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A Historical Overview of Methods for the Estimation of Erosion Processes on the Territory of the Republic of Serbia

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Abstract: Erosion is a significant environmental challenge in Serbia, shaped by natural and human factors. Pronounced relief, fragile geological substrate, a developed hydrographic network, and a climate characterized by an uneven distribution of precipitation throughout the year make this area prone to activating erosion processes and flash floods whenever there is a significant disruption in ecological balance, whether due to the removal of vegetation cover or inadequate land use. Researchers have recorded approximately 11,500 torrents in Serbia, most of which were activated during the 19th century, a period of significant social and political change, as well as intensive deforestation and the irrational exploitation of natural resources. By the mid-19th century, the effects of land degradation were impossible to ignore. As the adequate assessment of soil erosion intensity is the initial step in developing a prevention and protection strategy and the type and scope of anti-erosion works and measures, this article presents the path that the anti-erosion field in Serbia has taken from the initial observations of erosion processes through the first attempts to create the Barren Land Cadastre and Torrent Cadastre to the creation of the Erosion Potential Method (EPM) and its modification by Dr. Lazarević that resulted in the creation of the first Erosion Map of SR Serbia in 1971 (published in 1983). In 2020, a new Erosion Map of Serbia was created with the application of Geographic Information System (GIS) technologies and based on the original method by Professor Slobodan Gavrilović—the EPM—without the modifications introduced by Lazarević. We compared the 1983 and 2020 erosion maps in a GIS environment, where the change in soil erosion categories was analyzed using a confusion matrix. The updated erosion maps mirror the shift in methodology from a traditional approach (Lazarević's modification) to the modern GIS-based method (Gavrilović's original EPM) and reflect technological improvements and changes in land use, conservation practices, and environmental awareness.

Keywords: soil erosion; water erosion; environmental degradation; land use changes; erosion potential method; Gavrilović's erosion calculation; mapping; confusion matrix; GIS

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1. Introduction

Soil erosion is one of the most widespread and severe forms of degradation, directly affecting the disruption of natural soil functions [1,2]. It reduces agricultural productivity, degrades ecosystem functions, decreases biodiversity, and increases hydrogeological risks that result in infrastructure damage, loss of life, and the displacement of human populations [3]. The direct consequences of erosion processes are reflected in reducing organic matter content, infiltration capacity, and production potential [4–7]. Indirect consequences include lowering groundwater levels [4,8], sediment deposition (in watercourses and lower parts of catchments) [5,6,9,10], increased CO_2 emissions, impacts on climate change [6,9,11–14], and the triggering of flash floods and infrastructure damage [15,16]. As soil quality refers to soil's capacity to provide and sustain a range of ecosystem services and functions of interest to humans and to maintain ecosystem health, soil erosion presents a significant negative impact [13,14]. The type and intensity of erosion are determined by a combination of the area's biophysical characteristics and anthropogenic activities [1,2].

Scientists have recently begun considering soil a non-renewable resource, as its loss and degradation cannot be compensated for during a human lifetime. All current research shows that soil erosion rates are much higher than the rate of soil's formation [1,2]. Proper soil management aims to maintain erosion intensity at or below the natural rate of new soil formation [17].

The Food and Agriculture Organization of the United Nations (FAO) defines permissible soil loss as any average cumulative rate of soil erosion that does not lead to a significant degradation of soil functions and the ecosystem services the soil provides. The values of permissible soil loss are determined by soil and climatic characteristics (the same factors that influence the rate of soil formation) [11].

It is estimated that in Europe, soil formation rates probably range from ca. 0.3 to 1.4 $t \cdot ha^{-1} \cdot year^{-1}$ [18]. The European Environment Agency (EEA) has set limiting values ranging from 1 $t \cdot ha^{-1} \cdot year^{-1}$ for shallow sandy soils to 5 $t \cdot ha^{-1} \cdot year^{-1}$ for deeper, well-developed soils [11]. In Serbia, the average rate of soil formation on slopes is 0.1 mm per year (approximately 1.3 $t \cdot ha^{-1} \cdot year^{-1}$). Geological (natural) erosion is wearing away soil at a rate lower than 0.1 mm per year. The average annual production of erosive material amounts to 6.34 $t \cdot ha^{-1} \cdot year^{-1}$, which is 4.88 times more than that of natural (geological) erosion [19,20].

According to the Global Assessment of Soil Degradation (GLASOD), the total global area of severely degraded land amounts to $305 \cdot 10^6$ hectares, of which $224 \cdot 10^6$ hectares results from water erosion [21]. Economic activities contribute to active changes in land use on 60% of the terrestrial surface [22], while 33% of the land is already degraded, and over 90% could become degraded by 2050. In some areas, the productivity of eroded land is irrecoverable, even with the extensive use of fertilizers and other fossil energy inputs. According to some studies, $10 \cdot 10^6$ hectares of arable land is abandoned yearly due to soil erosion [23–25].

Currently, the erosion processes of various destruction categories are present on 86.4% of Serbia's territory, with severe and excessive erosion processes affecting 35% [26–29]. The mean annual production of eroded material amounts to 37.25 million m^3, or 487.85 $m^3 \cdot km^{-2}$, 4.88 times higher than normal (geological) erosion [30,31].

As the adequate assessment of soil erosion intensity is the initial step in developing a prevention and protection strategy and the type and scope of anti-erosion works and measures, this article aims to present the long journey that the anti-erosion field in Serbia has taken from the observational recording of erosion processes to the application of the most modern methods and models for the detection and categorization of these processes. This article will present the emergence of awareness about the dangers and intensity of erosion processes, along with the chronology of efforts to document them, from the earliest investigative methods to the application of modern techniques. The production of the Republic of Serbia's first erosion map began in 1966 and was completed in 1983. The basis for creating the first erosion map was the original version by Prof. Slobodan Gavrilović, with the application of modifications proposed by Prof. Radenko Lazarević. The method was based on the Method for the Quantitative Classification of Erosion (MQCE), formally developed in 1954. During his research, Gavrilović discovered the possibility of further developing the MQCE, which was used to define erosion's intensity. The extensions of this method were directed towards quantifying erosion processes by assessing the sediment transported downstream that reaches control profiles [32].

Most of the global soil erosion modeling applications were carried out using the Universal Soil Loss Equation (USLE) or its revised versions (e.g., RUSLE). Only a few global or continental studies applied models other than those belonging to the USLE type, such as Water Erosion Prediction Project (WEPP), WaTEM/SEDEM, Rangeland Hydrology and Erosion Model (RHEM), and Pan-European Soil Erosion Risk Assessment (PESERA) [33]. Of all semi-quantitative models (The Pacific Southwest Inter-Agency Committee (PSIAC), The Modified Pacific Southwest Inter-Agency Committee (MPSIAC), the Factorial Scoring Model (FSM), the Vegetation-Surface Material-Drainage Density Model (VSD), Erosion hazard Units (EHU), CORINE erosion risk maps, the Coleman & Scatena Scoring Model (CSSM), the Fleming & Kadhimi Scoring Model (FKSM), the Wallingford Scoring Model (WSM), the Gavrilović Model (Erosion Potential Method—EPM), and Revised Universal Soil Loss Equation (RUSLE)), the EPM is the most quantitative because it uses descriptive evaluation for three parameters only: soil erodibility, soil protection, and the extent of erosion in the catchment. All other parameters are quantitative catchment descriptors. In comparison with some other procedures, the Gavrilović method does not explore the physics of erosion processes and is therefore advantageous for areas where minimal data are available or where there is a lack of previous erosion research. As such, this method can provide not only the amount of sediment production and sediment transport but also the erosion intensity as a preliminary result and indications or areas of potential erosion threats [32].

Today, this method encompasses erosion mapping, sediment quantity estimation, and torrent classification, and it has been extensively applied since 1968 for solving erosion and torrent-related problems in the Balkan countries [32]. The EPM has proven to be the most suitable method for the mountainous areas of the Balkans and for countries lacking existing databases (which, for example, represents a limitation for the Universal Soil Loss Equation (USLE) in (both hilly and valley) agricultural areas of the Balkans [34]).

The EPM is currently being applied worldwide, for example, in Croatia, Serbia, Slovenia, Italy, the Republic of Macedonia, Bosnia and Herzegovina, Montenegro, Iran, and Chile [32–43].

In regard to the traditional approach, where field mapping is used, the modern approach uses current achievements in the application of Geographic Information System (GIS) technologies. In order to perform a comparative analysis between the traditional and modern approaches, the available global and regional data were used to calculate soil losses due to water erosion, and the 1983 Erosion Map was digitized. The comparison of the traditional and modern approaches was performed in a GIS environment, where the change in the soil erosion category was analyzed by applying a confusion matrix. The confusion matrix compares the relationship between the traditional (1983 Erosion Map) and modern approaches (current situation) in terms of categories.

2. Materials and Methods

Serbia is located in the central part of the Balkan Peninsula, covering an area of 88,361 km^2. Its territory includes the vast plains of Vojvodina in the north and a hilly, mountainous area in the south, with the rivers Danube and Sava forming a natural boundary between these two regions [44] (Figure 1).

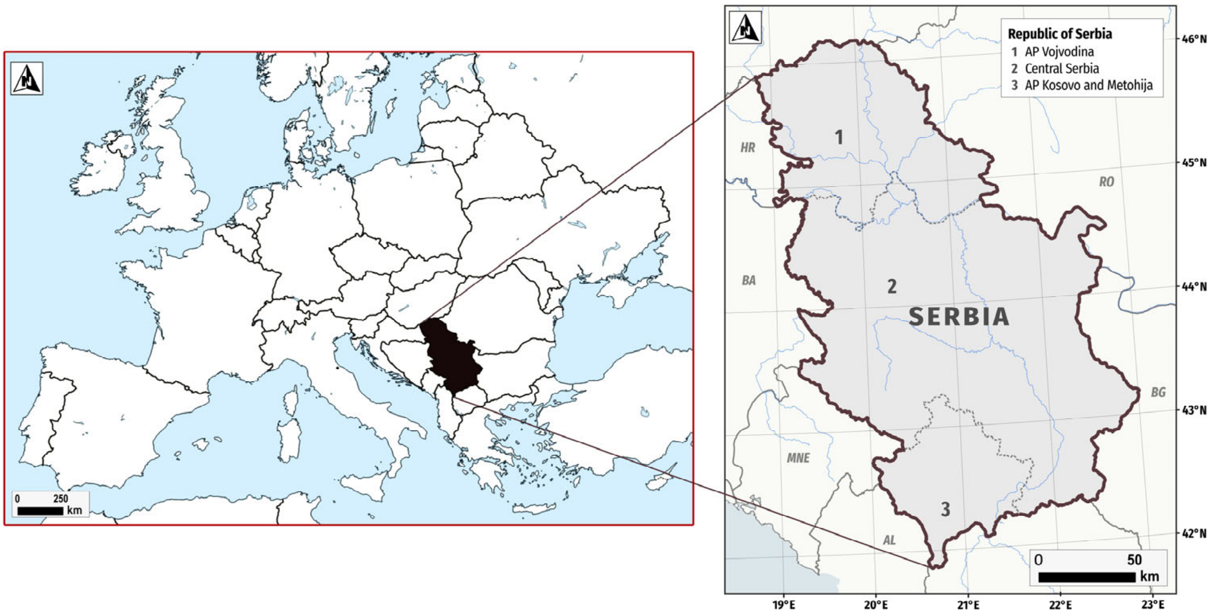

Figure 1. The position and topography of the Republic of Serbia.

Erosion is a significant environmental challenge in Serbia, shaped by natural and human factors. Pronounced relief, fragile geological substrate, a developed hydrographic network, and a climate characterized by an uneven distribution of precipitation throughout the year make this area prone to activating erosion processes and flash floods whenever there is a significant disruption in ecological balance, whether due to the removal of vegetation cover or inadequate land use [44–47]. The most widespread soils in Serbia are Dystrict Cambisol (2607.000 ha), Chernozem (1200.000 ha), Calcomelanosol/Calcocambysol (910.000 ha), Vertisol (680.000 ha), Fluvisol and humogley (675.000 ha), Pseudogley (500.000 ha), Eutric Cambisol (437.000 ha), and Rankers (324.000 ha), the most erodible of which are Pseudogley, with high water retention and poor drainage, and Rankers, prone to erosion on steep slopes [48]. The country's diverse geography and history have created a complex landscape where erosion processes are activated by a combination of natural characteristics and anthropogenic activities. Understanding these processes is essential for developing effective strategies to manage erosion and protect Serbia's natural resources [19].

Due to specific historical circumstances, including the final fall of the Serbian medieval state under Ottoman rule in 1459 and centuries of stagnation marked by uprisings and wars, it is possible to obtain a clearer picture of soil conditions in Serbia only from the mid-19th century, following the restoration of Serbian statehood. Earlier periods can only be reconstructed based on the limited number of preserved documents from the medieval era and accounts of Western travelers [47].

Evidence of land degradation due to deforestation—associated with mining activities in the mid-13th century—can be found in certain provisions of Emperor Dušan's Code (1349), as well as on the barren areas formed in the Kopaonik region and other serpentine and limestone massifs [47,49,50]. Accounts by medieval travelers describe Serbia as a densely forested country with minimal agricultural activity. This condition seemingly persisted throughout Ottoman rule. All accounts characterize Serbia as an expanse of untouched forest, with Alphonse de Lamartine (1790–1869) comparing Serbian forests to those of North America, synonymous at the time with wild and untamed nature [47,51–55]. However, significant ecological disruptions began to occur after Serbia's liberation from Ottoman rule. The 19th century brought rapid changes, including deforestation and soil degradation. The destructive effects of erosion became evident during the late 19th century, as flash floods caused frequent and severe damage [47,54,56,57]. These events forced the emerging Serbian state to recognize the importance of addressing erosion and land degradation. The first steps included developing legal regulations to protect forests and establishing trained forestry experts. By the early 20th century, Serbia began implementing organized erosion control measures, laying the groundwork for a systematic approach to managing this critical environmental issue.

To develop an effective anti-erosion and flood control strategy, it is essential to understand the magnitude of the issues and their potential destructive impacts. Establishing methods for documenting erosion processes has become a crucial aspect of anti-erosion initiatives. In presenting this development, this study utilized a multi-disciplinary approach that combined collecting and systematizing historical data, forming an informational basis with modern geographic information technologies. A comparative analysis was conducted to evaluate the spatial and quantitative parameters of the first Erosion Map of Serbia (1983), created using Lazarević's modified EPM, and the Erosion Map of the Republic of Serbia (2020), developed using the original EPM and the implementation of Geographic Information System (GIS) technologies, enabling the digital representation of real spatial environments.

2.1. The Causes and Consequences of Erosion Processes on the Territory of the Republic of Serbia

In Serbia, researchers have recorded approximately 11,500 torrents on basins ranging from a few hectares to several hundred square kilometers. Between 1950 and 2018, flash floods claimed over 130 human lives and caused material damage exceeding EUR 12 billion [58]. The main torrent areas in Serbia are the basins of the West Morava, Ibar, Lim, South Morava, Toplica, Nišava, and Timok rivers and, to a lesser extent, the Kolubara and Drina rivers [44,45]. Most of these torrents were activated during the 19th century, a period of significant social and political change, as well as intensive deforestation and the irrational exploitation of natural resources. The isolated and largely sedentary Serbian population believed that Serbia's forests were inexhaustible, continuing to exploit them freely and without restriction, as during the Ottoman occupation, even though the area had become much more densely populated. From the end of the First Serbian Uprising (1804) to the end of the 19th century, Serbia's population increased by over six times through immigration and high natural growth rates [47,59]. Between 1820 and 1910, Serbia's population growth rate was the highest in the Balkans, averaging 1.55% annually [47,55,59]. This demographic pressure necessitated land clearance for agricultural production and, later, for trade and the beginning of industrial development in the second half of the 19th century [47,50,59].

In the 19th century, agriculture began to take precedence over livestock farming, which had dominated for centuries, a trend that continued through the 20th century. In 1867, arable land and meadows occupied 15% of Serbia's land area, while a century later, about 62% of Serbia's territory was used for agriculture [54,55]. People initially cultivated land in non-forested areas, but the exhaustion of these lands by the first half of the 19th century prompted them to clear forests even in areas unsuitable for agriculture [47,60].

Agricultural production methods were primitive. Farmers did not practice crop rotation or fallowing. The earliest record of fallowing dates back to 1897 and shows that farmers used it on only 3.3% of arable land. As soon as farmers noticed reduced soil fertility, they would clear and burn a nearby forest area, converting it to arable land [47,55].

Serbia's autonomy within the Ottoman Empire in 1830 and the official abolition of feudalism in 1833 paved the way for legal reforms that enabled private land ownership and dismantled the Ottoman economic system based on the timar (Ottoman feudal land system, where a spahi (horseman) received land from the Sultan as a reward for military service, enjoying its income and administering it locally without owning it, as all land belonged to the state). However, private ownership was recognized only for arable land, while forests remained public property. Ownership rights and forest management became significant political issues no one wanted to address. Turbulent political events, state administrative instability, and the entire governance system in the second half of the 19th century prevented the enforcement of even the laws then in place. Within fifty years, four rulers, two regencies, three constitutional changes, several coups, one rebellion, and three wars affected the country [47,54].

By the mid-19th century, the effects of land degradation were impossible to ignore [61]. Josif Pančić (1814–1888) was the first to highlight severe ecological imbalances, particularly on the serpentine bases of bare steep slopes, and the dangers of flash floods threatening such areas [45,47,54]. Erosion was determined in all deforested areas of Serbia. Mountain regions became torrent-prone, and residents could expect flash floods every spring and autumn. Large rivers also began to flood more frequently due to the influence of numerous activated torrents. Notable floods occurred in 1840, 1864, 1869, 1871, 1874, and 1896 [47,54,56,57].

2.2. The First Attempts to Officially Record the Degree of Land Degradation in Serbia

Due to the alarming state of forests in Serbia, the Ministry of Finance decided in 1854 to send scholarship students abroad for education [62,63]. In France and other Alpine countries, the period from the late 18th century marked the establishment of the foundations of the erosion control and torrent management profession. Faced with devastating torrent floods, the French government encouraged scientific research into torrent phenomena and their causes, history, immediate and delayed consequences, and possible protective measures [64]. The results included works such as "Essay on the Theory of Torrents and Rivers" (Essai sur la théorie des torrents et des rivières, 1797) by Jean Antoine Fabre (1749–1837) and "Study of Torrents in the High Alps" (Étude sur les torrents des hautes-Alpes, 1841) by Alexandre Surell (1813–1887) [64,65]. By 1860, the "Law on Mountain Reforestation" was enacted, enabling state institutions to identify, map, and designate degraded areas as priorities for restoration [64]. One of the initiatives by Serbian scholarship students, through which they sought to implement good practices from the European countries where they studied, resulted in an 1872 request from the Economic Department of the Ministry of Finance to all local authorities to compile a list of barren areas that needed to be enclosed, preserved, and reforested [54,62]. The creation of the Barren Land Cadastre is considered the first attempt to record erosion processes in Serbia. Although this cadastre was not yet completed by 1901, the Forestry Department of the Ministry of National Economy, based on the work conducted up to that point, prohibited using over 30,000 hectares of barren land and thinned forests [62].

The Forest Law of 1929 stipulated that the Barren Land Cadastre be completed by 1940. The team completed most of the fieldwork by the deadline, but all collected materials were lost during World War II [62].

In the post-war period, anti-erosion efforts focused on managing torrents that disrupted rail and road traffic, shifting attention from the Barren Land Cadastre to creating the torrent cadastre. Work on this cadastre began in 1950, with the forestry service and the Institute for Water Management of the People's Republic of Serbia jointly conducting the survey [28]. When the first survey results were published (1955), the process was still ongoing, with plans for annual, successive updates. Table 1 shows the results of the organized data collected up to that point.

The preliminary results showed that erosion affected nearly 67% of forests and forest lands and 33% of agricultural land, rendering approximately 10,000 hectares unfit for agricultural production each year due to its destructive effects [44].

Table 1. Distribution of torrent streams by basin, according to 1955 torrent cadastre.

River Basin	Number of Torrential Streams	Total Length of Main Streams (km)	Total Area Under Erosion (km^2)
Drina	120	307	830
Lim	111	309	487
W. Morava	61	196	316
Skrapež	19	100	139
Đetinja	19	73	156
Ibar	81	302	475
S. Morava	220	1.55	2
Toplica	156	899	175
Kolubara	80	200	350
Timok	72	250	920
Total	939	4.186	5.848

Source: [46].

Weaknesses of Initial Torrent Cadastres

In 1955, as the awareness of the scale and severity of erosion processes in PR Serbia grew, the Academic Council of the FPR Yugoslavia initiated the "First Conference on the Scientific Basis of Erosion Control" in Belgrade, with a strong focus on creating torrent cadastres [66,67].

Following this, experts developed numerous torrent cadastres across the FPR and later SFR Yugoslavia, covering entire basins and even some republics (e.g., SR Montenegro). However, these cadastres exhibited significant shortcomings due to heterogeneity, subjectivity among field teams, and the varying interests of the organizations involved. Scientifically, a crucial flaw lay in the imprecise definition of what constituted a torrent and the insufficiently objective criteria for its classification, which allowed for differing interpretations, leading to unreliable results [66].

Experts established an inter-republic commission to clarify the definition of a torrent. Since many streams lacked flow monitoring data to determine water regimes, researchers identified torrents primarily through local population surveys and assessments of erosion status within catchments and streambeds. The inter-republic commission concluded that a torrent catchment must be affected by erosion processes of at least Category I, II, or, less frequently, III intensity, as per Prof. Gavrilović's classification [27]. If a catchment was subject to severe erosion, it was assumed to have a torrent regime, regardless of streambed conditions or sediment amounts. Ultimately, the commission determined that previous failures in forming reliable torrent cadastres stemmed from the lack of foundational data to provide the basic parameters for their creation. Thus, they agreed that developing an erosion map was a prerequisite for producing a representative torrent cadastre [66].

Additionally, they concluded that the erosion map would have invaluable professional significance, serving as a primary resource for the future planning and construction of various water management, hydroelectric, and land improvement systems, as well as infrastructure projects like roads, urban areas, industrial facilities, and more [68,69].

2.3. The Creation of the First Erosion Map of the Socialist Republic of Serbia (1966–1971)

In 1966, the Institute for Forestry and Wood Industry of SR Serbia [70,71] began creating the first Erosion Map of the Republic of Serbia, completing it in the spring of 1971.

The Department of Erosion and Reclamation was established within the institute a year before researching fundamental issues in erosion and participating in the work on the map [72]. They conducted field mapping using topographic maps at a scale of 1:100,000, processing the data on maps at a scale of 1:50,000, and presented the final version in 1971 on a map with a scale of 1:200,000. A single field team completed the four-year fieldwork to minimize subjective factors and potential errors [73]. Over the following decade and additional field research, they modified the map, and the Institute for Forestry and Wood Industry in Belgrade published it in 1983.

2.3.1. The Erosion Potential Method

Researchers used two methods for mapping erosion phenomena: qualitative and quantitative methods. While the first group produced maps for entire countries or parts of them, including the USA, USSR, Bulgaria, Hungary, Czechoslovakia, and others, the second group, based on dimensioned parameters, was less commonly used and mainly applied to smaller areas [22]. However, the advantage of quantitative methods is evident as they display both the quality of the phenomenon and the amount of soil loss per unit area per year. Therefore, researchers created the first Erosion Map of SR Serbia using the quantitative Erosion Potential Method (EPM), also known as the Gavrilović method [74]

This method resulted from research in 1954 under Professor Slobodan Gavrilović at the "Jaroslav Černi" Institute for Water Management [74]. Developed for application across the entire territory of the SFR Yugoslavia, the method had to accommodate all climatic variations in the area [27,36]. Thus, sample catchments were established in several regions of Yugoslavia, differing by parameters such as climate, geology, soil, terrain, and visible erosion processes [75]. In addition to erosion, researchers at hydrometric profiles in these sample catchments observed water runoff and sediment transport. After years of measurements on torrential streams of the Southern, Western, and Great Morava rivers and the Ibar, Timok, and Vardar rivers, erosion sediment characteristics were determined [27,75]. Simultaneously, researchers of the "Jaroslav Černi" Institute developed original experimental equipment to help them study erosion intensity under controlled laboratory conditions. They conducted experiments on different soil types, "bombarded" with rain of varying intensities and drop sizes and under different temperatures [75]. Simultaneously, researchers of the Department of Erosion and Reclamation laboratory at the Faculty of Forestry tested erosion intensity on undisturbed samples [44,74].

These field and laboratory studies enabled the creation of the EPM, which quickly became a standard method and tool for all engineering challenges related to erosion and torrents, including preparing technical documentation, water management foundations, and studies [35].

The initial version of the method included the following modules:

- Quantitative erosion classification (1954);
- Quantitative sediment regime (1955);
- Torrent classification (1956);
- Optimization of methods for calculating the volume of anti-erosion works (1958) [10].
- The method was further refined with new modules:
- EPM Phase I (1966);
- EPM Phase II (1968);
- EPM Phase III (1986);
- Erosion area identification (1998);
- Method for active flood control on unmanaged watercourses (1998);
- Development of information and GIS procedures and applications for the EPM (from 1985 to the present) [36,75].

Since erosion is a spatial phenomenon, it is represented on a map according to a classification based on an analytically calculated erosion coefficient (Z), which depends not on climatic characteristics but on the characteristics of the soil, vegetation cover, terrain, and the visibility of erosion processes. The erosion coefficient (Z) is obtained from the following expression [27,36]:

$$Z = Y \cdot X \cdot a \cdot \left(\varphi + \sqrt{I_{mean}} \right) \quad (1)$$

Z—erosion coefficient.
Y—soil erodibility coefficient (soil resistance to erosion).
X·a—catchment area management coefficient.
φ—numerical equivalent of visible and clearly expressed erosion processes.
I_{mean}—mean slope of the investigated catchment area [m/m].

$$W_{year} = T \cdot H_{year} \cdot \pi \cdot \sqrt{Z^3} \cdot A \quad (2)$$

W_{year}—total production of erosion material in the catchment area [$m^3 \cdot year^{-1}$].
T—temperature coefficient of the area.
H_{year}—mean annual precipitation [mm].
π—Ludolph's number (Archimedes' constant)—3.14159.
Z—erosion coefficient.
A—catchment area [km^2].

Prof. Gavrilović categorized erosion processes according to the erosion coefficient Z. The values typically range from 0.1 to 1.5 or higher, indicating a spectrum from well-preserved catchment areas minimally affected by erosion to those extremely degraded due to soil erosion. Z values can fall outside these limits only in exceptional cases [27]. Based on the dominant erosion type and the erosion coefficient Z values, 13 categories are determined (Table 2).

Table 2. Erosion coefficient Z values according to Gavrilović.

Category of Destructiveness (Erosivity)	Strength of Erosion Processes	Dominant Type of Erosion	Erosion Coefficient Z	Mean Value of Z
I	Excessive Erosion	Deep	>1.51	1.25
		Mixed	1.21–1.50	
		Surface	1.01–1.20	
II	Severe Erosion	Deep	0.91–1.00	0.85
		Mixed	0.81–0.90	
		Surface	0.71–0.80	
III	Medium Erosion	Deep	0.61–0.70	0.55
		Mixed	0.51–0.60	
		Surface	0.41–0.50	
IV	Slight Erosion	Deep	0.31–0.40	0.30
		Mixed	0.25–0.30	
		Surface	0.20–0.24	
V	Very Slight Erosion	Traces of Erosion	0.01–0.19 or less	0.10

Source: [27].

Soil Resistance to Erosion Coefficient (Y)

The coefficient Y represents the reciprocal value of the soil's resistance to erosion and depends on the geological substrate, climate, and pedological characteristics (Table 3).

Table 3. Values of Y coefficient.

No.	Soil Types and Other Substrates	Mean Y Coefficient
1	Sands, gravel, and loose soils	2.0
2	Loess, tuffs, saline marshes, steppe soils, etc.	1.6
3	Disintegrated limestones and marls	1.2
4	Serpentines, red sandstones, flysch deposits	1.1
5	Podzol soils and alike, decomposed shales, mica schists, gneiss slates, clay slates	1.0
6	Core limestones, red rocks, and humus–silicate soils	0.9
7	Cambisol and mountain soils	0.8
8	Vertisol, humogley, and wetlands	0.6
9	Chernozem and alluvial soils of good structure	0.5
10	Bare, compact eruptives (volcanic origin)	0.25

Source: [27].

Researchers at the Department of Erosion and Reclamation Laboratory at the Faculty of Forestry in Belgrade dimensioned the values of the coefficient Y. These values refer to the reciprocal resistance of soil formations and rocks to the effects of "soil bombardment by raindrops" and their resistance to the removal of soil particles by flowing water and aeolian erosion [27,36,76].

Catchment Area Management Coefficient (X·a)

The catchment area management coefficient refers to the protection of soil from atmospheric influences in natural conditions (vegetation) (coefficient X) or artificially created conditions, i.e., the application of technical, biotechnical, and biological anti-erosion works on the catchment area or erosion area (coefficient a). These are two coefficients, and their product ranges from 0.01 for protected soil to 1.0 for completely bare, unprotected, and unmanaged land (Table 4).

Table 4. Value of expression X·a.

	Conditions Affecting the Value of Coefficient X·a	X·a
No.	I—Catchment area or region before implementation of anti-erosion measures	
1	Completely bare, uncultivable land (bare land)	1.0
2	Arable land with plowing up- or downhill	0.9
3	Orchards and vineyards without ground vegetation	0.7
4	Mountain pastures and drylands	0.6
5	Meadows, fields, and similar agricultural crops	0.4
6	Degraded forests and thickets with eroded soil	0.6
7	Forests or thickets with good structure and vegetation	0.05
No.	II—Catchment area or region after implementation of anti-erosion measures	
1	Plows with contour direction	0.63
2	Arable land well cared for and protected by mulching	0.54
3	Contour strip cultivation with crop rotation (fields)	0.45
4	Contour orchards and vineyards	0.315

Table 4. *Cont.*

	Conditions Affecting the Value of Coefficient X·a	X·a
No.	II—Catchment area or region after implementation of anti-erosion measures	
5	Terracing of arable land, terraces, and tiers	0.36
6	Grassland restoration and pasture and dryland reclamation	0.3
7	Creation of medium-density contour ditches	0.24
8	Construction of contour trenches of medium density, retardation waterways, and micro-accumulations	0.27
9	Basic afforestation in pits or strips	0.2
10	Afforestation with construction of tiers	0.1
11	Channel regulation, dam construction, and channelization	0.7

Source: [27].

Visible and Clearly Expressed Erosion Process Coefficient (φ)

The coefficient φ represents the numerical equivalent of visible and clearly expressed erosion processes in a catchment area or region (Table 5).

Table 5. Values of coefficient φ.

No.	Conditions Affecting the Value of Coefficient φ	The Mean Value of φ
1	The catchment area is completely under gully erosion and primordial processes (deepening, incision, slumps)	1.0
2	About 80% of the catchment area is under furrow and gully erosion	0.9
3	About 50% of the catchment area is under furrow and gully erosion	0.8
4	The entire catchment area is subject to surface erosion: disintegrated debris from embankments, some furrows, and gullies, as well as strong karst erosion	0.7
5	The entire catchment area is under surface erosion but without furrows and gullies (deep processes) and the like	0.6
6	Land with 50% of the area covered by surface erosion, while the rest of the catchment area is preserved	0.5
7	Land with 20% of the area covered by surface erosion, while 80% of the catchment area is preserved	0.3
8	The soil in the catchment area has no visible signs of erosion, but there are minor slips and slides in watercourses	0.2
9	A catchment area without visible signs of erosion but mostly under arable land	0.15
10	An area without visible signs of erosion, both in the catchment area and in watercourses, but predominantly under forests and perennial vegetation (meadows, pastures, etc.)	0.1

Source: [27].

According to the original version of the EPM [27], the coefficient φ is determined directly in the field. This parameter is the only one in the EPM with a subjective component, which is why some authors [77] classify it as a semi-quantitative indicator. To overcome this drawback, some authors have determined the value of φ using multispectral satellite imagery and specific spectral channels obtained through remote sensing [78–80].

The Mean Slope of the Terrain in a Catchment Area

The mean slope of the terrain reflects the impact of topographical characteristics, determined by using the square root of the mean catchment slope, i.e., the erosion area or soil parcel. A correctly generated erosion map and the representative value of the erosion coefficient form the basis for further calculations of erosion production, transport, and sediment structure [36].

2.3.2. Lazarević's Modification of the Erosion Potential Method

During his work on an erosion map, Professor Lazarević introduced certain modifications to Gavrilović's method. The most significant changes were related to calculating the erosion coefficient Z, with the observation that the most reliable value of the mean slope can be determined from a topographic map.

Table 6 shows the values of the erosion coefficient Z, according to Lazarević, which increases the number of categories based on the values of the erosion coefficients to 12, including a new category—sediment accumulation. The following tables present the input parameter coefficient values according to the original method's modified version [36].

Table 6. Erosion coefficient Z according to Lazarević.

Destructiveness Category (Erosivity)	Strength of Erosion Processes	Erosion Coefficient Z
1	Excessive erosion	1.41–1.50
2	Excessive erosion	1.21–1.40
3	Excessive erosion	1.01–1.20
4	Severe erosion	0.86–1.00
5	Severe erosion	0.71–0.85
6	Medium erosion	0.56–0.70
7	Medium erosion	0.41–0.55
8	Slight erosion	0.31–0.40
9	Slight erosion	0.21–0.30
10	Very slight erosion	0.11–0.20
11	Very slight erosion	<0.11–0.10
12	Sediment accumulation	0

Source: [70].

Soil Erodibility Coefficient (Y)

Lazarević classifies the values of the Y coefficient into seven categories (Table 7).

Table 7. Soil erodibility coefficient Y.

No.	Soil Type—Rock	Value of Y
1	Soil	1.0–0.8
2	Skeletal and skeletonized soil	0.7
3	Impermeable and non-resistant rocks (slates, flysch, clay)	0.6
4	Permeable and non-resistant rocks (sand, gravel, loess)	0.5
5	Semi-permeable rocks	0.4
6	Impermeable and resistant rocks (volcanic rocks)	0.25
7	Permeable and resistant rocks (limestone, dolomite)	0.1

Source: [70].

The first two categories relate to the skeletal content of soil, while the remaining five focus on the geological substrate. In contrast, Gavrilović (Table 4) analyzes soil type and geological substrate together within the same category. One critique of this classification is the qualification of sands as a more resistant type of rock compared to "soil" (without further elaboration on which types and conditions of soil are considered) since the previous measurements produced the opposite results [36,81].

Catchment Area Management Coefficient (X·a)

In contrast to Gavrilović, Lazarević uses the X coefficient values (without the coefficient a) in a unified manner, i.e., without a partial analysis of areas before and after implementing anti-erosion works (Table 8) [36,81].

Table 8. Protection coefficient of soil from atmospheric influence and erosion X.

No.	Land Use Method	Value of X
1	Area without vegetation cover	1.0
2	Fields with plowing along and across the slope, vineyards	0.9
3	Fields with plowing along contour lines	0.8
4	Multi-field crop rotation	0.6
5	Degraded pastures	0.4
6	Degraded forests	0.3
7	Meadows	0.2
8	Well-established forests	0.1

Source: [70].

Visible and Clearly Expressed Erosion Process Coefficient (X·a)

The values of the φ coefficient according to Lazarević (Table 9) and the original values from Gavrilović (Table 5) are divided into six and ten categories, respectively.

Table 9. Visible erosion process coefficient φ.

No.	Erosion Process State	Mean Value of Coefficient φ
1	Areas are deeply eroded by ravines, water divides, and furrows, cut into eluviated and diluviated deposits or very weathered non-resistant rocks; such areas cannot be used without specific anti-erosion measures, and riverbeds are dominated by sediment accumulation.	1.01–1.50
2	Firm surface and hidden linear erosion on slopes above 10°; degraded forests and pastures with individual water divides and furrows; riverbeds dominated by sediment accumulation.	1.00–0.71
3	Areas under plowing on slopes of 5–10° (φ = 0.5); degraded pastures and forests with damaged cover; barren lands on resistant impermeable rocks (φ = 0.3); watercourses erode and cut into the land.	0.70–0.41
4	Weak erosion in forests with weaker cover, on poorer meadows and pastures, on slopes up to 10° (φ = 0.25); forests and meadows on slopes 10–30° (φ = 0.2); forests and meadows on the lower part of the slope; fields on slopes 3–5°; riverbeds dominated by deep erosion.	0.40–0.21
5	Latent erosion; well-established forests with good ground cover occupying the ridge areas; good meadows and pastures on slopes up to 10°; extensive plains with slopes less than 3°; carbonaceous rocks (bare karst or with preserved vegetation); deep erosion in riverbeds.	0.20–0.10 and less
6	Sediment accumulation on alluvial plains, at narrow areas between slopes and embankments, behind protective barriers, etc.; closed karst.	0

Source: [70].

The original intent of this coefficient was related to the percentage of eroded surfaces, expressed by a maximum coefficient value of 1 (100%). In Lazarević's approach, this coefficient's values increase to 1.5. Moreover, Lazarević introduces a new "erosion category" with a coefficient value of 0 for accumulation areas (e.g., alluvial plains) where sediment deposition occurs, which aligns with the geographic perception of geomorphological processes. This interpretation does not consider that deposited sediment continues downstream with the first occurrence of large waters, and alluvial plains can also be viewed as sources of erosion material. Some authors argue that this modification of the EPM with the φ coefficient inadequately addresses the erosion and sediment transport process "since sediment accumulation in alluvial valleys is only a temporary phase in sediment transport from the source to the mouth" [36,81].

2.3.3. Application of GIS Technologies in Creating Erosion Map of Serbia (2020)

In contrast to the traditional approach, which relied on field-based cartography, modern methods employ Geographic Information System (GIS) technologies. GISs enable the representation of real spatial environments in digital form, specifically through databases designed for computer processing. One of the numerous advantages of a GIS is its ability to extract relevant information about the complex relationships among factors involved in dynamic spatial processes. It allows for the proper systematization, analysis, and visualization of all relevant spatial data [36,40].

To create an erosion map, which includes spatial information and quantitative indicators of erosion production, it is necessary to establish three levels of databases according to the scheme in Figure 2, adapted for applying the Erosion Potential Method (EPM) (Figure 2). The first level is the zero database, which enables the creation of various primary databases as a foundation for applying the aforementioned models. The zero database essentially represents a collection of basic information that can provide fundamental input data for EPM applications after appropriate processing and interpretation. Climatic and hydrological characteristics in the zero database include information on rainfall and air temperature measurement series. Depending on the scale and level of detail, these data can be collected from global databases and authoritative meteorological and rain gauge stations in Serbia. Climatic data are collected in the form of a numerical database. Digital terrain models in the zero database are presented as raster databases, which are raw and unprocessed, and, depending on the scale of the erosion map, are displayed with varying levels of detail. In the initial processing phase, soil and geological characteristics are represented through soil and geological maps of various scales, which may be in paper form or scanned raster format. Land use (surface structure) is presented in the zero database as a raster. The final input parameter in the zero database is the archive, consisting of textual records, reports, the relevant professional and scientific literature, and documentation on completed planning and project activities. The primary or analytical database represents the processing and assessment phase of the zero database to generate a secondary or synthetic database. The primary database of the digital terrain model phase includes analyses of topographical factors (Isr) using geo-information tools. Soil maps in the primary database are processed through geo-referencing and digitization, after which input data are generated. Land use (surface structure), depending on the scale and quality of the base maps, is represented as raster databases using geo-information tools. Archival data are analyzed in this phase, and certain corrections are introduced that represent improvements or deteriorations in the conditions of the study area. The final stage of creating the erosion map involves the development of the secondary (synthetic) database, with the results derived from applying the EPM. It quantifies the intensity of erosion processes, i.e., erosion production and sediment transport. The synthetic output result is the erosion map, which, depending on the scale, holds both scientific and practical value [36].

This modern approach to creating erosion maps was applied in 2020 during the development of the "Draft Spatial Plan of the Republic of Serbia (2021–2035)", specifically in the thematic booklet titled "Emergencies, Natural Disasters (Protection and Safety of People and Property—Erosion, Floods, Landslides, Earthquakes, War Destruction, and Technological Accidents)".

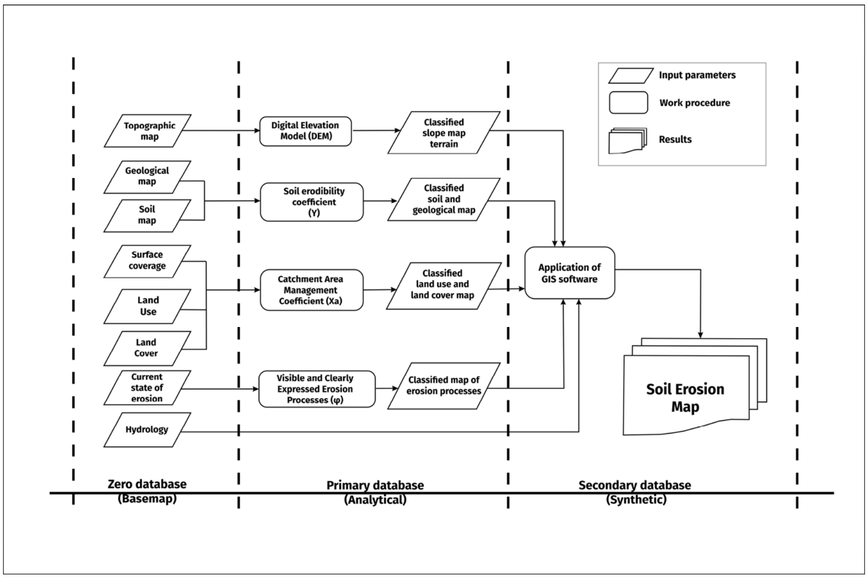

Figure 2. The algorithm of the process of creating an erosion map according to the EPM [36].

The basis for creating the erosion map was the original method by Professor Slobodan Gavrilović—the EPM—without the modifications introduced by Lazarević. Over the past few decades since the creation of the first erosion map, Gavrilović's EPM has become the most commonly used quantitative model in Serbia and the former Yugoslavia. With some modifications, it has also been applied in several European countries and globally. Numerous studies have confirmed the scientific verification of the EPM model [82]. Research on eleven selected methods and models for assessing soil erosion has characterized the EPM model as the most quantitative among all regional models discussed [77,83]. In contrast to the acceptance of Gavrilović's method on the regional and global levels, evidenced by the number of scientific papers and projects in which it has been used, Lazarević's modifications have not found broader application in the scientific community or engineering design practice. Also, Lazarević's modifications have never been used in new remote sensing methods and machine learning algorithms applied to the scientific and technical aspects of the original EPM [36].

Since the logic of the EPM is based on forming relatively homogeneous spatial units in the study area, catchment area, or erosion parcel, for which the erosion coefficient Z is determined, the representative value of the erosion coefficient is the weighted arithmetic mean of the selected units. This approach aligns with the logic of GISs, where the basic unit of the two-dimensional space is the pixel, which, in Gavrilović's approach, corresponds to the primary examined entity [36,84]. Based on this relationship, Gavrilović's algorithm can be applied to an elementary surface (pixel) and a set of pixels, i.e., a raster [36,37,84,85]. This way, a corresponding database is created, and a digital map is generated, carrying information at the pixel and raster levels. Therefore, specific "themes" in raster format represent the components of the formula used to calculate the erosion coefficient Z, which, through raster algebra, explicitly influences the spatial distribution of Z [36,86].

Due to the dynamics of developing the spatial plan, short timeframes, limited financial resources, incomplete databases, and the need to create an erosion map that would similarly treat the entire territory of the Republic of Serbia, the team utilized available global and regional databases. The team compiled a land cover inventory using the 2018 Corine Land

Cover database [87]; obtained information on soil characteristics from the European Soil Database [88], with a scale of 1:1,000,000; and used the SRTM (Shuttle Radar Topography Mission) 2021 digital elevation model (DEM) for the analysis of topographic parameters. The resolution of the digital elevation model is three arc seconds in geographic projection (WGS84 datum), approximately corresponding to 90 × 60 m in the projected Gauss–Krüger Mercator projection. Given that input data had varying spatial resolutions (from 90 to 500 m), homogenization was ensured by applying interpolation methods to the output resolution of 500 m to minimize the loss of detail. This method of homogenizing datasets is standard and has been applied in similar research in the European Union. For instance, researchers from the Joint Research Centre (JRC) have used the RUSLE2015 method with quantified and verified input data with varying spatial resolutions (ranging from 25 to 1000 m) [36,89]. The 1983 Erosion Map created by Prof. Lazarević was digitized for comparison purposes. The comparison of traditional and modern approaches was conducted in a GIS environment, where the change in soil erosion categories was analyzed using a confusion matrix [90,91]. The confusion matrix compares the categorical relationships between the traditional approach (1983 Erosion Map) and the modern approach (current state) [36].

3. Results and Discussion

Comparison Between 1983 and 2020 Erosion Maps

The comparison of spatial and quantitative parameters between the erosion maps created using the modified method by Lazarević (1983) (Figure 3) and the original version of the EPM (2020) (Figure 4) reveals significant differences.

The results obtained using the confusion matrix are presented in a table, where the columns represent the outcomes of the modern approach, and the rows represent those of the traditional approach. The value ranges for the Z coefficient were applied according to Lazarević (Table 6) to compare the traditional and modern approaches. Table 10 illustrates the differences in areas under 12 different erosion categories, with the exception that, in the modern approach, category 12 (sediment accumulation) was not designated as a separate category.

Table 10. Confusion matrix between traditional approach (1983 Erosion Map) and modern approach (current state in 2020) for mapping water erosion. Changes in erosion severity categories are presented in km^2.

		2020												
	Category	1	2	3	4	5	6	7	8	9	10	11	12	Total (1983)
1983	1	4.78	42.41	32.42	33.11	34.9	28.4	13.74	5.53	3.65	228.8	97.3	0	525.09
	2	1.24	6.46	7.35	7.07	5.11	3.1	3.94	3.05	3.08	60.86	53	0	154.3
	3	2.76	12.08	7.31	12.65	12.34	11.3	9.05	6.57	17.06	69.55	65.6	0	226.32
	4	29.44	148.4	217.4	296.8	409.8	362.6	813.5	456.8	199.2	1369	1110.2	0	5413.22
	5	27.14	86.73	194.8	379.3	652.8	568.5	1440.2	753.9	266.3	958.7	1331.5	0	6659.95
	6	11.09	48.04	76.85	129.6	139.0	129.7	227.8	138.1	103.5	575.7	500.5	0	2080.09
	7	31.82	105.9	238.29	502.0	1070.7	658.4	1552.5	929.8	546.9	1659.1	1677	0	8972.64
	8	19.66	114.0	194.2	303.4	481.35	403.9	489.7	351.1	605.87	1975.9	1855	0	6794.3
	9	27.06	94.12	187.63	328.7	571.63	540.0	826.2	493.4	551.23	2313.7	2538.	0	8472.06
	10	33.19	206.5	343.3	371.6	430.28	420.2	435.8	293.2	1033.8	7273.2	6612.	0	17,453.5
	11	16.68	44.13	56.24	70.0	290.36	249.4	858.7	1010.8	11,033.13	2510.9	3519.8	0	19,660.4
	12	1.96	7.22	17.56	27.0	143.4	181.6	215.3	820.4	2699.8	4004.9	3966.4	0	12,085.7
	Total (2020)	206.82	916.1	1573.4	2461.5	4241.6	3557.3	6886.5	5262.9	17,063.8	23,000.5	23,326.9	0	88,497.5

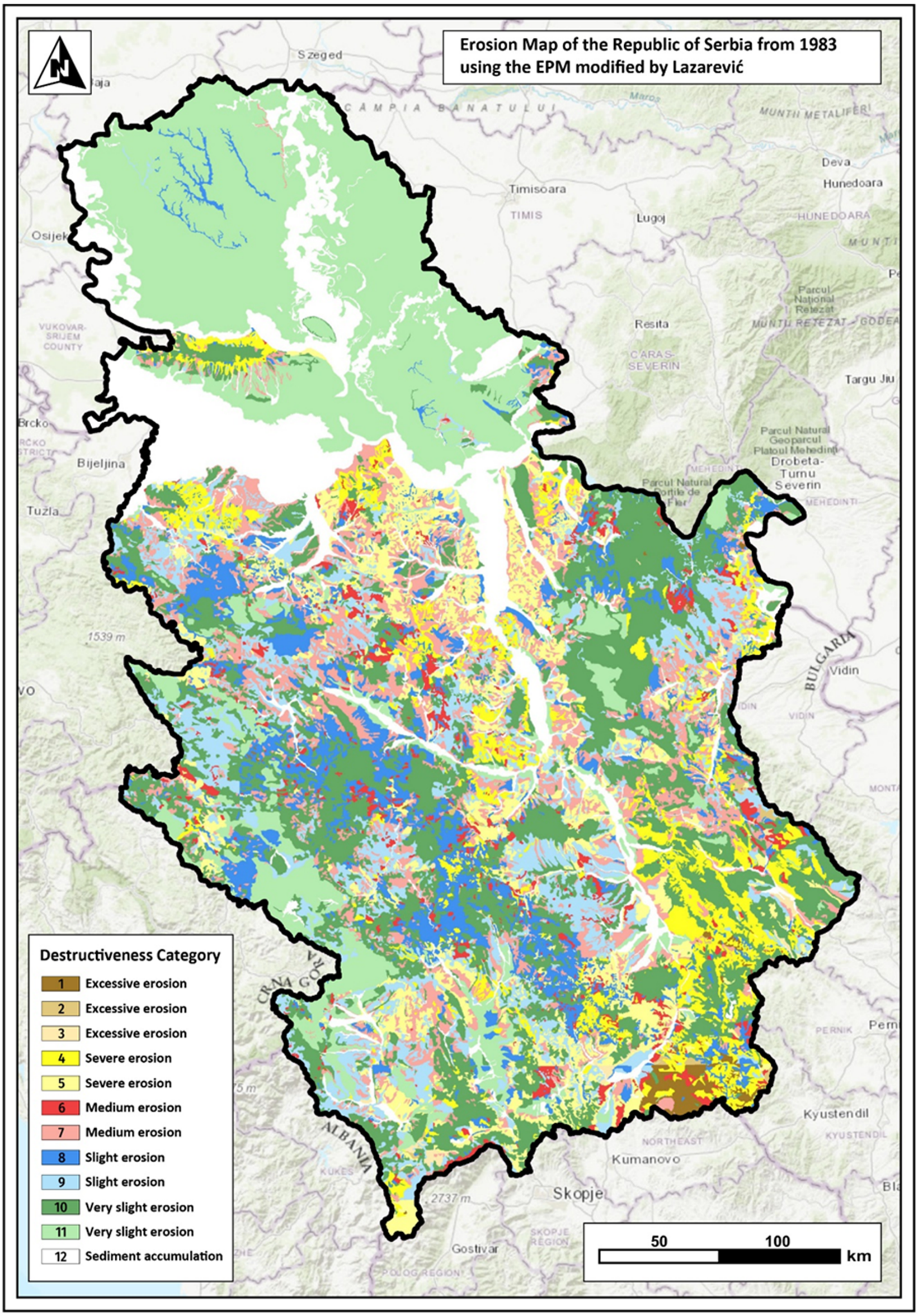

Figure 3. The Erosion Map of the Republic of Serbia from 1983, using the EPM modified by Lazarević [36].

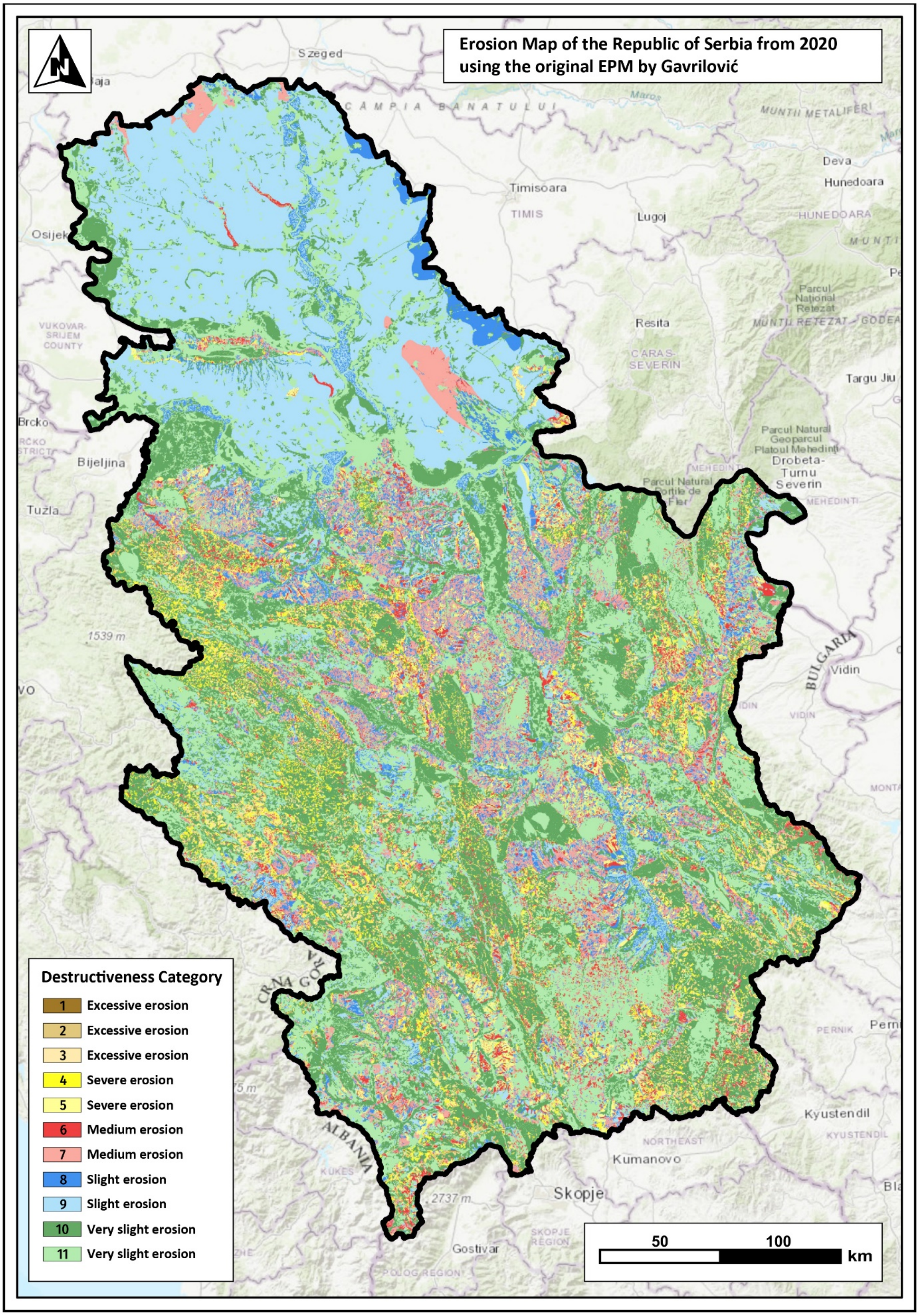

Figure 4. The Erosion Map of the Republic of Serbia from 2020, using the original EPM by Gavrilović [36].

There are several differences between the original EPM and Lazarević's modified EPM. While the approach of Gavrilović considered soil erosion a natural process often accelerated by anthropogenic influences, making it essential to use representative indicators reflecting its complexity, Lazarević's modified EPM utilizes five parameters and incorporates one coefficient (erosion type "φ") determined through fieldwork. This coefficient is the primary factor in soil erosion and is described as the "carrier of all parameters".

The coefficient X·a of the original EPM is numerically weighted according to the surfaces' natural status and after implementing erosion control measures. Maps generated with this information can serve as guidelines for reducing erosion processes. In Lazarević's modified EPM, values are provided only for different land cover types.

The coefficient Y of the original EPM results from the synthesizing characteristics associated with specific responses to erosion, considering geological and pedological properties. So, the values are provided separately for each group of geological and pedological factors. The coefficient Y of Lazarević's modified EPM primarily pertains to geological formations, while soil types are scarcely mentioned—all pedological layers are categorized as "soil" with variable values determined visually in the field.

The coefficient φ of the original EPM is defined in the field and enhanced with relevant remote sensing data. The coefficient φ of Lazarević's modified EPM represents a combination of coefficients Y and X·a, reducing their significance in assessing soil erosion intensity.

The Gavrilović method has been widely accepted at the regional and global levels, as evidenced by numerous scientific papers and projects that have utilized it. In contrast, Lazarević's modification has not gained significant traction in scientific circles or engineering practice, as shown by the limited number of papers and projects in which it has been applied.

The original EPM is suitable for the analytical modeling of all relevant factors using GIS methods and techniques. Identified extremes are verified in the field, and their objective characteristics are used for model validation and/or calibration. In Lazarević's modified EPM, field assessments focus on soil erosion's visible and observable intensity.

Modern remote sensing methods and machine learning algorithms have been applied to the scientific and professional aspects of the original EPM. However, these advancements have not been incorporated into Lazarević's modified version of the EPM.

According to Gavrilović, the erosion coefficient (Z) is calculated analytically across all scales, ranging from small watersheds (scales of 1:5000 and 1:2500) to national levels (scale of 1:1,000,000). These calculations utilize GIS databases, geospatial layers (vector and raster formats), and the coefficients Y and X·a. The analytical approach cannot be applied consistently across all scales when using the modified version of the EPM.

The erosion map generated using Gavrilović's method is available in raster and vector formats, with defined scale levels and polygon sizes. In contrast, the erosion maps created using the modified version of EPM are in vector format, but the scale levels and polygon sizes are not clearly defined.

Between 1983 and 2020, changes occurred in the areas covered by different erosion categories (Table 11).

Table 11 compares the erosion conditions shown on the 1983 map created using Lazarević's modified EPM and the 2020 map created using the original EPM. It reflects the differences in the intensity and distribution of erosion across Serbia during these two periods and how socio-economic, demographic, and technological advancements have contributed to changes in erosion patterns.

Table 11. Comparison of erosion status on 1983 and 2020 maps.

Erosion Category	1983		2020	
	km^2	%	km^2	%
Excessive Erosion	905.71	1.02	2696.39	3.05
Strong Erosion	12,073.17	13.64	6703.15	7.57
Medium Erosion	11,052.73	12.49	10,443.81	11.8
Weak Erosion	15,266.36	17.25	22,326.73	25.23
Very Weak Erosion	37,113.82	41.94	46,327.46	52.35
Sediment Accumulation	12,085.71	13.66	/	/

The significant reduction in areas under Strong Erosion and the decrease in areas under medium erosion can be attributed to demographic and socio-economic shifts over nearly half a century, which have influenced the intensity of mechanical water erosion and changes in land use patterns. Hilly and mountainous regions, where these categories are the most pronounced, have long suffered from agrarian overpopulation. The surplus labor force in these regions was forced to remain there because, due to underdeveloped industries, nearby cities could not absorb them. They had no choice but to expand agricultural land at the expense of forests and meadows, regardless of terrain configuration, which inevitably led to increased erosion [92]. This phenomenon caused the areas of arable land in hilly regions to triple and those in mountainous regions to increase more than sevenfold between 1889 and 1959. From 1892 to 1959, areas under cereal crops increased by 300%, while the population grew by only 37%; in other words, the areas under cereal crops expanded nine times faster than the population [93]. The 1983 map reflects the effects of these demographic and socio-economic circumstances.

However, starting in the 1980s, the mountainous regions of Serbia, like the Republic of Serbia as a whole, began to lose their population capacity. This population loss was not evenly distributed across all areas and settlement types but was the most pronounced in minor settlements, where population decline has persisted for over 60 years. These settlements lost 0.5% of their population between 1948 and 1953 and up to 12.9% between 1981 and 1991. From 1948 to 2011, most minor mountain settlements lost 42.7% of their population [94]. Since accelerated erosion is a consequence of anthropogenic activity, demographic regression inevitably reduced erosion, as recorded on the 2020 map.

Additionally, advancements in the use of Geographic Information Systems (GISs) over this period have significantly increased the accuracy of erosion mapping [36].

The updated erosion maps mirror the shift in methodology from a traditional approach (Lazarević's modification) to the modern GIS-based method (Gavrilović's original EPM) and reflect technological improvements and changes in land use, conservation practices, and environmental awareness.

The differences in erosion classification between the two maps can be attributed to improvements in data quality, mapping techniques (such as GISs), and changing land use practices and environmental factors over nearly four decades.

Only the modified EPM recognizes sediment accumulation as a category. Since the 2020 erosion map was created based on the original EPM, this category was not identified [36].

It is important to emphasize that the application of the modern approach presented here, using the original version of the Erosion Potential Method (EPM), and its result in the form of an erosion map, is the outcome of activities undertaken to develop the bases required for the preparation of workbooks [95]. This database holds significant value for providing an overview of soil erosion conditions at the national level; however, it does not aim to address soil erosion issues at the regional and local levels. When mapping erosion processes for engineering problem-solving (designing erosion control works, protection against erosion and torrent floods) or conducting specific research aimed at conducting professional and scientific analyses at the regional and local levels, as well as on smaller watershed areas (up to 1000 km^2), it is necessary to use more detailed databases. Additionally, field activities, which are an integral part of the process of creating erosion maps at these levels, are essential [36].

4. Conclusions

Socio-political and economic circumstances influenced the high intensity of deforestation during the 19th century, which resulted in the activation of erosion processes, flash floods, and slow anti-erosion actions. A basis for precisely recording the intensity and distribution of erosion processes is necessary to organize this successfully. The first attempt at this, a decision to create a Bare Land Cadastre, was made in 1872 but was not realized even nearly 70 years later, and during World War II, all collected data were destroyed. The exact circumstances, political instability, and financial scarcity affected the spontaneous execution of anti-erosion works and the focus on quick and short-term solutions. Relying almost exclusively on technical construction works and sidelining biological works, whose effects are much slower, resulted in abandoning the creation of a Bare Land Cadastre and redirecting attention to the creation of a flood cadastre.

During the 1950s, the anti-erosion field underwent significant scientific and infrastructural development. During this period, many flood cadastres were created, ranging from the national to the local government level; however, their analysis showed subjectivity and insufficient precision. The experts of the inter-republic commission decided to implement a significant project to create the first Erosion Map of SR Serbia, which lasted from 1966 to 1971, and some additional modifications until its final publication in 1983. The foundation was based on the quantitative method of Prof. Slobodan Gavrilović—the EPM—which underwent modifications by Prof. Radenko Lazarović, who led the project.

Traditional approaches to mapping and assessing erosion intensity, such as the modified version of the Erosion Potential Method (EPM) by Prof. Lazarević, have evolved into modern approaches utilizing the original version of the EPM by Prof. Gavrilović and advanced Geographic Information System (GIS) technologies. Comparing erosion maps from 1983 and 2020 reveals significant changes in erosion intensity and distribution, driven by demographic, socio-economic, and technological changes and improvements in data usage and mapping techniques. While the modified version of the EPM provided valuable insights through field research, modern approaches enable quantitative analysis across various spatial levels with increased precision and reliability. Contemporary data and methods provide a strategically important basis for national planning and implementing erosion control measures. However, fieldwork and tailored databases are still needed for more detailed analyses at the regional and local levels. These changes reflect a broader shift toward sustainable land management and a greater awareness of the importance of soil and ecosystem conservation.

The digital databases used are of significant value for reviewing the state of soil erosion at the national level. Still, they do not aim to address soil erosion issues at the regional and local levels. When mapping erosion processes for engineering purposes (designing erosion control works, protection against erosion and torrential floods) or for specific research aimed at producing expert scientific analyses at the regional and local levels, as well as for catchments with smaller spatial coverage, it is essential to use more detailed databases accompanied by mandatory field activities. These field activities are an integral part of the process of creating erosion maps at the mentioned levels.

The credibility and objectivity of the Erosion Map of SR Serbia depend on the stability of variable parameters, primarily the land use method. The 1983 Erosion Map fixed the field conditions that, with minor oscillations, persisted from the 1930s until the map's creation. Therefore, it is a representation of that period. However, given the turbulent social and economic dynamics that are continuously occurring, it has become outdated and represents the past state.

The technological and informational advances of recent decades have left a mark on numerous disciplines that address space as a physical dimension, including the issue of mapping erosion processes. In earlier periods, spatial data processing was predominantly based on analog maps and field research, while in the modern context, mapping erosion processes rely on computer technology and remote sensing. This approach led to the creation of the 2020 Erosion Map, developed for the needs of the "Draft Spatial Plan of the Republic of Serbia (2021–2035)", specifically the annex (thematic volume) titled "Emergencies, Natural Disasters (Protection and Safety of People and Goods—Erosion, Floods and Flash Floods, Earthquakes, War Destruction) and Technological Accidents". The original version of the EPM (according to Prof. Slobodan Gavrilović) has been globally applied in creating complex models, scientific research activities, and national engineering practices in recent decades. Therefore, the spatial and quantitative parameters of the erosion map were created using the original version of the EPM, along with the application of modern models.

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