *NSA* (%)	$NSA = (A_{NSA}/A) \cdot 100$	A_{NSA}—Neogen sediments area A—total area of the settlement
Vegetation—Forest cover *FC* (%)	$FC = (A_{FC}/A) \cdot 100$	A_{FC}—forest area in 2011 A—total area of the settlement
Agrarian–geographical		
Deagrarization index agricultural land *Index AgL* (–)	Index $AgL = (AgL_2/AgL_1) \cdot 100$	AgL_2—agricultural land (ha) in 2011 AgL_1—agricultural land (ha) in 1961
Deagrarization index arable land *Index ArL* (–)	Index $ArL = (ArL_2/ArL_1) \cdot 100$	ArL_2—arable land (ha) in 2011 ArL_1—arable land (ha) in 1961
Share of arable land in agricultural land *ArLs* (%)	$ArLs = (ArL/AgL) \cdot 100$	ArL—arable land (ha) in 2011 AgL—agricultural land (ha) in 2011
General agrarian population density *GDAgL* (rural population/100 ha)	$GDAgL = RP/AgL \cdot 100$	RP—rural population in 2011 AgL—agricultural land (100 ha) in 2011
Specific agrarian population density *SDArL*(rural population/100 ha)	$SDArL = RP/ArL \cdot 100$	RP—rural population in 2011 ArL—arable land (100 ha) in 2011
Demographic		
Depopulation index *Index RP* (–)	Index $RP = (RP_2/RP_1) \cdot 100$	RP_2—rural population in 2011 RP_1—rural population in 1961
Density rural population *DRP* (rural population/km^2)	$DRP = RP/A$	RP—rural population in 2011 A—total area of the settlement
Vitality index *Index V* (–)	Index $V = (WRP/ORP) \cdot 100$	WRP—economically active rural population in 2011 ORP—rural population older than 65 yr in 2011
The average age of the rural population *RPav* (years)	Age and Sex, data by settlements 2011	
Old rural population *ORP* (%)	$ORP = (ORP/RP) \cdot 100$	ORP—rural population older than 65 yr in 2011 RP—rural population in 2011
Household index *Index H* (–)	Index $H = (H_2/H_1) \cdot 100$	H_2—total number of households in 2011 H_1—total number of households in 1961
Household index size *Index Hs* (–)	Index $Hs = (Hs_2/Hs_1) \cdot 100$	Hs_2—average household size in 2011 Hs_1—average household size in 1961

The index was classified according to the following scale: high index < 10; medium–high index = 10–30; medium index = 30–50; medium–low index = 50–70; low index > 70–100 and growth index > 100.

The data for the Z coefficient for 1971 were obtained from the 1:500,000 erosion map of Serbia [91]. To obtain this data for 2011, we used the CORINE land cover database (2012), which was published by the European Environment Agency (EEA) [92]. The coefficient of the erosion type was determined using satellite images from the Landsat 8 satellite, which belongs to the Geological Topographic Institute of the United States (USGS) [93–98]. Our results were obtained from all of the gathered data and maps. The data for the mean altitude (*Aav*) and terrain slope (I) were obtained from the 25–m digital elevation model over Europe (EU–DEM) [99]. The lithological data were obtained from the digitalization of a 1:100,000 basic geological map [100]. The vegetation data were obtained from the CORINE land cover database (2012), which was published by the European Environment Agency (EEA) (Copernicus Land Monitoring Service). The demographic and agrarian–geographic indicators were identified from data analyses by the Statistical Office of the Republic of Serbia for 1961 and 2011 [63], respectively. QGIS 3.8.0. was used for the data analysis, synthesis and visualization.

The determination of the controlling factors among the considered variables that contribute to changes in erosion intensity was carried out using two statistical tools: correlation analysis and principal component analysis (*PCA*). All the statistical calculations were implemented using the open-source *R* statistical computing environment with the stats package [101].

In this study, we identified 17 indicators that could provide insights into mutually conditioned relationships, including erosion intensity, natural conditions, land use, deagrarization intensity, human pressure on the land, the degree of depopulation and the demographic vitality of the population. However, the main issue with identifying the typological features is the huge number of variables that determine the attributes, characteristics and features of the area being studied. Based on previous multivariate analysis studies, the principal component analysis algorithm has proven to be the most convenient method for the typologization of the relationship between erosion intensity and agricultural production [43,102–105]. According to the above-mentioned studies, factor analysis starts from the assumption that a high level of correlation between two or more variables leads to their replacement by a common indicator, thereby providing insights into the unambiguous quantitative formulation of hidden structures via the definition of new indicators.

Correlation coefficient matrices should not be singular, which is why it is necessary to calculate the Kaiser–Meyer–Olkin (KMO) indicator of a sample's adequacy and also carry out Bartlett's sphericity test. KMO values range from 0.0 to 1.0; however, a score of 0.50 is the suggested minimum value for a good PCA [102,106–108]. In this study, the KMO values for the high–high and low–low clusters were 0.64 and 0.67, respectively. Likewise, to perform the factor analysis successfully, Bartlett's sphericity test must be significant, as well (i.e., $p < 0.05$). The statistical significance obtained in this study was $p < 0.0001$. We also applied the Ward method for hierarchical grouping using the squared Euclidean distance [43,103].

3. Results

3.1. Spatio–Temporal Analysis of Changes in Erosion Intensity

Our comparative quantitative analysis of the two-time series showed a decrease in erosion intensity in the Velika Morava River Basin (Table 4). The results of the EPM model showed that the specific annual gross erosion was W_1 = 1013 m^3/km^2/yr in 1971 and W_2 = 747 m^3/km^2/yr in 2011. The average erosion coefficient in 1971 was Z_1 = 0.529, while it was Z_2 = 0.420 in 2011. This meant that during the period of 1971–2011, the intensity of soil erosion decreased by 20.6%. According to Table 4, 2219 km^2 (33%) of the study area was classified as erosion category V and IV in 1971, while 3055 km^2 was classified as these two categories in 2011 (45.4%). The results also indicate that 2093 km^2 (31.1%) was classified as erosion category III in 1971, while 2580.5 km^2 was classified as this category in 2011 (38.3%). Finally, 2422 km^2 (36%) of the study area was classified as erosion category I and II in 1971, while 1098 km^2 was classified as these two categories in 2011 (16.3%). It could be concluded that the biggest change lies in the reduction in areas with an excessive and intensive risk of erosion (54%). On the other hand, there was a 38% increase in areas with a weak and very weak risk of erosion, as well as a 19% increase in areas with a medium risk of erosion.

Table 4. Erosion category 1971 and 2011 in the Velika Morava River Basin.

Erosion Category	Erosion Intensity	F (km^2) 1971	F (%) 1971	F (km^2) 2011	F (%) 2011
I	Excessive erosion	310.3	4.6	4.0	0.1
II	Intensive erosion	2111.8	31.4	1094.0	16.2
III	Medium erosion	2093.2	31.1	2580.9	38.3
IV	Weak erosion	1060.1	15.7	1021.1	15.2
V	Very weak erosion	1159.2	17.2	2034.5	30.2

3.2. Erosion Intensity Characteristics in Rural Settlements

The changes in erosion intensity in rural areas were analyzed for 1971 and 2011. For each rural settlement, the average erosion coefficient *Z* was determined for 1971 (Z_1) and 2011 (Z_2) (Figure 2A,B). As presented in Figure 2C, only 4% of the total number of rural settlements in the Velika Morava River Basin had a medium Index *Z*, whereas 37% and 47% of rural settlements had a medium–low and low Index *Z*, respectively. Finally, 13% of the rural settlements recorded growth in terms of soil erosion intensity. The local Moran's *I* statistics for Index *Z* identified two clusters that represented two distinctively different areas (Figure 2D).

The univariate LISA cluster map singled out a large compact high–high cluster of rural settlements that gravitated toward larger urban centers in the north of the Velika Morava River Basin. Meanwhile, a large low–low cluster in the southern part of the basin indicated a decrease in soil erosion intensity over the period of 1971–2011.

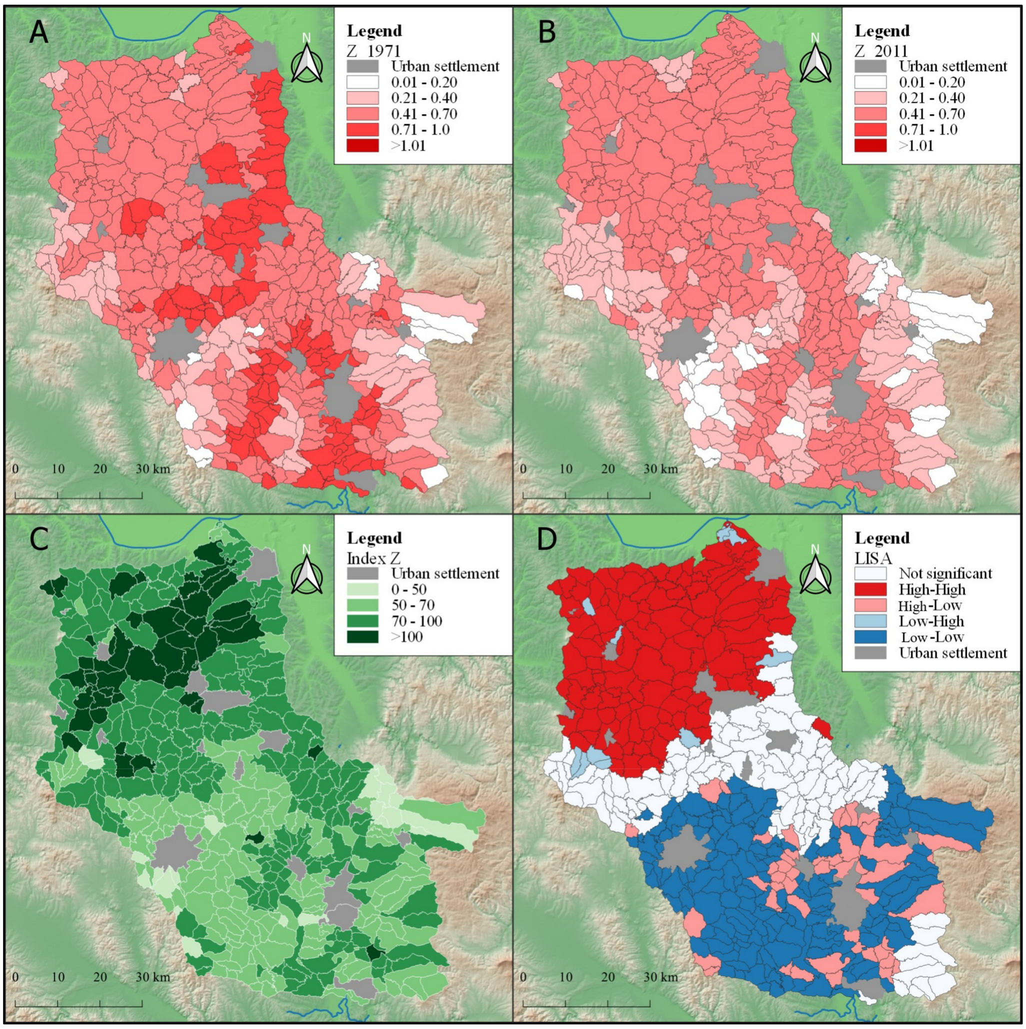

Figure 2. The average coefficient of erosion *Z* in rural settlements of the Velika Morava River Basin in 1971 (**A**) and 2011 (**B**); Index *Z* for the period 1971–2011 (**C**); LISA univariate cluster map of Index *Z* for the period of 1971–2011 (**D**).

3.3. Agricultural Land Use Characteristics in Rural Settlements

The basic agrarian characteristic of the Velika Morava River Basin is the rapid reduction in agricultural land. During the research period of 1961–2011, the total area of agricultural land decreased by 38% (1961 = 462,515 ha; 2011 = 286,866 ha). Out of 438 rural settlements, the largest proportion of settlements (38%) comprised 500–1000 ha of agricultural land in

1961 (Figure 3A), whereas the largest proportion of rural settlements (37%) consisted of 200–500 ha of agricultural land in 2011 (Figure 3B).

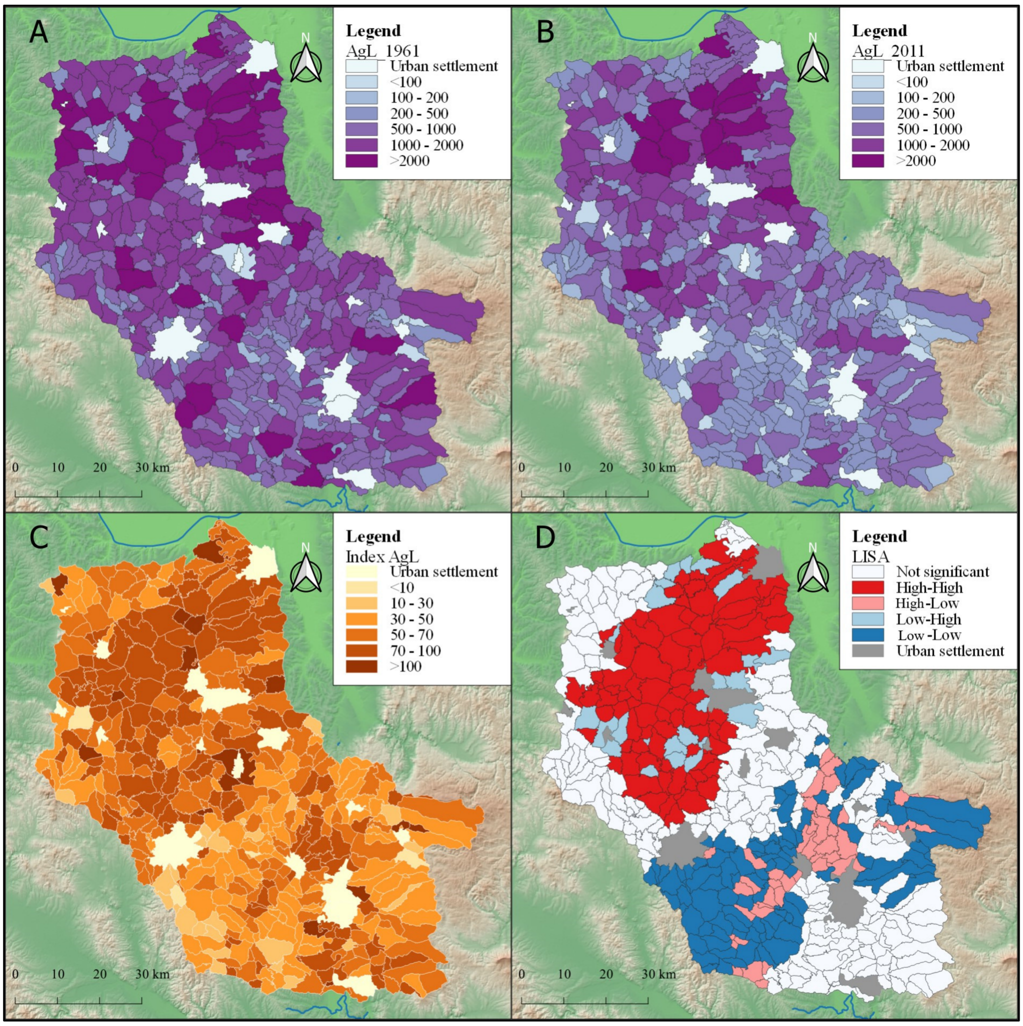

Figure 3. Agriculture land (*AgL*) in rural settlements of the Velika Morava River Basin in 1961 (**A**) and 2011 (**B**); Index *AgL* for the period of 1961–2011 (**C**); LISA univariate cluster map of Index *AgL* for the period of 1961–2011 (**D**).

According to Figure 3C, 7% of the rural settlements had a high and medium–high deagrarization index, 26% had a medium deagrarization index, 33% had a medium–low deagrarization index and 30% had a low deagrarization index, while only 4% experienced an increase in agricultural land. The mapped agrarian univariate LISA indicators (Figure 3D) indicated clusters of strong deagrarization areas (low–low), i.e., areas with low deagrarization index values, in the southern part of the Velika Morava River Basin. The cluster of high deagrarization index values and agricultural growth were expressed as a high–high cluster, which were dominant in the northern and central parts of the basin. The clusters primarily reflected a relatively small increase in agricultural land in the area between 1961 and 2011.

3.4. Spatial Differentiation of Rural Settlements: Impact of Agricultural Land Use Changes on Changes in Erosion Intensity

The impact of deagrarization on changes in the intensity of soil erosion in the rural area of the Velika Morava River Basin was demonstrated by the bivariate LISA indicators (Figure 4). Based on the bivariate LISA values of Index *AgL* and Index *Z*, the spatial patterns of four clusters were detected. In general, there was a difference between the northern part of the basin (with high–high and low–high clusters) and the southern part of the basin (with low–low and high–low clusters).

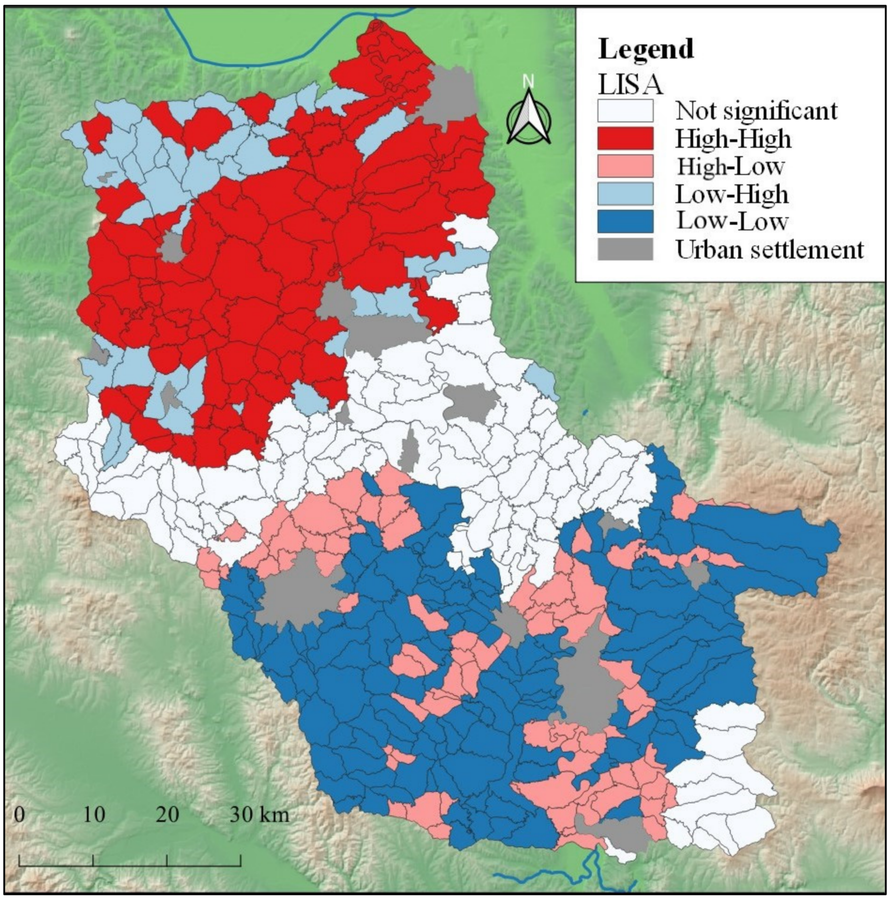

Figure 4. Bivariate LISA cluster map: Index *AgL*/Index *Z*.

The high–high cluster is comprised of rural areas characterized by small changes in erosion and deagrarization intensity (Figure 4). Out of the 88 rural settlements within the Velika Morava River Basin, around 20% belong to this cluster. In terms of space, these rural settlements represent single units of urban centers in the northern and central parts of the basin (Mladenovac, Požarevac, Sopot, Aranđelovac, Topola, Smederevska Palanka and Velika Plana). During the analyzed period, there were no changes in the soil erosion category within this cluster. To be more precise, the erosion coefficient remained in the same category of medium erosion (1971: Z_1 = 0.550; 2011: Z_2 = 0.529). The average value of the soil erosion index was high (Index Z = 98) and ranged from 49 to 135. Actually, in 42 rural settlements (48%), the value of this index was above 100, which implies an increase in erosion intensity. Generally speaking, the increase in soil erosion intensity was not large and in most of the settlements, it was up to 15% compared to the values from 1971.

There was not a distinct deagrarization process. The mean value of the deagrarization index in the settlements in this cluster was Index *AgL* = 83. The rural population in this part of the basin owned a total of 130,741 ha of agricultural land in 1971. The biggest number of settlements (37%) comprised 1000–2000 ha of agricultural land (Figure 3A). On the other hand, the population cultivated 106,113 ha of agricultural land in 2011. The largest proportion of settlements comprised 1000–2000 ha of agricultural land (36%) (Figure 3B). According to Figure 3C, 23% and 69% of rural settlements had a medium–low and low deagrarization index, respectively. In the other settlements, there was a slight increase in the area of agricultural land.

The studied area is characterized by intensive agriculture and the use conventional tillage which further increases the intensity of erosion. In addition, a high percentage of the working age population engaged in agriculture in the area allows the improvement of the production process with intensive and frequent tillage interventions and performing work-intensive jobs, which has a direct impact on increasing the intensity of erosion [45,109,110].

The low–high cluster was characterized by rural settlements that experienced higher deagrarization intensity, followed by small changes in erosion intensity. This cluster included 38 settlements, which was 9% of the total number of settlements in the Velika Morava River Basin. These settlements did not have a unique distribution and were mostly surrounded by settlements in the high–high cluster (Figure 4). Just as in the previous cluster, only relatively small changes in soil erosion intensity were detected among the settlements in this cluster. The mean erosion coefficients in 1971 and 2011 were $Z_1 = 0.529$ and $Z_2 = 0.456$, respectively, with an average Index $Z = 87$. Therefore, over time, the erosion intensity of settlements in this cluster remained within the same category.

However, the deagrarization process demonstrated a more severe decline. Agricultural land reduced by over 50% (Index $AgL = 46$) over the study period. The total area of agricultural land in all of the settlements covered 43,593 ha in 1971. All in all, 58% of rural settlements comprised 1000–2000 ha of agricultural land (Figure 3A). The relatively high intensity of soil erosion compared to the deagrarization intensity could be explained by the positions of the settlements. The rural settlements in this cluster were in the territory around the peri-urban belt (i.e., rural areas near larger urban settlements), which was a direct consequence of the intensification of agricultural production under the influence of the agrarian markets in the surrounding urban centers [110–112].

The low–low cluster was the largest cluster among the rural areas in the Velika Morava River Basin and was characterized by the largest changes in both erosion and deagrarization intensity (Figure 4). There were 132 rural settlements in this cluster, which was 30% of the total number of settlements in the Velika Morava River Basin. This cluster covered the southern part of the basin, which primarily includes mountainous areas and rural settlements in gravitational zone of urban centers, such as Kragujevac, Paraćin, Ćuprija, Jagodina and Despotovac to the north and Ćićevac to the south. The average erosion coefficient in 1971 was $Z_1 = 0.516$, whereas it was $Z_2 = 0.327$ in 2011. This meant that during the study period, the medium erosion level was replaced by low/weak erosion. The average erosion index value was Index $Z = 64$. Half of the rural settlements had Index Z below the average value, which meant that in these rural areas, the erosion intensity reduced by as much as 75% compared to that in 1971.

The reduction in soil erosion intensity was a consequence of the rather intense deagrarization process in the rural areas. The average deagrarization index (Index $AgL = 41$) indicates that there was an observable trend of abandoning agricultural land within this cluster. Specifically, most of the rural settlements (55%) had a medium deagrarization intensity, whereas 18% of the settlements had a medium–high and high deagrarization index (Figure 3C). The losses of available agricultural land were more than evident. In total, all the settlements within this cluster comprised a total of 122,154 ha of agricultural land in 1971. The highest number of settlements (45%) consisted of 500–1000 ha of agricultural land (Figure 3A). Over the period of 40 years, the area of agricultural land reduced to a total of 50,794 ha, with a demonstration of the very prominent fragmentation of agricultural land. According to Figure 3B, half of the rural settlements comprised 200–500 ha of agricultural land.

The studied area is characterized by the process of deagrarization, in which, in addition to the absence of intensive practices, we can observe agricultural land use change, which is consistent with the prevailing representation of the autarkic type of agricultural production. Agricultural practices are less intensive, which has a direct impact on the reduction of production productivity and, consequently, on the reduction of erosion intensity.

The high–low cluster was characterized by lower deagrarization intensity, followed by larger changes in erosion intensity. In terms of space, the settlements within this cluster did not represent a single whole, but were instead aerially grouped and were generally positioned around the settlements in the low–low cluster (Figure 4). Out of the total number of rural settlements in the Velika Morava River Basin, this cluster consisted of 79 settlements (11%). The spatial distribution of the settlements indicated that they mostly included urban centers in the central part of the basin (e.g., Kragujevac, Jagodina, Ćuprija and Paraćin). This cluster experienced a significant reduction in soil erosion intensity (Index Z = 69). The medium erosion coefficient in 1971 was Z_1 = 0.696, whereas it was Z_2 = 0.483 in 2011. The distribution of the Z index was in the range of 35–102 and the predominant erosion index was below the average value.

Concerning the reduction in soil erosion, the deagrarization process was also of lower intensity (Index *AgL* = 79). Low deagrarization dominated the settlements in this cluster (Figure 3C). The relatively low reduction in agricultural holdings also affected the relatively large reduction in soil erosion intensity. These settlements were mainly located at lower altitudes where the dominant Neogene sediment was vulnerable to the forceful processes of erosion and denudation. On the other hand, the economic transformation caused an increase in demand for non-agricultural occupations around the urban centers [106], which led to the fragmentation of agricultural holdings [110,112–116]. This was reflected in the unfavorable demographic features of the population (i.e., the population decrease of 20%, followed by the process of population aging) [117].

3.5. Geographic Indicators of Changes in Soil Erosion Intensity

In this study, we applied the statistical analysis method to determine the effects and sequences of the dominant factors affecting changes in soil erosion intensity. With this in mind, two bivariate clusters were analyzed: the high–high and low–low clusters. These were the most dominant clusters, according to their features and the catchment of rural settlements. The mathematical interactions between various variables were described using a correlation matrix (Table 5). Generally, the results indicated high correlations between the variables at a significance level of α = 0.05.

In the high–high cluster, the correlation values ranged from $r = -0.951$ to $r = 0.980$. The analysis of the results showed that the effects of the physical–geographical indicators on erosion intensity were lower in this cluster than in the low–low cluster. Out of the physical–geographical factors, Z_2 only had a relatively high negative correlation with I ($r = -0.445$) and *FC* ($r = -0.405$). This meant that with an increase in the inclination angle, there was an increase in the forest cover and a decrease in erosion intensity. The very strong ratio of $NSA = f(Aav)$ to $NSA = f(I)$ showed the direct correlation between the lithological complex *NSA* and the altitude and inclination angle. Additionally, the results showed that there were positive correlations between Z_2 and Index *ArL* and between Z_2 and *ArL* ($r = 0.473$ and $r = 0.583$, respectively). By the same token, it could be concluded that erosion intensity was affected by changes in arable land with a particular influence on the arable land share within the total area of agricultural land. Along with the deagrarization of agricultural land, there was simultaneously an ongoing deagrarization process of the arable land, as there was a positive correlation ($r = 0.711$) for Index $ArL = f$(Index AgL). Additionally, there were noticeable effects of physical–geographical factors on the share of arable land within the total area of agricultural land. This further implied the higher prevalence of arable land on the lithological complex of *NSA*, located at lower altitudes and on terrain with lower inclination angles. There was a similar situation in this cluster as in the low–low cluster: *SDArL* was directly linked to *GDAgL* and showed a high level of correlation ($r = 0.932$). However, the agrarian pressure on the land (*SDAgL* and *GDAgL*) was exclusively determined by demographic indicators (i.e., the Index *RP*, *DRP*, Index *V* and Index *H*). The balanced coefficients of correlation pointed out that these indicators had almost identical effects on *SDAgL* and *GDAgL*, which was not the case with the low–low cluster. The deagrarization process was also defined by demographic indicators (i.e., *DRP*, Index *V*, *RPav*, *ORP* and Index *H*), as indicated by the relatively high correlation coefficient values ($r > 0.546$). The highest correlation was between Index *P* and Index *H* ($r = 0.980$), which meant that Index *H* was the most significant of the demographic indicators. This was also not the case with the low–low cluster. The main characteristic of this cluster was the direct correlations between the agrarian land pressure indicators and almost all the demographic indicators, as well as the statistically weaker effect of the physical–geographical indicators in comparison to the agrarian–geographical indicators. This meant that the erosion intensity was exclusively determined by agrarian–geographical and demographic changes.

The order of significance of the variables was determined by the magnitude of their eigenvalues, as presented in Figure 5. Eigenvalues explain the percentage of variance and the cumulative variance of the principal components. It is evident that the first point at which it is possible to carry out the reduction of the number of factors is between the third and fifth factor. In this study, the first four principal components explained 70.50% of the total variance.

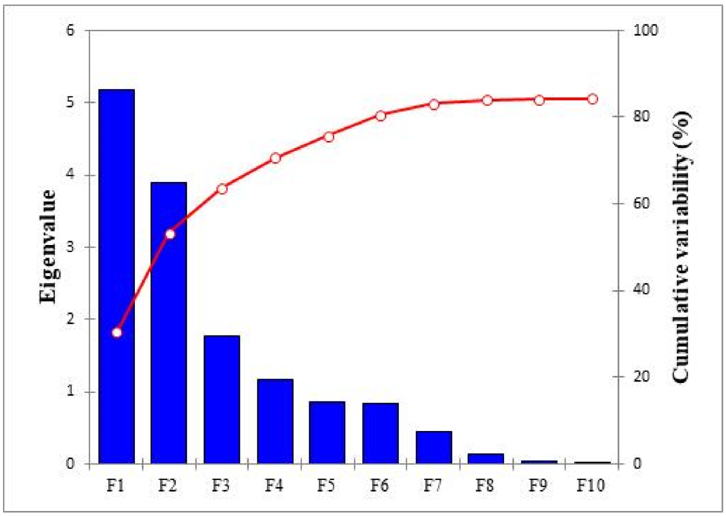

Figure 5. Eigenvalues and cumulative variance of principal components (high–high).

Table 5. Correlation matrix of the principal component analysis [Pearson (*n*)] for high–high cluster. Values in bold are different from 0 with a significance level α = 0.05.

	Z_2	*Aav*	*I*	*NSA*	*FC*	Index *AgL*	Index *ArL*	*ArLs*	*GDAgL*	*SDArL*	Index *RP*	*DRP*	Index *V*	*RPav*	*ORP*	Index *H*	Index *Hs*
Z_2	**1**																
Aav	**−0.379**	**1**															
I	**−0.445**	**0.893**	**1**														
NSA	**0.254**	**−0.856**	**−0.837**	**1**													
FC	**−0.405**	0.010	0.174	0.063	**1**												
Index *AgL*	0.091	0.028	−0.026	0.034	**−0.272**	**1**											
Index *ArL*	**0.473**	**−0.236**	**−0.288**	**0.235**	−0.182	**0.711**	**1**										
ArLs	**0.583**	**−0.692**	**−0.705**	**0.643**	0.042	0.054	**0.596**	**1**									
GDAgL	−0.091	0.020	0.065	−0.125	−0.040	0.002	−0.008	0.018	**1**								
SDArL	**−0.290**	0.177	**0.232**	**−0.253**	−0.051	0.052	−0.176	**−0.290**	**0.932**	**1**							
Index *RP*	−0.052	0.051	0.087	−0.164	−0.109	0.164	0.069	−0.074	**0.483**	**0.521**	**1**						
DRP	−0.186	**−0.219**	−0.132	0.109	0.120	0.020	0.001	0.098	**0.508**	**0.504**	**0.777**	**1**					
Index *V*	−0.014	**−0.214**	−0.151	0.109	−0.154	0.044	0.014	0.049	**0.415**	**0.404**	**0.706**	**0.659**	**1**				
RPav	0.162	0.125	0.056	−0.095	0.095	−0.087	0.035	0.054	**−0.314**	**−0.343**	**−0.547**	**−0.521**	**−0.848**	**1**			
ORP	−0.007	**0.239**	0.184	−0.142	0.119	−0.027	0.018	−0.050	**−0.358**	**−0.351**	**−0.606**	**−0.597**	**−0.951**	**0.859**	**1**		
Index *H*	−0.050	0.059	0.081	−0.181	−0.067	0.130	0.060	−0.053	**0.462**	**0.484**	**0.980**	**0.769**	**0.713**	**−0.534**	**−0.621**	**1**	
Index *Hs*	0.049	−0.034	0.013	0.064	**−0.242**	0.162	0.074	−0.087	0.046	0.101	0.055	−0.029	−0.045	−0.052	0.091	−0.136	**1**

The data from the PCA were subjected to varimax rotation. After the varimax rotation, four factors affecting changes in the intensity of soil erosion were identified (Table 6). The Factor 1 component explained 26.23% of the soil erosion variance within the dataset. Factors

2 and 3 explained 47.51% and 58.90% of the soil erosion variance, respectively. The addition of Factor 4 increased the model-explained variance to 70.50%.

Table 6. Percentage of variance and cumulative variance after varimax rotation (high–high).

	Factor 1	Factor 2	Factor 3	Factor 4
Variability (%)	26.23	21.28	11.39	11.59
Cumulative (%)	26.23	47.51	58.90	70.50

Based on the obtained results for the factor scores following the varimax rotation (Table 7), the typology of the rural settlements was established according to the dominant variables for changes in soil erosion intensity. There were four types of rural settlements: Factor 1, demographic type; Factor 2, agricultural type of specific physical–geographical characteristics; Factor 3, agrarian type; Factor 4, anthropopression type. The order of significance of the basic indicators in the high–high cluster indicated that the demographic component was the most significant for rural settlements and was essential for understanding ongoing changes in soil erosion intensity.

Table 7. Results after varimax rotation (high–high). Rotation method: varimax with Kaiser normalization; bold values indicate correlated variables included in the *PCs* > 0.40.

Variable	Factor 1	Factor 2	Factor 3	Factor 4	Communality
Z_2	−0.090	0.487	**0.498**	−0.142	0.887
Aav	−0.121	**−0.928**	0.045	0.021	0.889
I	−0.069	**−0.905**	−0.061	0.070	0.842
NSA	0.030	**0.876**	−0.064	−0.099	0.858
FC	−0.104	−0.008	**−0.417**	0.054	0.447
Index *AgL*	0.084	−0.064	**0.836**	−0.008	0.941
Index *ArL*	−0.017	0.328	**0.801**	−0.026	0.800
ArLs	−0.043	**0.819**	0.252	0.003	0.810
GDAgL	0.307	−0.013	0.026	**0.870**	0.872
SDArL	0.327	−0.233	−0.036	**0.885**	1.000
Index *RP*	**0.790**	−0.142	0.189	0.339	0.866
DRP	**0.701**	0.130	−0.071	0.412	0.775
Index *V*	**0.951**	0.117	−0.009	0.093	0.951
RPav	**−0.831**	−0.025	0.052	−0.019	0.776
ORP	**−0.909**	−0.147	0.056	−0.033	0.889
Index *H*	**0.818**	−0.144	0.158	0.304	0.970
Index *Hs*	**−0.048**	−0.011	0.164	0.070	0.111

Factor 1: Demographic type. This type included 30% of the rural settlements in the high–high cluster. This component consisted of the Index *P*, *DRP*, Index *V*, *RPav*, *ORP* and Index *H* variables. The demographic type comprised settlements that experienced positive changes in population numbers and household number, followed by a higher rural population density. That is why the settlements with the highest increase in rural population (Index *RP* = 125–289) and households number (Index *H* = 165–371) exhibited the highest anthropogenic pressure on the rural area (*DRP* = 166–249 rural population/km^2). Likewise, this component had the highest positive correlation with Index *V* (r = 0.951). In some of the settlements, the values of Index *V* were twice as large as the economically active population in comparison with the older population. On the other hand, this settlement type was inversely proportional to *RPav* and *ORP*, which was proven by their high negative correlations (r = −0.831 and r = −0.909, respectively). The average population age ranged from 39.5 to 47.5 years old. In the settlements with the highest demographic growth, the share of the elderly population was 15%. With this in mind, it could be concluded that the rural areas were determined by positive demographic changes, with high population vitality. Index *V* had a negative correlation with the average population age (*RPav*) and the share of elderly people within the overall rural population (*ORP*).

Factor 2: Agricultural type of specific physical–geographical characteristics. This was the most common settlement type, as it comprises 42% of all rural settlements within the cluster. This type of rural settlement consisted of the *Aav*, *I*, *NSA* and *ArLs* variables. This factor had the highest negative correlations with altitude and inclination angle, whereas its highest positive correlations were with the lithological complex *NSA* and *ArL*. This meant that the changes in the altitude and inclination angle of the terrain were inversely proportional to the presence of the lithological complex *NSA*. The share of the lithological complex *NSA* was calculated from the share of arable land within the overall area of agricultural land. Therefore, this type of rural settlement was characterized by a higher arable land share within the overall area of agricultural land and was naturally predisposed to lower altitudes and shallower inclinations angles, as well as higher shares of the lithological complex *NSA*. The dominance of arable land within the overall area of agricultural land (*ArL* > 90%) was only present in settlements with an *NSA* > 90%. Additionally, these settlements were located at altitudes *Aav* < 100 m and on slightly inclined terrains ($I \leq 2°$). On the other hand, the settlements at higher altitudes (*Aav* > 300 m) and on steeper inclinations (*I* > 80) were characterized by the almost complete absence of the lithological complex *NSA* (*NSA* < 2%).

Factor 3: Agrarian type. This type included 16% of all rural settlements in this cluster. This component consisted of Index *AgL*, Index *ArL*, Z_2 and *FC* variables. This component only had a negative correlation with the share of forest cover, whereas it had positive correlations with all of the other variables. This meant that erosion intensity Z_2 was higher in rural settlements with lower shares of forest cover and with a higher index of agricultural and arable land. Therefore, this type included rural settlements where the intensity of erosion was primarily determined by the deagrarization intensity of agricultural and arable land, as well as forest cover. For instance, these rural areas were characterized by low average shares of forest cover (*FC* = 7%) and the prevalence of settlements with below average forest cover. Therefore, these were the settlements where deagrarization was not expressed, as indicated by the average values of Index *AgL* = 95 and Index *ArL* = 106. Positive changes were more evident in the use of arable land, as half of the rural settlements of this type exhibited an 36% increase in Index *ArL*.

Factor 4: Anthropopression type. This type included 13% of the settlements in this cluster. This component consisted of the *GDAgL* and *SDArL* variables. This component had a highly positive correlation with agrarian densities, meaning that agrarian pressure on agricultural land (*GDAgL* = 286 rural population/100 ha) was followed by agrarian pressure on arable land (*SDArL* = 370 rural population/100 ha).

In the low–low cluster, the correlation values ranged from $r = -0.951$ to $r = 0.998$ (Table 8). The results of the correlation matrix showed that Z_2 had the highest negative correlation with *F* ($r = -0.789$). Likewise, Z_2 had rather high negative correlations with *I* ($r = -0.782$) and *Aav* ($r = -0.725$). The very strong ratios between $Aav = f(I)$, $Aav = f(FC)$ and $I = f(FC)$ indicated that with the increase in altitude, the inclination angle of the terrain also increased, as well as forest cover. At the same time, this meant that Z_2 decreased. *Z2* had a relatively high positive correlation with *NSA* ($r = 0.498$). The results also show that the ratios between *NSA* and *I* and between *NSA* and *Aav* had negative values ($r = -0.552$ and $r = -0.428$, respectively). This further implied that Z_2 was higher on the lithological complex *NSA*, which was exclusively located at lower altitudes and on terrains with smaller inclinations angles within the basin. This conformed with the results of previous research [43]. Additionally, the results showed that the correlations between Z_2 and Index *AgL* and between Z_2 and *ArLs* had positive values ($r = 0.409$ and $r = 0.602$, respectively). With that in mind, it could be concluded that the erosion intensity was primarily affected by the share of arable land within the total area of agricultural land. Along with the deagrarization of agricultural land, the deagrarization of arable land also occurred, since Index *AgL* had a positive correlation with Index *ArL* ($r = 0.685$). *SDArL* was directly linked to *GDAgL*, which was shown by the high correlation level ($r = 0.998$) for $SDArL = f(GDAgL)$. The similar negative correlation coefficient values between *DRP* and *Aav*, *I* and *F* indicated that these physical–geographical factors had an almost identical effect on *DRP*. On the other hand, the results analysis showed that other demographic indicators had a high mutual interdependence, which was why depopulation was directly linked to changes in household number (r = 0.987) and less linked to changes in the average size of households (r = 0.455). There was also a direct connection between *RPav* and *ORP* since there was a high positive correlation (r = 0.936) for $RPav = f(ORP)$. Additionally, with the increase in the average population age and the share of the elderly population, there was a decrease in both the demographic vitality index and the average size of households. These results conformed with the results of previous research.

The order of significance of these ″aria′les was determined by the magnitude of their eigenvalues, as presented in Figure 6. Eigenvalues explain the percentage of variance and the cumulative variance of the principal components. It is evident that the first point at which it is possible to carry out the reduction of the number of factors is between the third and fifth factor. In this study, the first four principal components explained 73.47% of the total variance.

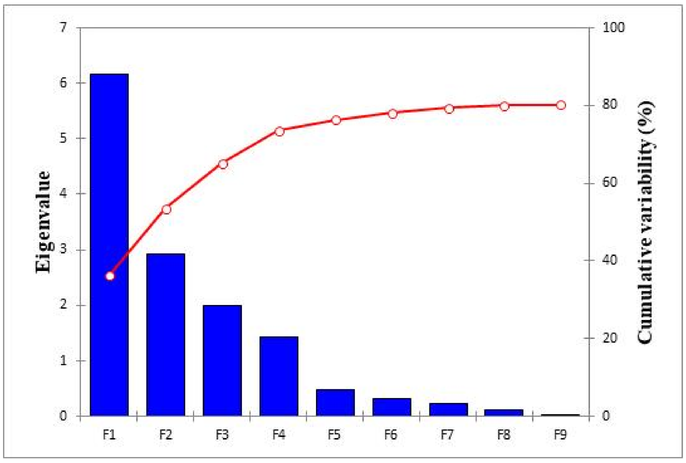

Figure 6. Eigenvalues and cumulative variance of principal components (low–low).

Table 8. Correlation matrix of the principal component analysis [Pearson (n)] for the low–low cluster. Values in bold are different from 0 with a significance level α = 0.05.

	*Z*2	*Aav*	*I*	*NSA*	*FC*	Index *AgL*	Index *ArL*	*ArLs*	*GDAgL*	*SDArL*	Index *RP*	*DRP*	Index *V*	*RPav*	*ORP*	Index *H*	Index *Hs*
*Z*2	**1**																
Aav	**−0.725**	**1**															
I	**−0.782**	**0.821**	**1**														
NSA	**0.498**	**−0.428**	**−0.552**	**1**													
FC	**−0.789**	**0.735**	**0.890**	**−0.361**	**1**												
Index *AgL*	**0.409**	**−0.383**	**−0.474**	**0.179**	**−0.561**	**1**											
Index *ArL*	**0.254**	**−0.250**	**−0.240**	**0.276**	**−0.222**	**0.685**	**1**										
ArLs	**0.602**	**−0.736**	**−0.628**	**0.396**	**−0.515**	**0.471**	**0.652**	**1**									
GDAgL	−0.134	0.170	0.054	0.121	0.157	**−0.249**	**−0.213**	**−0.257**	**1**								
SDArL	−0.145	**0.186**	0.065	0.112	0.167	**−0.253**	**−0.222**	**−0.274**	**0.998**	**1**							
Index *RP*	−0.037	−0.143	−0.057	0.003	−0.026	−0.048	−0.084	−0.055	−0.024	−0.040	**1**						
DRP	**0.353**	**−0.458**	**−0.463**	**0.414**	**−0.445**	**0.271**	0.157	**0.300**	−0.005	−0.047	**0.263**	**1**					
Index *V*	0.095	**−0.368**	**−0.355**	**0.244**	**−0.267**	**0.343**	**0.289**	**0.338**	0.047	0.021	**0.348**	**0.536**	**1**				
RPav	−0.157	**0.409**	**0.389**	**−0.319**	**0.281**	**−0.387**	**−0.411**	**−0.468**	−0.039	−0.016	**−0.364**	**−0.432**	**−0.856**	**1**			
ORP	**−0.174**	**0.436**	**0.415**	**−0.351**	**0.294**	**−0.372**	**−0.348**	**−0.417**	−0.070	−0.054	**−0.303**	**−0.391**	**−0.839**	**0.936**	**1**		
Index *H*	−0.020	−0.168	−0.079	−0.010	−0.061	−0.002	−0.057	−0.022	−0.044	−0.062	**0.987**	**0.311**	**0.381**	**−0.379**	**−0.313**	**1**	
Index *Hs*	0.124	**−0.255**	**−0.311**	**0.367**	**−0.181**	**0.173**	**0.238**	**0.218**	**0.184**	0.158	**0.455**	**0.435**	**0.634**	**−0.741**	**−0.696**	**0.393**	**1**

The data from the PCA were subjected to varimax rotation. After the varimax rotation, four components affecting changes in the intensity of soil erosion were identified (Table 9). The first component explained 25.23% of the soil erosion variance within the dataset. The second and third components explained 47.47% and 60.72% of the soil erosion variance, respectively. The addition of the fourth component increased the model-explained variance to 73.47%. The square cosines of the variables indicated the best-described variables for each principal component.

Table 9. Percentage of variance and cumulative variance after varimax rotation (low–low).

	Factor 1	Factor 2	Factor 3	Factor 4
Variability (%)	25.23	22.24	13.26	12.74
Cumulative (%)	25.23	47.47	60.72	73.47

Based on the obtained results for the factor scores after the varimax rotation (Table 10), the typology of rural settlements was established, according to the dominant variables for changes in soil erosion intensity. There were four types of rural settlements: Factor 1, agricultural type of specific physical–geographic characteristics; Factor 2, demographic–agrarian type; Factor 3, anthropopression type; and Factor 4, population type. The order of significance of the basic indicators in the low–low cluster indicated that changes in agricultural land use and soil erosion were exclusively the result of the common effects of the specific physical–geographical indicators.

Factor 1: Agricultural type of specific physical–geographic characteristics. This type was the most common and included 52% of the rural settlements in this cluster. This component consisted of the Z_2, *Aav*, *I*, *NSA*, *FC*, Index *AgL*, *ArLs* and *DRP* variables. Based on the variable values for this type, it could be concluded that the erosion intensity was primarily affected by physical–geographical conditions (i.e., the *Aav*, *I*, *F* and *NSA* indices). This component had positive correlations with Index *AgL*, *ArL* and *DRP*, which meant that the interdependence of these variables also affected soil erosion intensity. This was why the erosion intensity was higher in places with a lower deagrarization intensity of agricultural land, whereas the share of arable land within the area of agricultural land was higher, along with the pressure of the rural population in the settlements. This correlation was best illustrated by the following example. The lowest erosion intensity (Z_2 = 0.133) was characteristic of rural settlements located in mountainous areas at the edge of the Velika Morava River Basin. These rural settlements were at an average altitude *Aav* = 630 m, with an average terrain inclination angle *I* = 16°. Forest cover occupied 80% of the settlement area and the share of the lithological complex *NSA* was 3%. In rural areas with these kinds of natural conditions, there was an intense deagrarization process with a 64% reduction in agricultural land.

Factor 2: Demographic–agrarian type. This type of rural settlement consisted of the Index *ArL*, Index *V*, *RPav*, *ORP* and Index *Hs* variables. The demographic–agrarian type comprised 36% of the rural settlements in this cluster. There was a high negative correlation between *RPav* and *ORP* and positive correlations between Index *V*, Index *Hs* and Index *ArL*. The fall in the average size of households was accompanied by lower demographic vitality and a higher average age of the population and a higher share of elderly people. The ratios between the demographic variables conformed with the deagrarization intensity of arable land. By the same token, the deagrarization of arable land was higher in settlements of this type. Generally speaking, negative demographic tendencies were a main feature of most rural settlements of this type. Within the analyzed period, there was a decrease in the average household size (Index *Hs* = 62). Additionally, the average population age was *RPav* = 50.5 years and 46% of the settlements had a population that was older than the average. A third of the rural population consisted of people older than 65 years of age and the average vitality index demonstrated the dominance of the older population in comparison to the economically active population.

Table 10. Results after varimax rotation (low–low). Rotation method: varimax with Kaiser normalization. Bold values indicate correlated variables included in the *PCs* > 0.40.

Variable	Factor 1	Factor 2	Factor 3	Factor 4	Communality
Z_2	**0.888**	−0.007	–0.084	–0.047	0.798
Aav	**−0.818**	−0.236	0.134	−0.106	0.755
I	**−0.935**	−0.208	−0.008	−0.037	0.918
NSA	**0.508**	0.271	0.157	−0.048	0.359
FC	**−0.869**	−0.106	0.115	−0.028	0.780
Index *AgL*	**0.418**	0.395	−0.313	−0.190	0.465
Index *ArL*	0.235	**0.490**	−0.313	−0.294	0.480
ArLs	**0.614**	0.396	−0.293	−0.193	0.657
GDAgL	−0.063	0.074	**0.969**	−0.040	0.950
SDArL	−0.076	0.053	**0.964**	−0.055	0.941
Index *RP*	−0.011	0.226	−0.028	**0.943**	0.942
DRP	**0.432**	0.362	0.021	0.245	0.378
Index *V*	0.172	**0.816**	0.021	0.230	0.748
RPav	−0.189	**−0.946**	0.001	−0.178	0.962
ORP	−0.221	**−0.881**	−0.050	−0.142	0.847
Index *H*	0.015	0.236	−0.059	**0.915**	0.897
Index *Hs*	0.159	**0.680**	0.182	0.304	0.613

Factor 3: Anthropopression type. Out of the total number of rural settlements in this cluster, only 4% belonged to this type. The agrarian pressure on the land variable characterized these rural settlements, as shown by the high positive correlation between *GDAgL* and *SDArL*. This was a consequence of the extreme deagrarization of agricultural and arable land in some of the settlements of this type, which was an indicator of the quite small area of agricultural land and the underdeveloped agricultural production. Still, some settlements were determined by these variables and exerted a real agrarian pressure on the land due to the sustainability of both the rural population and the area of agricultural land.

Factor 4: Population type. This type of rural settlement consisted of the Index *P* and Index *H* variables. The population type comprised 9% of the rural settlements in this cluster. The high positive correlations between these variables categorized the rural settlements according to depopulation intensity and the change in household numbers within the cluster. This meant that depopulation intensity was lower in places where the household number decrease was smaller. The most prominent rural area in this cluster was a part of the peri-urban belt around Kragujevac. A positive demographic trend was followed by a high multifold increase in the population and household numbers (Index *RP* = 358, Index *H* = 379, respectively). Additionally, the main feature of these settlements was the intense and balanced deagrarization of both agricultural and arable land (Index *AgL* = 33 and Index *ArL* = 33, respectively).

4. Discussion

The clear differentiation of the study area along the north–south direction undoubtedly indicated the dynamic interactions between natural conditions, demographic and settlement indicators and changes in land use. We observed the broader context of the historical, political and socio–economic patterns during the analyzed period. The historical conditions of agricultural development during the 1960s were determined by the appearance of agricultural cooperatives, which enabled the application of modern technologies via cooperative relationships and contributed to the increase in agricultural production and productivity [118]. However, after that period, the further evolution of rural settlements was directed towards the planned centralized industrialization of socialist Serbia. Economic phenomena and processes were founded on the paradigms of classical industrialization and Marxism, specifically industrialization and the marginalization of agriculture [118]. The politics of this accelerated industrialization were motivated by the large agrarian population density and the differences in economic productivity between the agriculture and non-agricultural fields of human activity [119,120]. Industry hired a lot of workers, causing dramatic decreases in the rural population and agricultural production. These were the most intense during the following period of 1961–1981, when the urban population increased by up to 50% in certain cities (e.g., Aranđelovac, Kragujevac and Topola) [121]. These migration movements followed the same direction for decades (south–north and village–town/city). The tendencies toward the deepening disparity between the north and the south and between the rural and urban [122] were evident in this area.

Structural changes in agriculture as a whole, but primarily those in agricultural land use brought about during the 1990s, were the result of the socio–economic conditions in that period, which was characterized by political instability, social system crisis, sanctions, hyper-inflation and war [123]. The overall reduction in the prices of agricultural products and the increase in market uncertainty became spontaneously (without a pre-planned restructure) oriented towards financially less demanding agricultural production. This was also reflected in the structural changes in arable land [103], which led to the phenomena of excessive land fragmentation and small average farm sizes that were common in former socialist republics [42,85,124,125]. Individual production could not provide commercial profits, so survival relied on agricultural activities alone [42].

The second transition phase ensued after the political changes at the beginning of the 21st century. The main characteristic of this period in post-socialist countries was the reduction in total agricultural production, as well as changes in the share of market-oriented agriculture [113,115,126]. These changes in Serbia mostly caused reductions in the land use categories that were the most intensely cultivated [103].

Urbanization flows were highlighted in the northern parts of the Velika Morava River Basin, where two of the identified clusters (i.e., the high–high and low–high clusters) were a part of a medium sized peri-urban belt, including Smederevo, Požarevac, Smederevska Palanka, Mladenovac and Aranđelovac [127]. These were sustainable rural areas and their development and dynamics were directly related to the urban centers in terms of their production and socio–economic context. Similarly, settlements located to the south of the cluster were in agricultural areas [128]. The relatively high soil erosion intensity in the northern part of the basin and the small changes in erosion intensity over the years were indicators of this agricultural sustainability. Yet, in the low–high cluster, there were huge losses in agricultural land. In this part of the basin, more than any other, there was a rural–urban conflict. This phenomenon was accompanied by dynamic changes in land use [129]. The intensification of migration flows due to the need to find work was the cause of the decrease in the agricultural labor force and as a result, there was also a reduction in intense labor within agricultural production [123]. The higher degree of mechanization partly compensated for the active participation of the labor force in agriculture and helped to increase the productivity of agricultural production. On the other hand, the balance of natural conditions explained the statistical significance of anthropogenic factors as the basic determinants of erosion intensity.

Unlike the northern part of the basin, where the rural–urban conflicts lean toward sustaining erosion intensity, this was not the case in the southern part of the basin (i.e., the low–low cluster). These settlements were oriented toward local agricultural production, whereas the peripheral parts of the cluster included economically weaker rural areas [128]. The sociohistorical dynamics during the study period harmed the demographic, settlement and agrarian features of the area. Here, the urbanization process did not have a positive effect. Regardless of the favorable geographic positions of certain rural settlements, most of them were spatially located in hilly and mountainous parts of the basin, where the different natural conditions (i.e., higher altitudes) affected the flows of population migrations and the intensification of the deagrarization process. The other demographic features also highlighted the differences between the high–high and low–low clusters in terms of the spatial distribution of the demographic aging process and vitality index (Figure 7A,B).

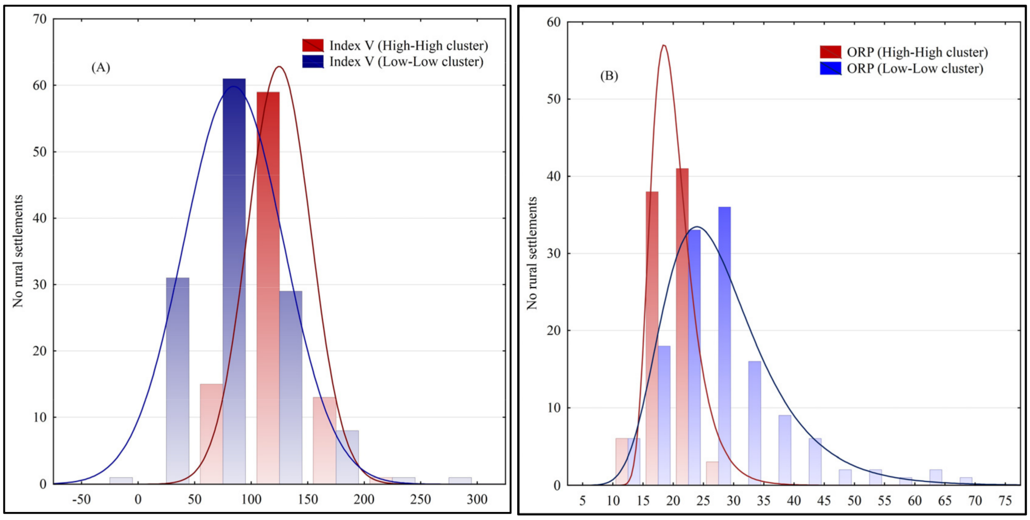

Figure 7. Histogram of demographic variables in rural settlements: (**A**) vitality index (Index *V*) and (**B**) old rural population (*ORP*) according to the high–high cluster and the low–low cluster.

The process of agricultural land abandonment has occurred the most intensively in post-socialist Central and Eastern European countries and European Russia, which began in the 1950s and was mainly due to technological, political and demographic processes [130,131]. The significant reduction in soil erosion identified in the Czech Republic (8.5%) [132], in some Russian river basins (2.0–3.8 fold) [130,133], in the Republic of Srpska (20%) [134] and in Poland (75%) [24]. A similar tendency of soil erosion intensity reduction was recorded in Serbian river basins: the Trgoviški Timok River Basin (59%), the Temštica River Basin (30%), the Nišava River Basin (30%) [43], the Ljig River Basin (43%) [93], the Vranjskobanjska River Basin (83%), the Rasina River Basin (33%) and the Jablanica River Basin (21%) [93,135,136].

Apart from its scientific and practical importance, the study also has some limitations.

(1) This study does not include a temporal component within the 1971–2011 period due to the lack of data on population and agricultural land for ten-year census periods at the settlement level. In this context, it was not possible to determine the soil erosion intensity and identify the key drivers for shorter time periods. Due to the limitations of the EPM model, the study was also unable to determine the intensity of soil erosion at different intra-annual levels.

(2) The spatial aspect of the study did not include smaller regional units within rural settlements, where the zones most at risk of soil erosion are found.

(3) Previous research in Serbia has shown that erosion control measures have an impact on reducing soil erosion [137]. However, this research did not consider the effect of anti-erosion studies.

5. Conclusions

In this study, we found that land use changes had direct effects on soil erosion intensity. The use of spatial statistical techniques and analyses have shown that changes were more pronounced in the southern part of the basin (i.e., the low–low cluster), while a slower decrease of erosion intensity was observed in the northern part of the basin in areas surrounding the peri-urban belts (i.e., the high-high).

As the Velika Morava River Basin is significant for maintaining national cohesion on different levels, this research could further support agricultural development and the development of the rural areas as a whole. Becoming familiar with the dynamics of changes in agricultural land use and soil erosion intensity could enable appropriate planning for land uses and define the economic adequacy of certain types of agricultural production. Likewise, the results of this study could form a basis for projecting and constructing facilities that require larger geographical spaces and an understanding of the causal relationships between physical–geographical, demographic and agrarian–geographical factors (e.g., roads, urban settlements, industrial facilities, melioration systems, etc.). The observed disparities between the northern and southern parts of the basin could be used to identify the main advantages and drawbacks of each area and contribute to obtaining spatial–demographic balance among the settlement network.

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