www.gi.sanu.ac.rs, www.doiserbia.nb.rs
J. Geogr. Inst. Cvijic. 2025, 75(1), pp. 17–32

Original scientific paper

UDC: 630*58
https://doi.org/10.2298/IJGI240701017P

Received: July 1, 2024
Reviewed: October 15, 2024
Accepted: November 8, 2024

HISTORICAL CHANGES IN THE AREA UNDER FOREST—ESTIMATION APPROACH BASED ON CARTOGRAPHIC RESOURCES

Aleksandar Popović[1]* *, Biljana Šljukić*[1] *, Dragan Borota*[1] *

[1]University of Belgrade, Faculty of Forestry, Department of Forestry and Nature Protection, Belgrade, Serbia; e-mails: aleksandar.popovic@sfb.bg.ac.rs; biljana.sljukic@sfb.bg.ac.rs; dragan.borota@sfb.bg.ac.rs

Abstract: This paper analyzes changes in forested areas, as depicted in topographic maps, within the historical context of their publication in Serbia. The research focuses on the experimental field "Goč-Gvozdac" of the University of Belgrade – Faculty of Forestry, with additional reference to changes in Central Serbia. Changes were assessed across historical periods using four reference topographic maps: from 1893, 1929, 1971, and 1985. Data on shifts in forested areas (categorized as forest and other land) were obtained by vectorizing scanned analog maps using manual GIS editing tools. Additionally, currently available spatial data sets of land cover/use for 2021 were utilized for the analysis. The forest distribution across different geological formations was also evaluated. The results indicate a continuous increase in forested areas within the experimental field, rising from 77.6% in 1893 to 89.3% in 1985, and reaching 95.1% by 2021. The most significant increase occurred during the first reference period (1983–1929), while the smallest growth was observed in the last one. Data for Central Serbia also reveal a general upward trend in forested areas throughout the 20th century, consistent with findings from the experimental field. However, analyses in the 21st century indicate only minor changes in the forested area. The historical data on forest area changes provide valuable insights, enhancing our understanding of forest development and informing better forest management planning, organization, and activity implementation. This is significant for enhancing knowledge from educational and scientific research perspectives, as well as providing the foundation for forest management in preservation and qualitative improvement.

Keywords: forest; topographic maps; GIS; long-term change; Central Serbia

1. Introduction

One of the first maps of the territory corresponding to the borders of today's central Serbia was made by Adam von Weingarten in 1820, as a contribution to the historical-geographical document *Über Serbien*. In addition to the river valleys, the author describes the country as hilly, covered with dense and continuous forests (Matović, 2019). Different subjective descriptions from the past often form the basis of the interpretation of the forest conditions.

*Corresponding author, e-mail: aleksandar.popovic@sfb.bg.ac.rs

The development of cartography, from Zaharija Orfelin, Sava Popović Tekelija, Vuk Stefanović Karadžić, Jovan Bugarski, Vladimir Karić and Jovan Cvijić (Živković, 2012), to the first "land measurement" for the creation of a topographic map (1881–1892 in the Kingdom of Serbia) with the presentation of the forest layout, from this historical distance enabled the minimization of the above-mentioned subjectivity. Forests, in addition to long production processes, have long time frames for monitoring certain phenomena that often exceed a persons' working life, and are primarily characterized by a large surface coverage. Therefore, spatial management planning is extremely important. Topographic maps have been the spatial basis of forest management in Serbia since the beginning of their presentation and division. More than one century has passed since the creation of the first topographic map of Serbia (published in 1893). To date, the surveying process has been repeated several times in different time and spatial frames. Compared to the first survey, its content has been completely updated. The quantity and quality of available information in modern circumstances ensure overcoming the problems caused by the various specificities of forests. The currently available spatially comparable data form a suitable basis for monitoring changes in forest areas, especially considering the lack of such research, the reliability of information and the advantages of modern geoinformation systems for their manipulation. Due to the limited availability of data from the mentioned period until today, and their scope and reliable comparability, the paper analyzes the characteristics of changes in the forest areas Gvozdac River basin, an experimental field of the University of Belgrade – Faculty of Forestry, "Goč-Gvozdac". This forest was designated for the needs of science and teaching at the Faculty of Forestry of the University of Belgrade by the decision of the Serbian Government in 1956 (Izvršno veće Narodne Republike Srbije, 1956). This experimental field with an area of 3,731 hectares (ha) started operating on January 1, 1957. The first management planning process of this forest within the boundaries of the state forest area "Goč-Željin", defined in 1909 (Uređajni zapisnik, 1950), was carried out in 1933 (Uređajni zapisnik, 1937). The basis of forest division was a topographic map of the Vojnogeografski institut from 1929. The topographic maps provided an early depiction of forest vegetation significantly before the first maps of the condition of forests in the management plans of this area, which enhances their importance.

Knowledge and understanding of the past are necessary to assess the current situation and plan future actions properly. Forest change is a continuous process that has taken place in the past and is still happening. To understand the scale of the changes in forest areas, it is important to identify former forested areas and endangered parts, simulate their transformation, and take into account the migration of the human population, as well as industrial, agricultural, and urban development (Puziene, 2021). Historical maps (old cadastral maps, topographic maps, military maps, and thematic maps) are useful for the retrospective analysis of long-term forest changes (Kienast, 1993). If available, changes may be analyzed based on literary sources and preserved archival statistical data (Puzienė & Anikeniene, 2020). As the development of cartography progressed, an opportunity arose to monitor changes using topographic maps (Puziene, 2021) and make positive use of extensive past work. Surveys based on topographic maps are relatively rare (Istrate et al., 2023; Kaim et al., 2016) because they require extensive work on the vectorization of analog data. Attempts to automate this process have had good results only with newer maps releases (Ostafin et al., 2017). Contemporary research of this kind has been addressed by

several authors (Istrate et al., 2023; Jaworek-Jakubska et al., 2020; Kienast, 1993; Ostafin et al., 2017; Puziene, 2021, 2024; Puzienė & Anikeniene, 2020; Stäuble et al., 2008), mainly in Central Europe as part of landscape research. Research can have a more complex or simpler character, depending on the basic landscape zones (soil, groundwater, plant) that are the subject of research and the design of their categorization (Jaworek-Jakubska et al., 2020; Puzienė & Anikeniene, 2020). This kind of research is mostly focused on the local level (Ostafin et al., 2017), with the exception of broad-scale forest cover reconstruction (Polish Carpathians), using sampling methods (Kaim et al., 2016). This mainly happens because forestry policy decisions are dominantly implemented at that level (Jaworek-Jakubska et al., 2020). The long-term changes in forest-covered areas are crucial for experimental fields with a rich tradition of scientific and educational activities. Understanding past trends is essential for planning, regulating, and directing forest development (Puziene, 2021). It is vital for management planners to recognize the importance of the historical context of today's forests in order to monitor, manage, and plan effectively (Jaworek-Jakubska et al., 2020). The insights gained can serve as a theoretical foundation for managing and promoting sustainable forest development.

2. Materials and methods

2.1. Study area

The experimental field "Goč-Gvozdac" is a scientific-research complex formed in order to provide conditions for the education, training, and experimental work of students. The experimental field (Figure 1) is located in Central Serbia, within the territory of the municipalities of Kraljevo and Vrnjačka Banja. This border area of Goč Mountain, beginning from the Zapadna Morava River valley, extends spatially to Studena and Ravna Mountains, as well as to the higher massif of Željin Mountain. The space consists of the basin of the Gvozdac River, which is oriented in the east-west direction, bordered by two ridge systems on the north and south sides that meet at Prerovo Pass. The catchment area of the Gvozdac River gravitates toward the Ibar River. This relatively small area (3,988.47 ha) has a wide hypsometric coverage from 334 to 1,484 m a.s.l. (12 hypsometric intervals). This mountainous area has only a small portion below 500 m a.s.l. (1.3%). The area between 500 and 1,000 m comprises 55.3%, while elevations above 1,000 m make up 43.4% of the total area. The study area is characterized by very favorable conditions for the development of forest vegetation, considering that 71.7% of the total area is in the range of 800 to 1,200 m a.s.l., which are the assumed values for the development of a climate-regional (oroclimatogenic) mixed forest of beech and fir *Abieti-Fagenion moesiacae* Jov. 1976 (Tomić, 2004). The researched forest is today one of the most preserved forests in the Republic of Serbia. From 2014, the area is legally protected as a Special Nature Reserve.

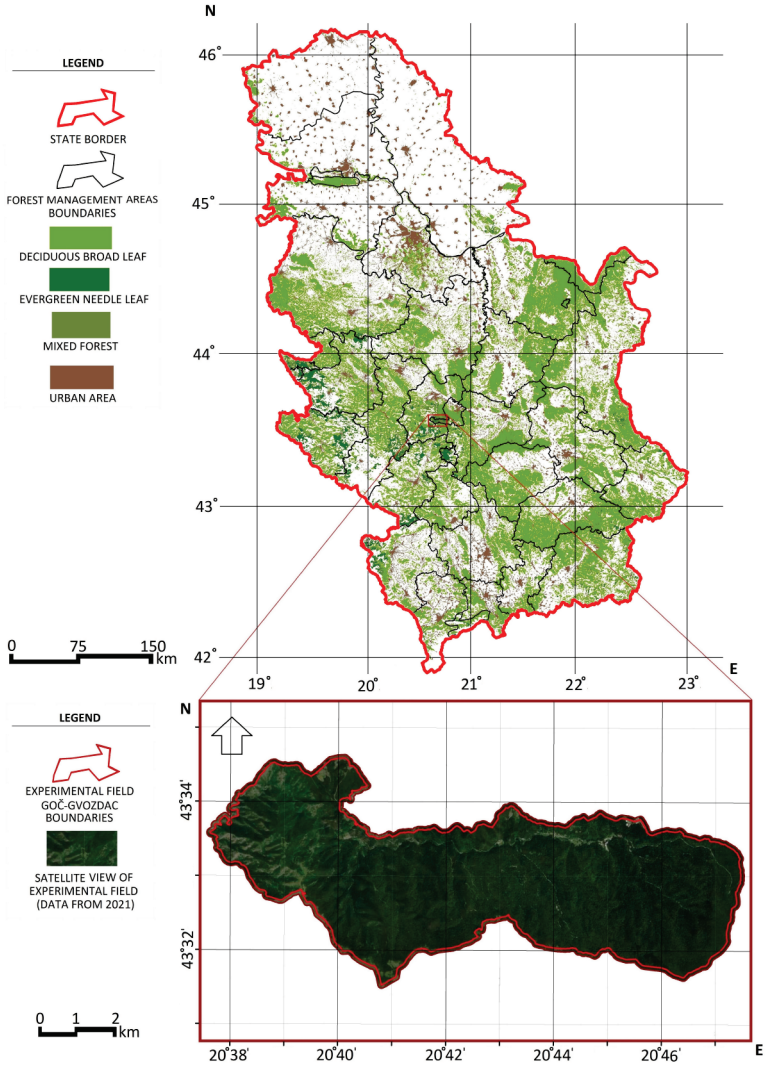

Figure 1. Satellite view of the experimental field "Goč-Gvozdac" in relation to the boundaries of forest management areas and the spatial distribution of forests in Serbia.
Note. Adapted from "ESA WorldCover 10 m 2021 v200 (Version v200)", by D. Zanaga, R. Van De Kerchove, D. Daems, W. De Keersmaecker, C. Brockmann, G. Kirches, J. Wevers, O. Cartus, M. Santoro, S. Fritz, M. Lesiv, M. Herold, N.-E. Tsendbazar, P. Xu, F. Ramoino, and O. Arino, 2022, ESA WorldCover 10 m 2021 v200 (Version v200) [Data set]. Zenodo.

2.2. Materials

Four topographic maps were used in the paper for the analysis of changes in forest cover. Map sheets that coincide with the area of the forest experimental field were used. The oldest of the maps is the General Staff map of the Kingdom of Serbia from 1893, published by the Geografsko odeljenje Glavnog Generalštaba Srpske Vojske (1893) at a scale of 1:75,000. This

is the first map created on the basis of a land survey. For this research, parts of two sheets were used: *D7 Studenica* and *E7 Trstenik*. The second map is the topographical map of the Kingdom of Yugoslavia from 1929 at a scale of 1:100,000, where the part of the sheet *102 Čačak* was used (Vojnogeografski institut, 1929). The third is a topographical map of the Socialist Federal Republic of Yugoslavia from 1971, at a scale of 1:25,000 – parts of two sheets *530-3-4 Kraljevo-Cerje* and *530-4-3 Kraljevo-Goč* (Vojnogeografski institut, 1971). The last used topographic map is from 1985 at a scale of 1:50,000 – parts of sheets *530-3 Kraljevo 3* and *530-4 Kraljevo 4* (Vojnogeografski institut, 1985). The years of print of the maps were previously indicated, while the data for the production were collected for many years.

As the geological background plays a very important role in the appearance of the forests, the paper specifically analyzed the change in the forest areas during the mentioned periods in relation to this parameter. For this purpose, the Basic Geological Map of Yugoslavia, part of sheet *K34-18 Vrnjci,* at a scale of 1:100,000 was used (Zavod za geološka i geofizička istraživanja, 1970).

The fact that 29 officers participated in the first topographical survey of the Kingdom of Serbia (from 1881 to 1892), including famous Serbian dukes (Putnik, Bojović, Mišić, Stepanović) (Bošković, 1931), speaks volumes about the starting material. According to Vemić (2007), with some criticism, Jovan Cvijić evaluated content positively as a breakthrough in the development of cartography. The map was made by photolithography in five colors: black (*gerip*), red (paved roads), blue (hydrography), dark (isohypse – terrain) and green (forests) (Bošković, 1931). The last category was the basis for monitoring changes in forest cover in subsequent editions of topographic maps. The survey was carried out using classical methods and with the help of basic geodetic instruments until 1952, when the mass application of photogrammetry began, which took over the primary role from 1957 (Vojnogeografski institut, 2024). Spatial data are based on satellite view (Zanaga et al., 2022). Sentinel-2 land cover/land use (10 m; available for 2021) were used for comparisons with the obtained data from topographic maps. For this purpose, one ("Trees") of nine spatial data classes generated by the algorithm was used.

2.3. Methods

The process of working methods is shown in the flowchart (Figure 2). Scanned sheets of topographic maps in raster form were processed with the help of ArcGIS Pro software (Version 3.1.0; Esri, n.d.-a). The WGS 1984 UTM (Universal Transverse Mercator) Zone 34N coordinate reference system was used for the GIS analysis. Spatial georeferencing was performed according to the displayed reference grids (intersections of x-y coordinates). For the spatial display, the units of degrees (°), minutes (′), and seconds (″) of latitude and longitude were used. The longitude value of topographic map sheets from 1893 was defined in relation to the prime meridian passing through Paris[1] (Janssen, 1884), while the other maps were defined according to the London (Greenwich – Astronomical Observatory) meridian. They were adjusted in relation to Greenwich (positive difference is 2°20′14″) (L'isle, 2018). Then, the areas under the forest were digitized within the boundaries of the researched area. The data were obtained using manual vectorization, manipulations, and

[1] At the International Conference on Meridians in Washington in 1884, the Greenwich Meridian was adopted as the main meridian.

geometry calculations. Manual vectorization was used due to inadequate accuracy of obtaining data automatically (Ostafin et al., 2017), as a consequence of the poor quality of the used map from 1893. The approach used so far (Istrate et al., 2023; Ostafin et al., 2017; Puziene, 2021, 2024; Puzienė & Anikeniene, 2020) of manual data vectorization has some advantages. Manual digitization confers much better resolutions than the available data (CORINE, ESRI); data sets for older periods are not available and the approach provides a higher degree of accuracy (Istrate et al., 2023). The following indicators were derived for the analysis of the trends of changes in the obtained basic values: the percentage share of the area under forest, the change in the area under forest, and the average annual change in the area under forest in absolute and relative amounts. The paper did not use the complex division of land categories and forest cover trajectory types (Jaworek-Jakubska et al., 2020) due to the impossibility of reliable classification of other land on the researched maps and the lack of such information from cadastral plans (practically due to the limitation of the level of information (detail) of the oldest used map). The well-known lack of the first topographic maps from the geodetic aspect (geodetic inaccuracy) (Istrate et al., 2023) did not significantly affect the quality of the research, considering the size of the study area.

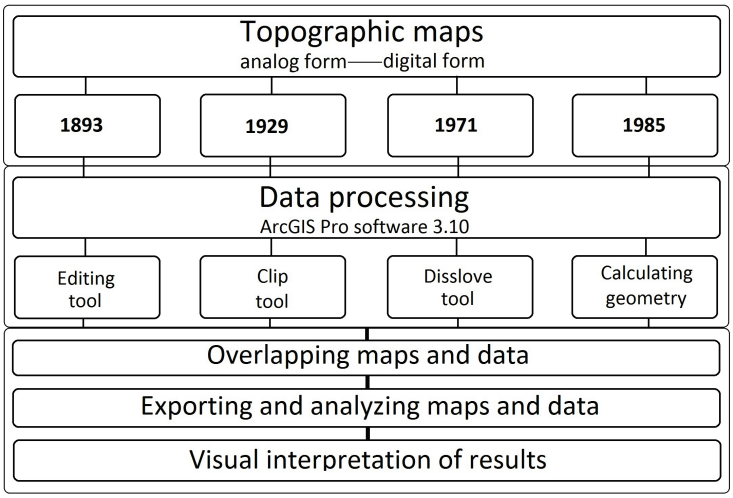

Figure 2. Metodology flowchart.

3. Results

The values obtained from the first topographical map from 1893 showed that the researched area had the smallest area under forest (Figure 3A). On the total area of 3,988.47 ha, 3,094.29 ha (77.6%) were under forest (Table 1). Forest dominated area mostly represented in the central parts of the north-oriented ridge systems that descend into the central part of the Gvozdac river catchment area (left side). Other land was dominantly located on the parts of the southern slopes on the right side of the watershed and the ridge belt of the higher zones of the lower part of the watershed. Areas without forest can be grouped into two units, in relation to the dominantly warm (right side of the watershed) and cold (left side of

the watershed) exposures. On the right side, there is the area around the reef system from *Dobra voda*, *Brezjak*, *Gvozdačka čuka* (to *Gajovača*), *Višnjica*, *Čukar* (*Beli kamen*), and *Veliko brdo* [2]. On the left side, there is also the area of the ridge system from *Velika livada* (*Ravna Mountain*), through *Čukar*, *Zli čukar*, *Kavgalija*, and *Cvetalica* (Studena Mountain) and a side ridge that gravitates toward the central part of the basin in the north-west direction.

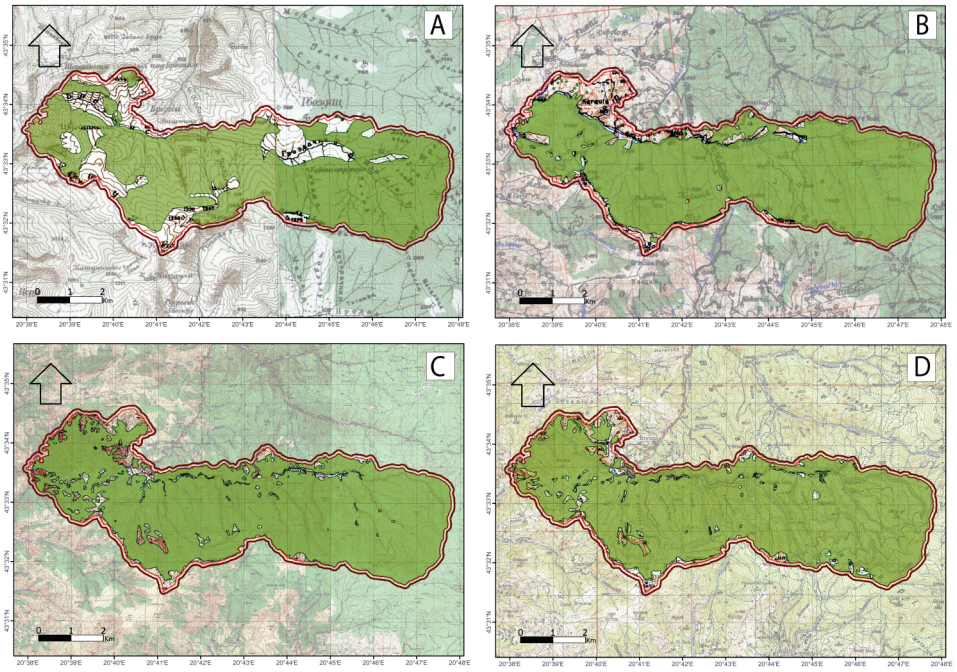

Figure 3. Georeferenced sheets of topographic maps from: 1893 (A); 1929 (B); 1971 (C); and 1985 (D), with the display of digitized areas under forest (green) for the "Goč-Gvozdac" area. The display is of identical scale (1:50,000) with the boundaries of the area highlighted (red line).

According to the second topographic map from 1929, the area of 3,399.93 ha (85.2% of the total area) was under forest. Forests occupied almost all the areas oriented to the north, while parts of the steep sides oriented to the south (in the lower part of the watershed) were still without forest cover (Figure 3B). The forest acquired a significantly more compact character and was practically formed from one continuous unit. In the period of almost four decades (36 years), there was an increase in the area under forest by 305.64 ha (7.6%)[3]. As a result, the remaining areas without forest cover were relatively small.

The values obtained in relation to the third and fourth topographic maps record a slight increase in the areas under forest. According to Figure 3C (1971), the area under forest was 3,543.74 ha (88.8% of the total area). Considering the similar time frame of the analysis (42 years) compared to the previous intermediate period, there was a significantly smaller

[2] The "original toponyms" are listed according to the largest scale map (Topographic map 1:25000).

[3] The percent refers to difference of forest area percents of the total study area.

increase in the area under forest. The area increased by 143.81 ha (3.6%), mostly thanks to the increase in the lower part of the Gvozdac River basin. According to Figure 3D (1985), the area under forest was 3,560.51 ha (89.3% of the total area). The structure of the change in the area under forest referred to slight changes in the areas of almost identical layout and shape of the unified forest area. In relation to the situation presented in the previous map, the shortest period of time passed (14 years) and the smallest increase in the forested area of 16.76 ha (0.5%) was achieved.

Table 1. Values of changes in areas under forest through the analyzed periods

	A	B	C	D	E	F	G	H
n	Year	Total area	Area under forest	$(C_n / B)\cdot 100$ Area under forest	$C_n - C_{n-1}$ Change	$\frac{E_n}{A_n - A_{n-1}}$ Change	$D_n - D_{n-1}$ Change	$\frac{G_n}{A_n - A_{n-1}}$ Change
		ha	ha	%	ha	ha/year	%	%/year
1	1893	3,988.47	3,094.29	77.6	/	/	/	/
2	1929		3,399.93	85.2	+305.64	+8.49	+7.6	+0.211
3	1971		3,543.74	88.8	+143.81	+3.42	+3.6	+0.086
4	1985		3,560.51	89.3	+16.76	+1.19	+0.5	+0.036

According to the average annual absolute and relative values of changes (Table 1), the biggest changes were recorded in the first period, from 1893 to 1929. In this period, there was an increase in the area under forest by 8.49 ha/year (0.211%). The next two reference periods indicate significantly lower rates of increase of 3.42 (0.086%) and 1.19 (0.036%) ha/year. The reason should primarily be sought in the historical circumstances of the development of the attitude toward the forest and the potential space for its increase, given that in 1929, the area under forest already amounted to more than 85%. The average growth rate of areas under forests for the total analyzed period of 92 years (1893–1985) was 5.06 (0.127%) ha/year.

Table 2. Values of changes in areas under forests in relation to the geological formation

Geological formation			I	II	III	IV	V	VI
Total area	Year	ha	2,391.82	720.86	490.10	148.99	126.36	110.33
		%	*60.0*	*18.0*	*12.3*	*3.7*	*3.2*	*2.8*
Area under forest	1893	ha	1,744.75	702.72	434.62	90.48	76.57	53.25
		%	*43.7*	*17.6*	*10.9*	*2.3*	*1.9*	*1.3*
	1929	ha	1,913.07	720.37	485.04	140.89	102.93	45.75
		%	*48.0*	*18.1*	*12.2*	*3.5*	*2.6*	*1.1*
	1971	ha	2,045.23	718.54	483.15	139.73	101.94	62.96
		%	*51.3*	*18.0*	*12.1*	*3.5*	*2.6*	*1.6*
	1985	ha	2,070.16	704.24	485.03	140.41	102.50	66.24
		%	*51.9*	*17.7*	*12.2*	*3.5*	*2.6*	*1.7*

Note. I – harzburgites (peridotites, serpentinites); II – granodiorites; III – chlorite-epidote-actinolite schists and metabasites; IV – calcschists and marbles; V – dacito-andensite; VI – sericite-chlorite schists and metamorphosed sandstones.

The structure of the space according to geological formation in relation to the total area of the considered area is relatively homogeneous (Table 2). Of the six different geological substrates according to the analyzed geological map, harzburgites (peridotites and serpentinites) are dominant on 60.0% of the total experimental field. Based on changes in the distribution of forests throughout the analyzed periods, the greatest increase is precisely on the most abundant geological formation. In this category, in the considered period (1893–1985), there was an increase in the area under forest by 325.42 ha (70% in relation to the total increase). The smallest increase of 1.52 ha (0.3%) occurred on granodiorites (with small variations in the interperiods). This part of the surface is of exceptional importance for the researched forest area, considering that it is almost completely overgrown with highly valuable mixed beech and fir forests.

4. Discussion

Changes in the area under forest in the last few decades have also been noted in other regions of Central Europe, dominantly due to natural succession (Jaworek-Jakubska et al., 2020; Puzienė & Anikeniene, 2020). To understand the changes in the analyzed area, it is necessary to look back at the broader picture of the changes in the state and attitude toward forests in the past. In Serbia, as in most European countries (Istrate et al., 2023; Jaworek-Jakubska et al., 2020; Ostafin et al., 2017; Puziene, 2021, 2024; Puzinė & Anikeniene, 2020), the changes in a historical context cannot be observed without looking into the distant past, when the borders of the states were intensively changing, which undoubtedly had consequences. Part of Central Serbia, from the period when the first analyzed topographical map was created until today, essentially does not have this problem. The geographical areas of Vojvodina, Central Serbia, and Kosovo and Metohija have different histories and differ significantly according to the structure of forests (Banković et al., 2009). Since the researched area is part of Central Serbia, special attention in this part will be devoted to this geographical area.

4.1. Changes in areas under forest in Central Serbia

Changing and unstable political circumstances, the structure of forest ownership, unsettled legal issues, the need for arable land, and changes in the structure of the rural and urban population are historical circumstances that indirectly and directly influence changes in the condition of forests. The different periods had varying levels of importance for the forest as a socio-economic resource, ultimately having a dominant effect on its condition.

By examining the sheets of the first topographical maps of the border territories at the time by Geografsko odeljenje Glavnog Generalštaba Srpske Vojske (1910–1916), the mountain areas that are now mostly under forest did not have such a status at the end of the 19th and the beginning of the 20th century. This was indicated by the description (Đorđević, 1914) and the *Forest Map of the Liberated Areas* from the beginning of the 20th century (Urošević, 1914). The above refers in particular to the then border mountain belt between Serbia and Turkey (Tara, Zlatibor, Zlatar, Jadovnik, Ozren, Javor, Golija, and Kopaonik Mountains). Đorđević (1900) stated that, during the period of the First and Second Serbian-Turkish (1876–1878) and Serbian-Bulgarian (1886) wars, the largest part of the forest was destroyed in the area of 122,805 ha. The attitude of destruction toward the forests in that period was evidenced by one of the oldest preserved expert texts on the condition of

forests (Bogdanović, 1880). The main problems of their destruction were felling (for the use of wood) and burning of forests (to increase arable land), unsettled property relations, and a sudden increase in the number of the population in that period. The state, municipal, and village forests, as well as private forests were equally destroyed (Đorđević, 1900). Of the total area of Serbia at the time (1893) of 4,830,260 ha, Đorđević (1900) stated that 1,546,000 ha, or 32.0% of the total area, were forests and forest lands. Based on the interpretation of Jekić (1928), the mentioned area (forests and forest land) also included pastures (4%), barren areas (2%), karsts, and rocky areas (1%), which indicates that in that period there were 25.0% of the total area. Data from 1989 indicate an increase in forested areas throughout the 20th century (Jović et al., 1992). For Central Serbia, on the area of 5,596,800 ha, the area under forest was 1,790,000 ha, or 32.1%. According to recent data from the first national forest inventory (Banković et al., 2009), in Central Serbia, the area under forest was 2,098,400 ha or 37.6%. The latest data from the second national forest inventory from 2023 (Cuchietti et al., 2023a) show higher values. On the surface of Central Serbia, 2,684,344 ha or 48.0% are under forest. Regardless of the relatively comparable scope of consideration, debatable interpretations of the concept of forest over different periods, the highlighted values clearly indicate the trend of the increase of the area under forest in Central Serbia from the first available data until today.

Since there are no data for the level of Central Serbia for the period from the middle of the 20th century, the available information for the territory of Serbia (with Vojvodina and Kosovo and Metohija) will be listed. According to statistical data from 1938 (Jović et al. 1992), the area under forest was 2,026,000 ha or 23.3% (overgrown area of 1,776,300 or 20.0%). Similar data were obtained from the forest inventory conducted in the period from 1946 to 1949 (Milojković, 1958). The area under forest was 2,104,000 ha or 23.8% (overgrown area of 1,706,000 ha or 19.3%).

In contrast to the previous values, which record positive changes, the area of forest per inhabitant is a parameter with a variable trend of change. Đorđević (1900) stated 0.66 ha per inhabitant, while Jekić (1928) stated 0.56 ha per inhabitant according to the 1910 census. In the middle of the 20th century, the forest area per inhabitant for the level of Serbia was 0.23 ha according to the number of inhabitants in 1956 (Milojković, 1958), and at the end of the century (1990) it was 0.24 ha (Jović et al. 1992). More recent research (Banković et al., 2009; Cuchietti et al., 2023a) states different but slightly higher values (0.30 ha per inhabitant in 2009, 0.43 ha per inhabitant in 2023).

Modern analyses of available data sets based on satellite images do not indicate major changes in the area under forest in the last two decades. Analyses in short periods are not of particular interest for these studies, but they are cited as one of the indicators of the development of the state of forests. According to satellite images from 2000 to 2019 (Cuchietti et al., 2023b), there was a slight increase in the area under forest at the level of Serbia (with Vojvodina and without Kosovo and Metohija) by 39.30% (3,048,385 ha) to 39.64% (3,074,568 ha). In absolute terms, there was an increase in the area under forest by 26,181 ha. According to similar analyzes for the level of Serbia with Kosovo and Metohija for the period from 2000 to 2018 (Tešić, 2022), an increase of 30.8% (2,726,921 ha) to 31.2% (2,760,349 ha) was determined. In accordance with these data, the increase amounts to 33,428 ha. The authors report insignificant positive trends of changes, but significantly different values. The data based on satellite images differ significantly from the values obtained by surveying the forest.

4.2. Changes in areas under forest in the researched area

The state of the forests of the researched area was first described by Đorđević (1900), who introduced the general public to the characteristics of the modest coniferous vegetation (8%) in the Kingdom of Serbia and described the large fir forest on Goč Mountain. According to the planning document for the management unit "Goč-Gvozdac" (Uređajni zapisnik, 1950), the area under forest was 89.0% of the total area. In the next operating period, the management unit was divided into two units, which made it impossible to reliably monitor changes. According to the current forest management plans of this area (Osnova gazdovanja šumama, 2018, 2021), the area covered by forest is 94.5% of the total area. These data are in agreement with the values obtained on the basis of processed spatial data sets of land cover from 2021 (Zanaga et al., 2022) for this area. The area "covered by tree crowns" is 95.1% of the total area. Comparing this value with the previous state according to the topographic map from 1985, there was an increase of 5.8% (0.161% per year), which are values that are in agreement with the established trend of increase (Figure 4).

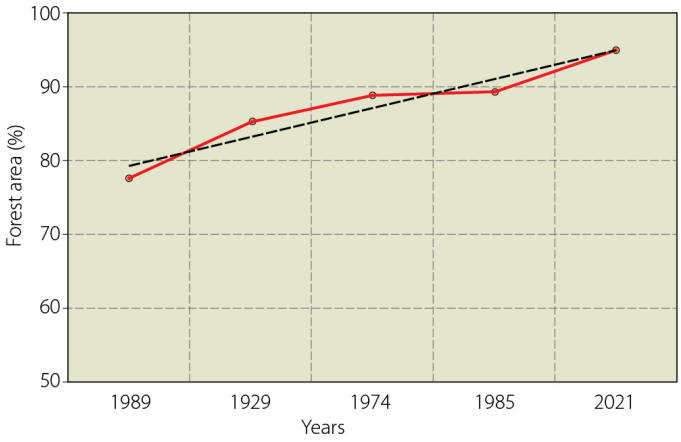

Figure 4. The long-term trend in the percentage of forest area including the latest land cover data (2021).

In the period between 1893 and 1929, the large increase in the area under forest can be explained by the relatively mosaic arrangement of forests and the existence of potential space for its expansion, the composition of tree species (fir, black pine and birch), and the nature of their seeds (dispersal by the wind). Furthermore, the change in the situation was significantly influenced by the adoption of legal acts defining the attitude toward forests (the first law on forests from 1891) and the increasingly controlled conditions of wood exploitation through the development of the forest management system. In the following periods, the greatest influence on the positive trends of increase was achieved by man through the afforestation of non-vegetated forest areas.

The state of the forests before 1893 can only be discussed based on the toponyms of this area, which were certainly created before they were entered on the topographic maps, and which have had continuity since the first one was created. According to the recorded toponyms (phytonyms, oronyms, hydronyms) that indicate the presence (absence) of certain

types of trees, we noted the following: In the western parts of the area, we noted the presence of pioneer forests of pine (*Borovita kosa*) and birch (*Brezovita kosa*, *Brezjak*), while in the eastern part we noted the presence of climate-regional forests of beech (*Bukovac*) and fir (*Ravni jelak*, *Jelače*, *Vlasić*). In the same way, we noted the absence of forests in the period of their creation (*Goline*, *Čelavi breg*, *Cvetalica*, *Čelavi potok*, *Krčanik*, *Prčnjača*, *Čukar*, *Zli čukar*, *Velika livada*). Thus, with significant reliability, it can be stated that the investigated area in relation to the presence, arrangement, and meaning of the recorded toponyms was to a significantly lesser extent covered by forest; especially as the toponyms from the first topographic map that indicated its presence (and particularly its absence) were mostly under forest. In current circumstances, toponyms that indicated the absence of forests in the past provide significant information about the characteristics and the habitat where it developed.

There is a lack of comparable literature data for the obtained area on the intensities of change at the annual level in absolute and relative amounts. In similar local studies (Istrate et al., 2023; Puzienė & Anikeniene, 2020), the absolute values of increase are generally not comparable, although the changes have the same increasing trend. The positive changes were undoubtedly influenced by the declaration of the area as an experimental field in 1956.

5. Conclusion

A long period has passed since the first descriptions of the condition and characteristics of forests in Serbia on a relatively subjective level until today. The first topographic maps, created more than a century ago showing the distribution of forests, as well as their subsequent editions, were not properly used in the age of available information technologies. In the paper, the mentioned advantages of topographic maps were used to more appropriately consider the question of the change of the area under forest in a historical context on a relatively modest surface coverage. The increase in the area under forest according to the conducted research in the selected locality has the following characteristics:

- In the period from 1893 to 1985, the area under forest increased from 77.6% to 89.3%, i.e. 11.7% of the total area. In absolute values, the increase is 466.22 ha (from 3,094.29 ha to 3,560.51 ha);
- In the period of the 92 years of consideration, the average annual increase was 5.06 ha. The annual rate of increase, absolute and relative values decreased over time. The largest increases were achieved in the first period (1893–1929), and the smallest in the last one (1971–1985);
- According to the current state (planning documents, spatial data sets) in relation to the reference year of observation (1893), there was an increase in the area under forest from 77.6% to 94.5% (planning documents), i.e. 95.1% (spatial data of land cover). In the past period of 128 years, the increase is 16.9% (17.5%);
- The results of the change in relation to the geological base, in addition to the dominant increase in the part covered by peridotites and serpentinites (70%), indicate another significant fact. Part of the best quality mixed forests of beech and fir on granodiorites (720.86 ha) was almost continuously overgrown with forest (1893 – 97.5%; 1929 – 99.9%; 1971 – 99.7%; 1985 – 97.7%). In addition to the favorable habitat conditions for the development of the forest on this formation (rocks of Neogene age, altitude), this fact

was significantly influenced by the defined management system developed in the specific locality. In the scientific and professional sense, this is the most significant contribution of man to the preservation and maintenance of this forest area;
- Practically, during the 20th century, a continuous increase in the area under forest was realized in the area of the experimental field.

Analyses of changes in forested areas based on topographic maps should be viewed as a reliable historical resource that objectively ascertains the state through different periods. At the same time, they are potentially applicable at the level of Central Serbia, given the established indications of trends and the availability of data. In the time of availability of satellite images and modern geoinformation systems, this category can lose its primacy only under the condition of using their capacities in full, which requires significantly more invested intellectual effort and time. It also refers to the length of the period for consideration of changes. The research attempted to use the quality of available information on topographic maps (extensive and demanding research) and the advantages of modern available technology for their processing. As pioneering research, in a certain sense, the activities carried out have significance in application to other areas of interest. In this way, we can make forest management planning more reliable, given that reliable information can be provided in a clear way about the trend of changes in the basic parameter of the state of the forest.

References

Banković, S., Medarević, M., Pantić, D., & Petrović, N. (2009). *Nacionalna inventura šuma Republike Srbije: šumski fond Republike Srbije* [The National forest inventori of the Republic of Serbia: The growing stock of the Republic of Serbia]. Ministarstvo poljoprivrede, šumarstva i vodoprivrede, Uprava za šume.

Bogdanović, V. S. (1880). Satiranje gore kod nas [Destruction of our forest]. *Težak. Ilustrovani list za poljsku privredu 1*(11), 5–7.

Bošković, S. (1931). Geodetski i kartografski radovi Vojnog geografskog instituta 1878–1930 [Geodetic and cartographic works of the Military Geographical Institute 1878–1930]. *Geometarski glasnik, 11*(1–2), 1–10.

Cuchietti, A., Morales-Hidalgo, D., & García, J. (2023a). Annex 2. Complementary document to the results of the Serbian Second National Forest Inventory. Land Use Assessment using the two-phase sampling approach. https://upravazasume.gov.rs/oglasna-tabla/naredbu-o-proglasenju-prirodne-nepogode-i-merama-zastite-i-sanacije-suma-ostecenih-vetrolomima-i-vetroizvalama-2/

Cuchietti, A., Morales-Hidalgo, D., & García, J. (2023b). Annex 1. Complementary document to the results of the Serbian Second National Forest Inventory. Land Cover Change assessment using the FAO Collect Earth tool from 2000 to 2019. https://upravazasume.gov.rs/oglasna-tabla/naredbu-o-proglasenju-prirodne-nepogode-i-merama-zastite-i-sanacije-suma-ostecenih-vetrolomima-i-vetroizvalama-2/

Đorđević, K. (1900). *Šume u Kraljevini Srbiji. Spomenica za svetsku izložbu u Parizu 1900. godine* [Forests in the Kingdom of Serbia. Monument to the World Exhibition in Paris in 1900]. Ministarstvo Narodne privrede, šumarsko odeljenje.

Đorđević, P. (1914). Rasprostranjenje šuma u oslobođenim oblastima Srbije [The distribution of forests in the liberated areas of Serbia]. *Glasnik Srpskog geografskog društva*, *3*(3–4), 249–250. https://www.glasniksgd.rs/index.php/home/article/view/831/pdf

Esri. (n.d.-a). *ArcGIS Pro* (Version 3.1.0) [Computer software]. ESRI Inc. https://www.esri.com/en-us/arcgis/products/arcgis-pro/overview

Geografsko odeljenje Glavnog Generalštaba Srpske Vojske. (1893). *Generalštabna karta Kraljevine Srbije 1.75.000. List D7 Studenica i list E7 Trstenik* [General Staff Map of the Kingdom of Serbia 1:75,000. Sheet D7 Studenica and sheet E7 Trstenik]. National Library of Serbia, signature: maps and plans, II 2/D7, IN: 600601012 and II 2/E7, IN: 600601019.

Geografsko odeljenje Glavnog Generalštaba Srpske Vojske. (1910–1916). *Generalštabna karta Kraljevine Srbije i susednih zemalja 1:150.000. List V5 Pljevlja, list G5 Ivanjica i list D5 Raška*. [General Staff Map of the Kingdom of Serbia and neighboring countries 1:150,000. Sheet V5 Pljevlja, sheet G5 Ivanjica and sheet D5 Raška]. National Library of Serbia, signature: maps and plans, II 5/V5, IN: 601001424; II 5/G5, IN: 601004724 and II 5/D5, IN: 601004727.

Istrate, G.-A., Istrate, V., Ursu, A., Ichim, P., & Breabăn, I.-G. (2023). Using Diachronic Cartography and GIS to Map Forest Landscape Change in the Putna-Vrancea Natural Park, Romania. *Land, 12(9),* Article 1774. https://doi.org/10.3390/land12091774

Izvršno veće Narodne Republike Srbije. (1956). *Odluka IV br. 733/1, 22. oktobar, 1956. (3.731 hectar)* [Decision IV no. 733/1 of October 22, 1956 (3,731 hectares)].

Janssen, M. (1884). Discussion, Session of October 6, 1884. In *International Conference Held at Washington for the Purpose of Fixing a Prime Meridian and a Universal Day* (III), pp. 43–51. Project Gutenberg. Retrieved from https://www.gutenberg.org/files/17759/17759-h/17759-h.htm

Jekić, J. (1928). *Prilozi za istoriju šumarstva u Srbiji* [Contributions to the history of forestry in Serbia]. „Davidović" Pavlovića.

Jaworek-Jakubska, J., Filipiak, M., & Napierała-Filipiak, A. (2020). Understanding of Forest Cover Dynamics in Traditional Landscapes: Mapping Trajectories of Changes in Mountain Territories (1824-2016), on the Example of Jeleniogórska Basin, Poland. *Forests, 11*(8), Article 867. https://doi.org/10.3390/f11080867

Jović, D., Tomanić, L., & Banković, S. (1992). Šumski fond i uređivanje šuma [The growing stock and forest management planing]. In S. Nikolić (Ed.), *Šumarstvo i prerada drveta u Srbiji kroz vekove* [Forestry and wood processing in Serbia throughout the centuries] (pp. 10–22). Savez inženjera i tehničara šumarstva i industrije za preradu drveta Srbije.

Kaim, D., Kozak, J., Kolecka, N., Ziółkowska, E., Ostafin, K., Ostapowicz, K., & Radeloff, V. C. (2016). Broad scale forest cover reconstruction from historical topographic maps. *Applied Geography, 67,* 39–48. http://dx.doi.org/10.1016/j.apgeog.2015.12.003

Kienast, F. (1993). Analysis of historic landscape patterns with a Geographical Information System: A methodological outline. *Landscape Ecology, 8,* 103–118. http://dx.doi.org/10.1007/BF00141590

L'isle, R. D. (2018). Historic Notes on the Difference of Longitude Between Paris and Greenwich. *The International Hydrographic Review, 3*(2), 177–181. (Original work published 1926). Retrieved from https://journals.lib.unb.ca/index.php/ihr/article/view/27797

Matović, M. (2019). *Fragmenti o Čačku* [Fragments about Čačak]. Narodni muzej Čačak.

Milojković, D. (1958). Stanje, problemi i perspektive daljeg razvitka šumskog fonda [State, problems and perspectives of further development of the growing stock]. In R. Ivkov & D. Simeunović (Eds.), *Razvoj šumarstva i drvne industrije Jugoslavije 1945–1956* [Development of forestry and wood industry in Yugoslavia 1945–1956] (pp. 15–44). Savez inženjera i tehničara šumarstva i drvne industrije Jugoslavije.

Osnova gazdovanja šumama. (2018). *Plan gazdovanja šumama za gazdinsku jedinicu Goč-Gvozdac A, za period od 2019. do 2028. godine* [Forest management plan for the management unit Goč-Gvozdac A, for the period from 2019 to 2028]. Univerzitet u Beogradu, Šumarski fakultet.

Osnova gazdovanja šumama. (2021). *Plan gazdovanja šumama za gazdinsku jedinicu Goč-Gvozdac B, za period od 2022. do 2031. godine* [Forest management plan for the management unit Goč-Gvozdac B, for the period from 2022 to 2031]. Univerzitet u Beogradu, Šumarski fakultet.

Ostafin, K., Iwanowski, M., Kozak, J., Cacko, A., Gimmi, U., Kaim, D., Psomas, A., Ginzler, C., & Ostapowicz, K. (2017). Forest cover mask from historical topographic maps based on image processing. *Geoscience Data Jurnal, 4*(1), 29–39. https://doi.org/10.1002/gdj3.46

Puzienė, R., & Anikėnienė, A. (2020, May 21–22). *Investigation of Forest Area Change in the 19th–21st Century Using Military Topographic Maps*. 11th International Conference "Environmental Engeneering", Vilnus Geodiminas Tehnical University, Lithuania. https://doi.org/10.3846/enviro.2020.659

Puziene, R. (2021). Investigation of the Change of Wooded Aareas in Forest Land in Raudone Eldership. *Baltic Surveying, 14*, 60–68. https://doi.org/10.22616/j.balticsurveying.2021.14.007

Puziene, R. (2024). Investigating Forest Cover Change Using Historical GIS Technologies: A Case Study with an Example of Jurbarkas District of the Republic of Lithuania. *Sustainability, 16*(11), Article 4825. https://doi.org/10.3390/su16114825

Sentinel-2. (2023). Sentinel-2 Land Cover Explorer, T34 zone [Raster data]. Retrieved from https://livingatlas.arcgis.com/landcoverexplorer/#mapCenter=21.21246%2C44.93392%2C7.9377167329514515&mode=step&timeExtent=2017%2C2023&renderingRule=0&year=2023

Stäuble, S., Martin, S., & Reynard, E. (2008). *Historical mapping for landscape reconstruction: Examples from the Canton of Valais (Switzerland*). 6th ICA Mountain Cartography Workshop Mountain Mapping and Visualisation (pp. 211–217). https://serval.unil.ch/resource/serval:BIB_2F24A582C26E.P001/REF.pdf

Tešić, D. (2022). Corine Land Cover change detection in Serbia and Bosnia and Herzegovina. *Researches Reviews of the Department of Geography, Turism and Hotel Management*, *51*(2), 98–110. http://doi:10.5937/ZbDght2202098T

Tomić, Z. (2004). *Šumarska fitocenologija* [Forestry phytocenology]. Univerzitet u Beogradu, Šumarski fakultet.

Uređajni zapisnik. (1937). *Privredni plan gazdovanja šumama za gazdinsku celinu Goč-Željin (sliv Gvozdačke reke), za period od 1936/37. do 1945/46. godine* [Economic forest management plan for the management area Goč-Željin (Gvozdac river basin), for the period from 1936/37 to 1945/46]. Direkcija šuma u Čačku. Šumska uprava u Kraljevu. Odeljenje za upravu državnih šuma, Ministarstvo šuma i rudnika Kraljevine Jugoslavije.

Uređajni zapisnik. (1950). *Privredni plan gazdovanja šumama za gazdinsku celinu Goč-Željin (gazdinska jedinica Goč-Gvozdac), za period od 1949. do 1959. godine* [Economic forest management plan for the management area Goč-Željin (management unit Goč-Gvozdac), for the period from 1949 to 1959]. Šumsko gazdinstvo u Rankovićevu. Biro za projektovanje u šumarstvu, Ministarstvo šumarstva Narodne Republike Srbije.

Urošević, K. (1914). Prostiranje četinara u Jugozapadnoj Srbiji [Distribution of conifers in Southwestern Serbia]. *Glasnik Srpskog geografskog društva*, *3*(3–4), 82–90. https://www.glasniksgd.rs/index.php/home/article/view/810/pdf_1

Vemić, M. (2007). Kartografija Srbije u XX veku [Cartography of Serbia in the 20th century]. *Journal of the Geographical Institute "Jovan Cvijić" SASA, 57*, 407–415. https://doi.org/10.2298/IJGI0757407V

Vojnogeografski institut. (2024). *Istorijat Vojnogeografskog instituta "General Stevan Bošković"* [History of the Military Geographical Institute "General Stevan Bošković"]. Retrieved June 14, 2024 from https://www.vgi.mod.gov.rs/lat/209/istorijat-209

Vojnogeografski institut. (1929). *Topografska karta Kraljevine Jugoslavije 1:100,000. List 102 Čačak* [Topographic map of the Kingdom of Yugoslavia 1:100,000. Sheet 102 Čačak].

Vojnogeografski institut. (1971). *Topografska karta Socijalističke Federativne Republike Jugoslavije 1:25,000. List 530-3-4 Kraljevo-Cerje i list 530-4-3 Kraljevo-Goč* [Topographic map of the Socialist Federal Republic of Yugoslavia 1:25,000. Sheet 530-3-4 Kraljevo-Cerje and sheet 530-4-3 Kraljevo-Goč].

Vojnogeografski institut. (1985). *Topografska karta Socijalističke Federativne Republike Jugoslavije 1:50,000. List 530-3 Kraljevo 3 i list 530-4 Kraljevo 4* [Topographic map of the Socialist Federal Republic of Yugoslavia 1:50,000. Sheet 530-3 Kraljevo 3 and 530-4 Kraljevo 4].

Zanaga, D., Van De Kerchove, R., Daems, D., De Keersmaecker, W., Brockmann, C., Kirches, G., Wevers, J., Cartus, O., Santoro, M., Fritz, S., Lesiv, M., Herold, M., Tsendbazar, N.-E., Xu, P., Ramoino, F., & Arino, O. (2022). *ESA WorldCover 10 m 2021 v200* (Version v200) [Data set]. Zenodo. https://doi.org/10.5281/zenodo.7254221

Zavod za geološka i geofizička istraživanja. (1970). *Osnovna geološka karta Socijalističke Federativne Republike Jugoslavije 1:100,000. List K-34-18 Vrnjc*i [Basic geological map of the Socialist Federal Republic of Yugoslavia 1:100,000. Sheet K-34-18 Vrnjci].

Živković, D. (2012). Srpska kartografija – od inženjerske do digitalne [Serbian cartography – from engineering to digital]. *Glasnik Srpskog geografskog društva, 92*(3), 1–17. https://doi.org/10.2298/GSGD1203001Z