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ASSESSING AVERAGE ANNUAL AIR TEMPERATURE TRENDS USING THE MANN–KENDALL TEST IN KOSOVO

Milivoj B. Gavrilov, Slobodan B. Marković, Natalija Janc, Milena Nikolić,
Aleksandar Valjarević, Blaž Komac, Matija Zorn, Milan Punišić†, Nikola Bačević

Temperatures were confirmed to rise in Kosovo in the last decades.

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Assessing average annual air temperature trends using the Mann–Kendall test in Kosovo

ABSTRACT: The annual trends of surface mean monthly air temperature and monthly extreme temperatures were analyzed from ten meteorological stations in Kosovo. The data refer to observation periods between 1949 and 1999 for four stations, and observation periods between 1965 and 1999 for the remaining six stations. Trends were analyzed for nine time series. Positive trends were found in six series, and negative trends were found in three series. After an assessment of these trends using the Mann–Kendall test, positive trends were confirmed in four series, a negative trend was confirmed in one series, and in one series there was no trend, whereas trends were characterized as slightly positive in two time series and slightly negative in one series.

KEY WORDS: air temperature trends, climate change, Mann–Kendall test, Kosovo

Ocena trendov povprečnih letnih temperatur zraka na Kosovu z uporabo Mann-Kendallovega testa

POVZETEK: V raziskavi so bili analizirani letni trendi povprečnih in ekstremnih mesečnih temperatur zraka, izmerjenih na desetih meteoroloških postajah na Kosovu. Podatki se pri štirih postajah nanašajo na opazovalno obdobje 1949–1999, pri preostalih šestih postajah pa na opazovalno obdobje 1965–1999. Trendi so bili analizirani za devet časovnih nizov. Pozitivni trendi so bili ugotovljeni v šestih nizih, negativni pa v treh. Po oceni teh trendov z uporabo Mann-Kendallovega testa so bili pozitivni trendi potrjeni v štirih nizih, negativni trend je bil potrjen v enem nizu, v enem nizu trenda ni bilo, rahlo pozitivni trendi so bili potrjeni v dveh časovnih nizih in rahlo negativni v enem nizu.

KLJUČNE BESEDE: trendi temperatur zraka, podnebne spremembe, Mann-Kendallov test, Kosovo

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1 Introduction

According to the Intergovernmental Panel on Climate Change (IPCC 2007) report, the average global surface air temperature of the world has increased by 0.7 °C in the last hundred years. Klein Tank et al. (2002) showed that trends in average temperature increased in the period between 1946 and 1999 in Europe. This increase in global and regional temperature varies seasonally and regionally. In Europe the trends are higher in central and north-eastern areas and in mountainous regions, whereas lower trends are found in the Mediterranean region and temperatures are increasing higher in winter than summer (all during the period from 1977 to 2000; Alcamo et al. 2007).

Historically, the climate of Kosovo has generally been analyzed as part of the climate of Serbia and Yugoslavia. Using extreme temperatures at fifteen meteorological stations in Serbia, Unkašević and Tošić (2013) suggested that the climate in the region warmed up between 1949 and 2009. Analyzing data between 1949 and 2007, Unkašević and Tošić (2009a) found that a slow decrease in summer temperatures until 1975 was followed by a temperature increase lasting until 2007. In addition to these papers, other recent works addressing the climate in Serbia with and without Kosovo have been published (Jovanović et al. 2002; Gburčik et al. 2006; Đorđević 2008; Unkašević and Tošić 2009b; Gavrilov et al. 2010; 2013; Pavlović Berdon 2012; Hrnjak et al. 2014; Tošić et al. 2014; Gavrilov et al. 2015; 2016). In addition, the weather and climate of Kosovo were investigated in the work of Sokolović et al. (1984).

This study focuses on average annual air temperature trends in Kosovo from 1949 to 1999 and from 1965 to 1999. The first period contains nearly two thirty-year-climate cycles, and the second contains more than one thirty-year-climate cycle. Therefore the results are proper indicators for recent climate change.

2 Area and data

2.1 Study area

Kosovo is located in the southwestern part of the Balkan Peninsula and covers an area of 10,887 km^2 (Figure 1). Its geomorphological characteristics and geographical location divide it into two regions; Kosovo proper in the east is a plateau with a relatively consistent elevation, and Metohija in the west is a hilly area bordered by high mountains. The climate of Kosovo is moderate continental with cold winters and warm summers, with a great range of extreme temperatures and a non-uniform distribution of rainfall. The average annual air temperature is 10.8 °C, and the annual amount of precipitation between 1949 and 1999 was 669 mm (Internet 1).

2.2 Data

This work contains an analysis of surface air temperature trends obtained from ten meteorological stations. The locations of the stations are presented in Figure 1, and their main parameters are given in Table 1

Table 1: List of meteorological stations and their geographical coordinates and elevations.

Number	Meteorological station	Elevation (m)	Latitude (°N)	Longitude (°E)
Stations operated from 1949 to 1999				
1	Kosovska Mitrovica	510	42° 53'	20° 52'
2	Peć	498	42° 40'	20° 18'
3	Prizren	402	42° 13'	20° 44'
4	Priština	573	42° 39'	21° 09'
Stations operated from 1965 to 1999				
5	Istok	465	42° 47'	20° 30'
6	Skivijane	415	42° 28'	20° 21'
7	Suva Reka	420	42° 21'	20° 49'
8	Gnjilane	520	42° 28'	21° 29'
9	Uroševac	580	42° 23'	21° 10'
10	Dragaš	1060	42° 04'	20° 39'

in accordance with the Republic Hydrometeorological Service of Serbia. Meteorological stations were divided into two groups, depending on the periods in which they were first established and operational. The first group consists of four stations that operated from 1949 to 1999, and the second group consists of the remaining six stations, which operated from 1965 to 1999. Nine of the stations have a relatively uniform elevation, varying between 402 m and 580 m, whereas the Dragaš station has an elevation of 1,060 m (in this paper it is referred to as a mountain station).

In order to obtain trends, we used three data sets: monthly mean temperatures, monthly maximum temperatures, and monthly minimum temperatures for all stations. From the monthly temperatures, the average annual mean temperatures, average annual maximum temperatures, and average annual minimum temperatures were calculated. Finally, from these three types of average annual temperatures, new data sets were derived, marked as: T, T_x, and T_n, respectively, for trend calculations for Kosovo (K) over two periods: 1949–1999 (P1) from four stations (Kosovska Mitrovica, Peć, Prizren, and Priština) and 1965–1999 (P2)

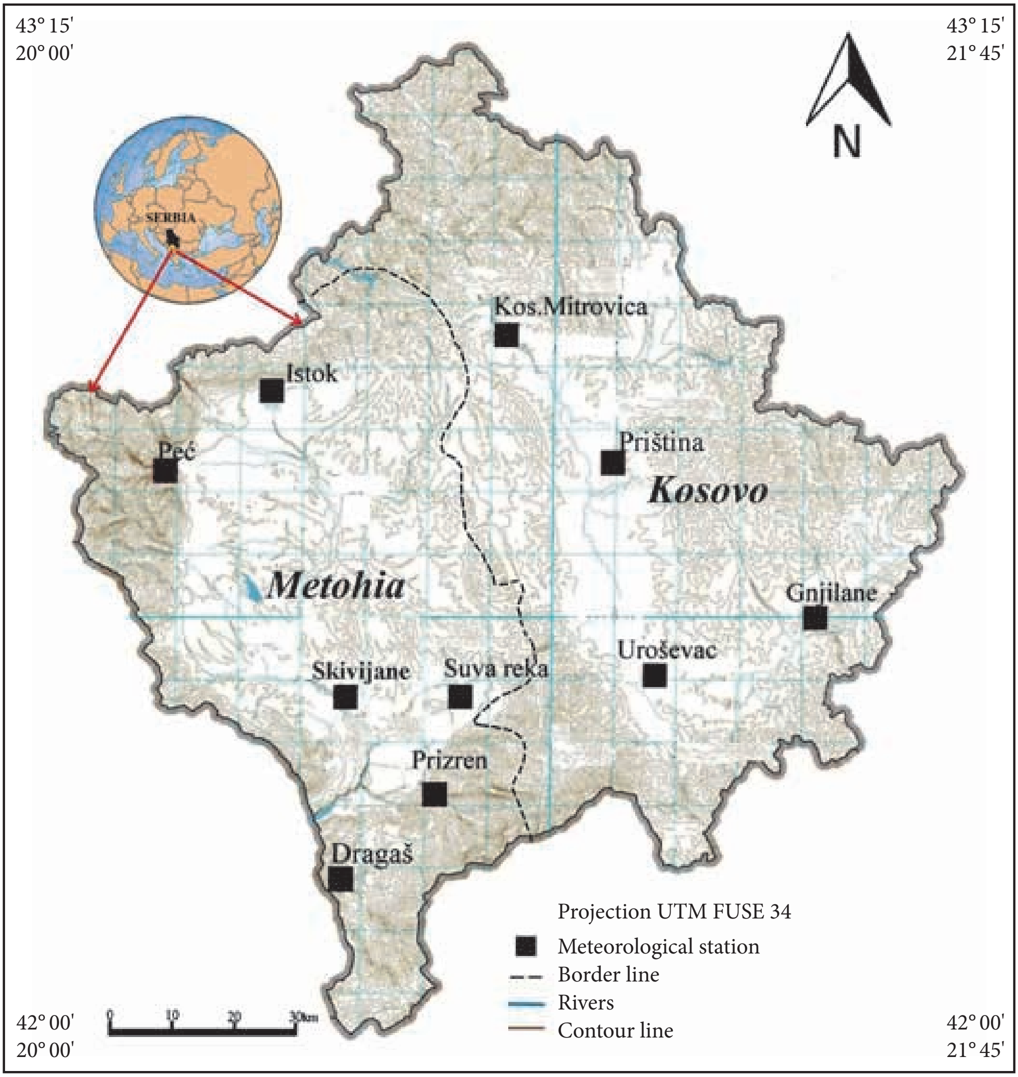

Figure 1: Kosovo.

from five stations (Istok, Skivijane, Suva Reka, Gnjilane, and Uroševac); whereas Dragaš (D) was treated as a special data set because it is a mountain station, with data available for the period from 1965 to 1999 (P2). Each of these data sets is marked with an acronym consisting of the abbreviation for the territory/station, period, and type of temperature. In total, all nine data sets (time series) were used for trend calculation (Table 2).

Table 2: List of nine time series to calculate air temperatures trends.

Territory/station	1949–1999 (P1)	1965–1999 (P2)
	K-P1-T	K-P2-T
Kosovo (K)	K-P1-T_x	K-P2-T_x
	K-P1-T_n	K-P2-T_n
	–	D-P2-T
Dragaš (D)	–	D-P2-T_x
	–	D-P2-T_n

Before the previous calculation, the homogeneity of the temperature data was examined according to the Alexandersson (1986) test. The test showed that the time series are not non-homogeneous for a significance level of 5%.

3 Methods

Temperature trends were analyzed for nine time series using two statistical approaches: calculation of the linear temperature trend equation and application of the Mann–Kendall test.

The first approach was to calculate the tendency (trend) equation of temperature using linear interpolation of the average annual temperatures (Wibig and Glowicki 2002). This method was used to determine the sign of the temperature trends and the trend magnitude (Gavrilov et al. 2015; 2016) as the difference in temperatures between the beginning and end of both periods P1 and P2.

The second statistical approach used the Mann–Kendall test (Kendall 1975; Gilbert 1987) to indicate statistically significant trends. The Mann–Kendall test is widely used in analysis of climatologic time series; for example, temperature and precipitation (Karmeshu 2012), extreme temperatures (Wibig and Glowicki 2002), hail (e.g., Gavrilov et al. 2010, 2013), aridity (Hrnjak et al. 2014), evapotranspiration (Tabari et al. 2011), and atmospheric deposition (Drapela and Drapelova 2011), and also in hydrological time series (Yue and Wang 2004) and other geophysical time series, such as soil freezing and thawing (Sinha and Cherkauer 2007) because it is simple and robust, and it can cope with missing values and values below the detection limit.

In using the Mann–Kendall test to define statistically significant trends, two hypotheses were tested: the null hypothesis, H_0, that there is no trend in the time series, and the alternative hypothesis, H_a, that there is a trend in the time series for a given significance level. Probability p in percent (Karmeshu 2012; Gavrilov et al. 2016) was calculated to determine the level of confidence in the hypothesis. If the computed value p is lower than the chosen significance level α (e.g., $\alpha = 5\,\%$), the H_0 (*there is no trend*) should be rejected, and the H_a (*there is a significant trend*) should be accepted; and if p is greater than the significance level α then the H_0 is accepted (or cannot be rejected). For calculating probability p and hypothesis testing, XLSTAT statistical analysis software was employed (Internet 2).

It is considered that accepting the H_a indicates that a trend is statistically significant. On the other hand, acceptance of the H_0 implies that there is no trend (no change), whereas often in practice the trend equation indicates the opposite; that is, that there is a trend. Therefore, to reduce the contradictions in analyzing the temperature trends between two independent statistical approaches – the trend equation and the Mann–Kendall test – the modified interpretation of the Mann–Kendall test will be offered. Moreover, this interpretation makes it possible to obtain more diverse results.

It is quite clear that, with decreasing probability p, statistical confidence in the H_0 decreases and confidence in the H_a increases, and vice versa. Because probability p takes values between 0% and 100%, for the purposes of this study a modified interpretation of the Mann–Kendall test was introduced and four levels of confidence were defined (Gavrilov et al. 2015; 2016). When the computed probability p is: (1) less or equal to 5%, the trend is significantly positive/negative; (2) greater than 5% and less than or equal to 30%, the trend is moderately positive/negative; (3) greater than 30% and less than or equal to 50%, the trend is slightly positive/negative; and (4) greater than 50%, there is no trend. As can be seen, in cases (1) and (4) both interpretations of the Mann–Kendall test have the same meaning; namely, that there is a significant trend and that there is no trend. Differences occur in cases (2) and (3), where the Mann–Kendall test claims there is no trend, and the modified Mann–Kendall test allows a trend with reduced levels of confidence.

4 Results and discussion

4.1 The values of trends

By applying both statistical approaches to each of the nine time series in Table 2, nine cases are obtained (Table 3).

Table 3: The trend equation *y*, the trend magnitude Δ*y*, and probability *p* of the confidences for all time series.

Time series	Trend equation	Δ*y* (°C)	*p* (%)
K-P1-T	$y = -0.006\,x + 10.97$	0.3	25
K-P1-T_x	$y = 0.013\,x + 23.50$	–0.7	17
K-P1-T_n	$y = 0.012\,x - 1.40$	–0.6	4.5
K-P2-T	$y = 0.021\,x + 10.31$	–0.7	1
K-P2-T_x	$y = 0.024\,x + 23.42$	–0.8	2
K-P2-T_n	$y = 0.011\,x - 2.17$	–0.4	24
D-P2-T	$y = -0.003\,x + 8.31$	0.1	89
D-P2-T_x	$y = 0.070\,x + 20.41$	–2.5	1
D-P2-T_n	$y = -0.047\,x - 1.76$	1.7	1

In Table 3 the first column is the time series; the second column is the linear trend equation, where *y* is the average annual value of the temperature in °C and *x* is the time in years; Δ*y* is the trend magnitude in °C; and *p* is the probability in percent, $\alpha = 5\%$ is the significance level (it is the same in all cases).

4.2 Evaluation of trends

In strictly formal terms, as evidenced by the trend equations in Table 3, in all cases some trends can be observed. However, not all trends have the same sign, magnitude, and probability. To obtain the final evaluation of temperature trends, values from Table 3, Figures 2–4, and the results of hypothesis testing were used.

Figure 2 and the trend equations for the time series K-P1-T, K-P1-T_x, and K-P1-T_n show that the trends are negative once and positive twice, respectively. Mann–Kendall test will prove whether these statements are true. Because the probabilities *p* are greater than the significance level, $\alpha = 5\%$, the H_0 cannot be rejected in the first two cases. The risk of rejecting the H_0 while it is true are 25% and 17%, respectively. Because the *p* in K-P1-T_n is lower than the significance level, the H_0 should be rejected and the H_a should be accepted. The statement that there is a trend is correct with a probability greater than 95%. In accordance with the modified Mann–Kendall test, these three trends are characterized as moderately negative, moderately positive, and significantly positive, respectively.

Figure 3 and the trend equations for the time series K-P2-T, K-P2-T_x, and K-P2-T_n show that the trends are positive in all cases. Mann–Kendall test will prove whether these statements are true. Because the probabilities *p* in K-P2-T and K-P2-T_x are lower than the significance level, $\alpha = 5\%$, the H_0 should be rejected and the H_a should be accepted in both cases. The statement that there are trends is correct with a probability greater than 98%. Because the *p* in K-P2-T_n is greater than the significance level, the H_0 cannot be rejected. The risk of rejecting the H_0 while it is true is 24%. In accordance with the modified Mann–Kendall test, these cases are characterized as significantly positive twice and moderately positive once, respectively.

Figure 4 and the trend equations for the time series D-P2-T, D-P2-T_x, and D-P2-T_n show that the trends are negative, positive, and negative, respectively. Mann–Kendall test will prove whether these statements are true. Because probability *p* in D-P2-T is greater than the significance level, $\alpha = 5\%$, the H_0 cannot be rejected.

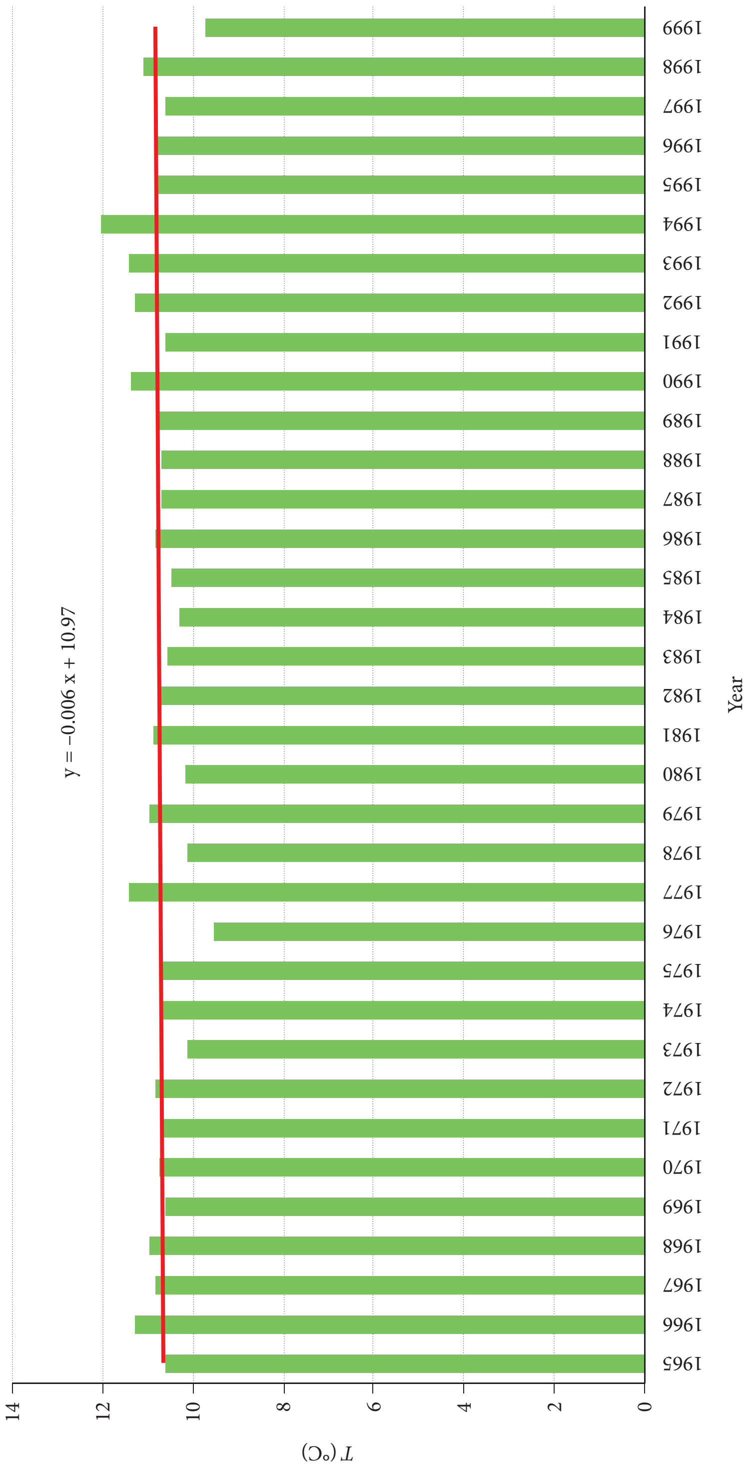
y = −0.006 x + 10.97
T (°C)
0
2
4
6
8
10
12
14
Year
1965
1966
1967
1968
1969
1970
1971
1972
1973
1974
1975
1976
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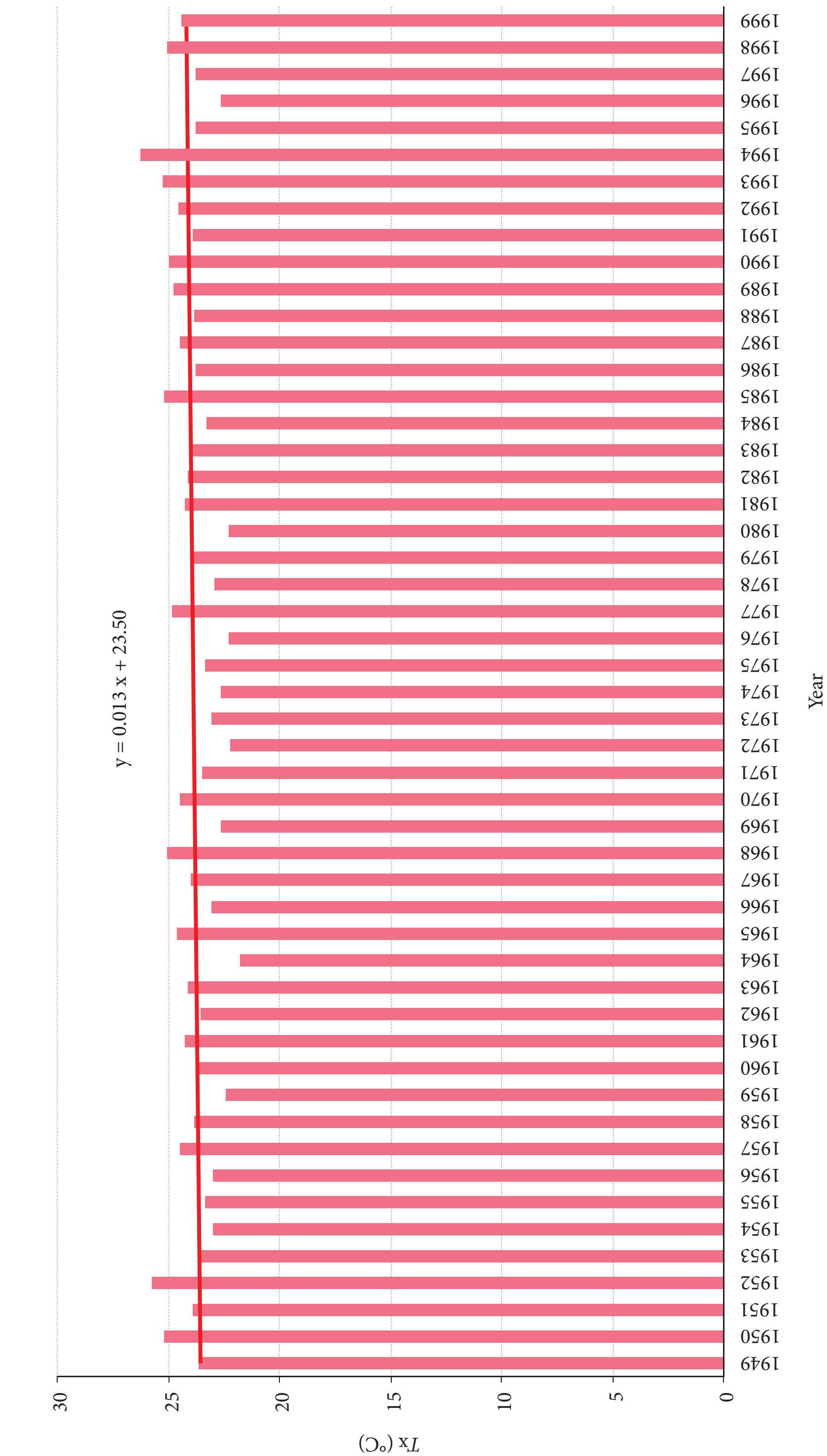
Figure 2a


y = 0.013 x + 23.50
Tx (°C)
Year
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5
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15
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25
30
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1954
1955
1956
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Figure 2b

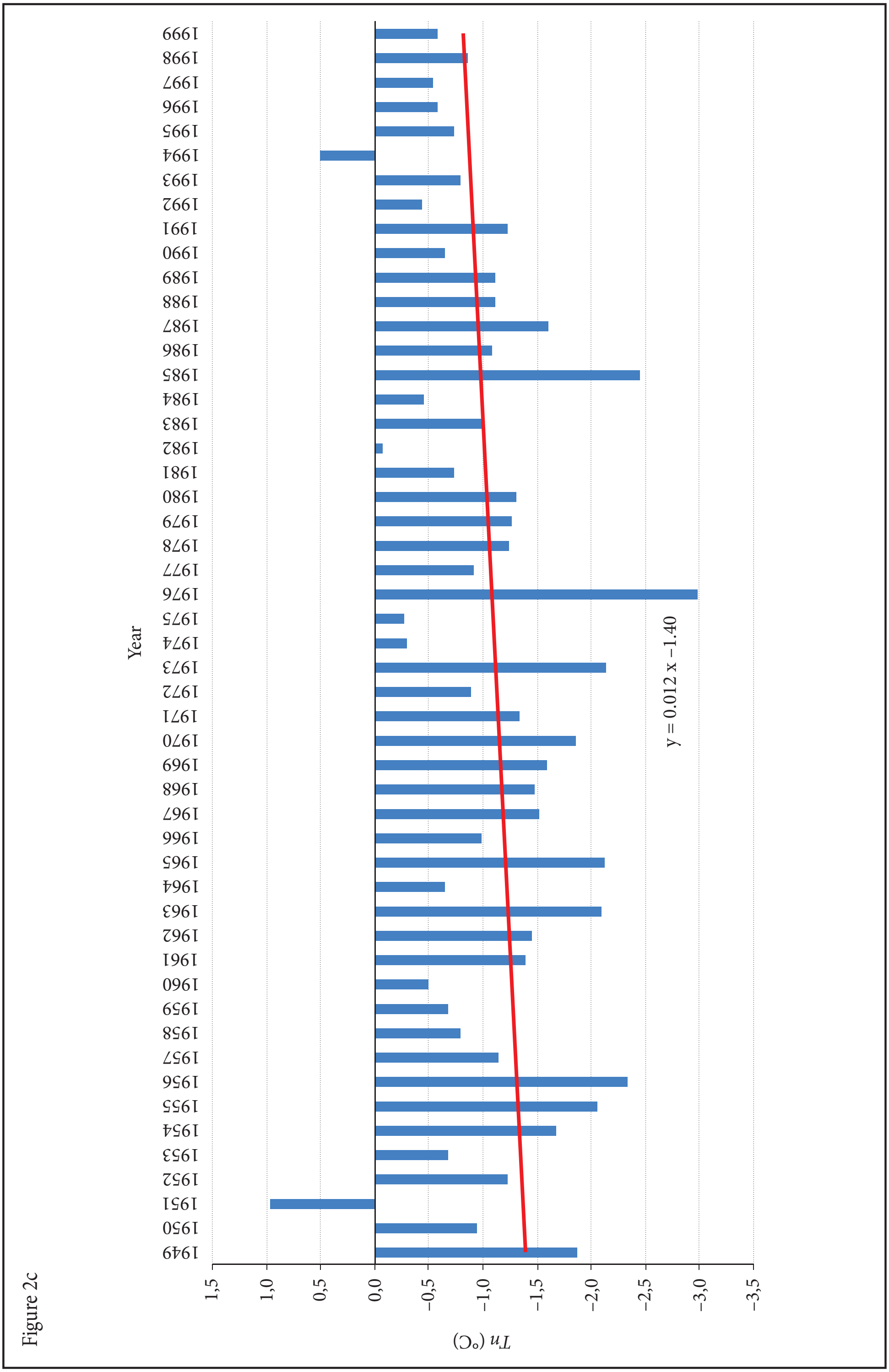
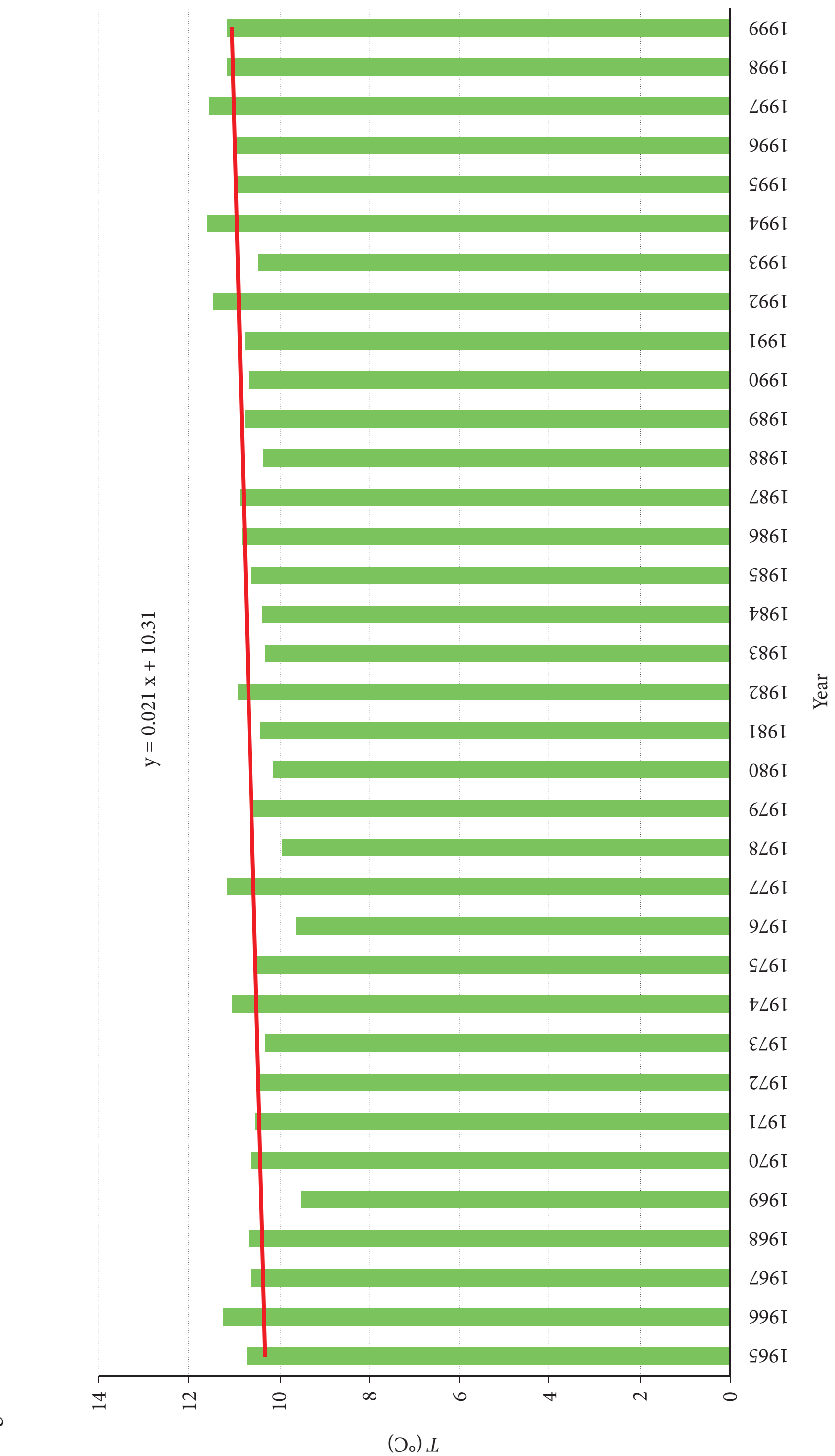


Figure 2: Distribution by year of the three types of temperatures: T, T_x, and T_n; the trend lines and the trend equations of temperatures in Kosovo for period P1 on panels a, b, and c, respectively.

Figure 3a


y = 0.021 x + 10.31
T (°C)
0
2
4
6
8
10
12
14
Year
1965
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1969
1970
1971
1972
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1999

Figure 3b

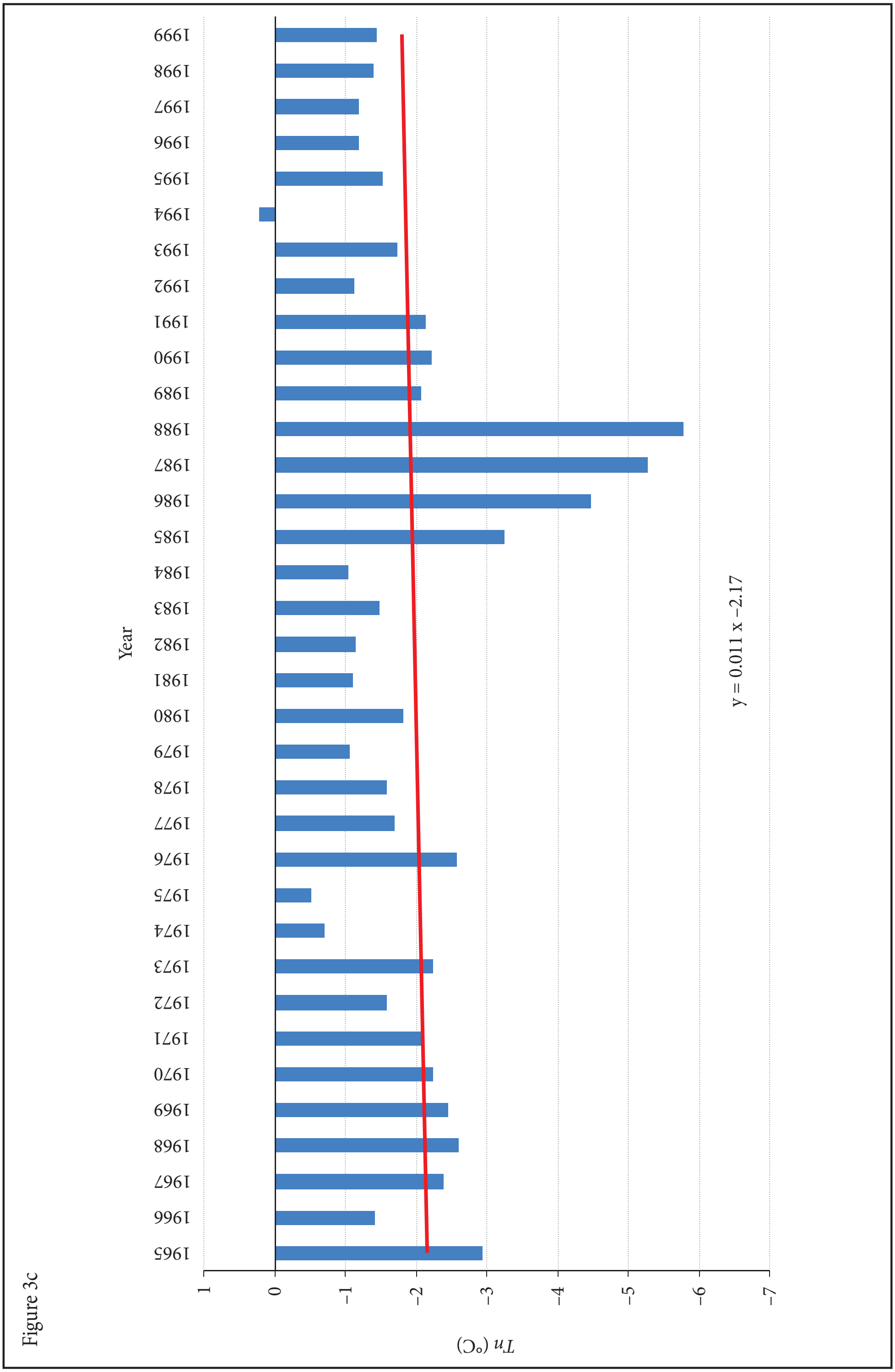
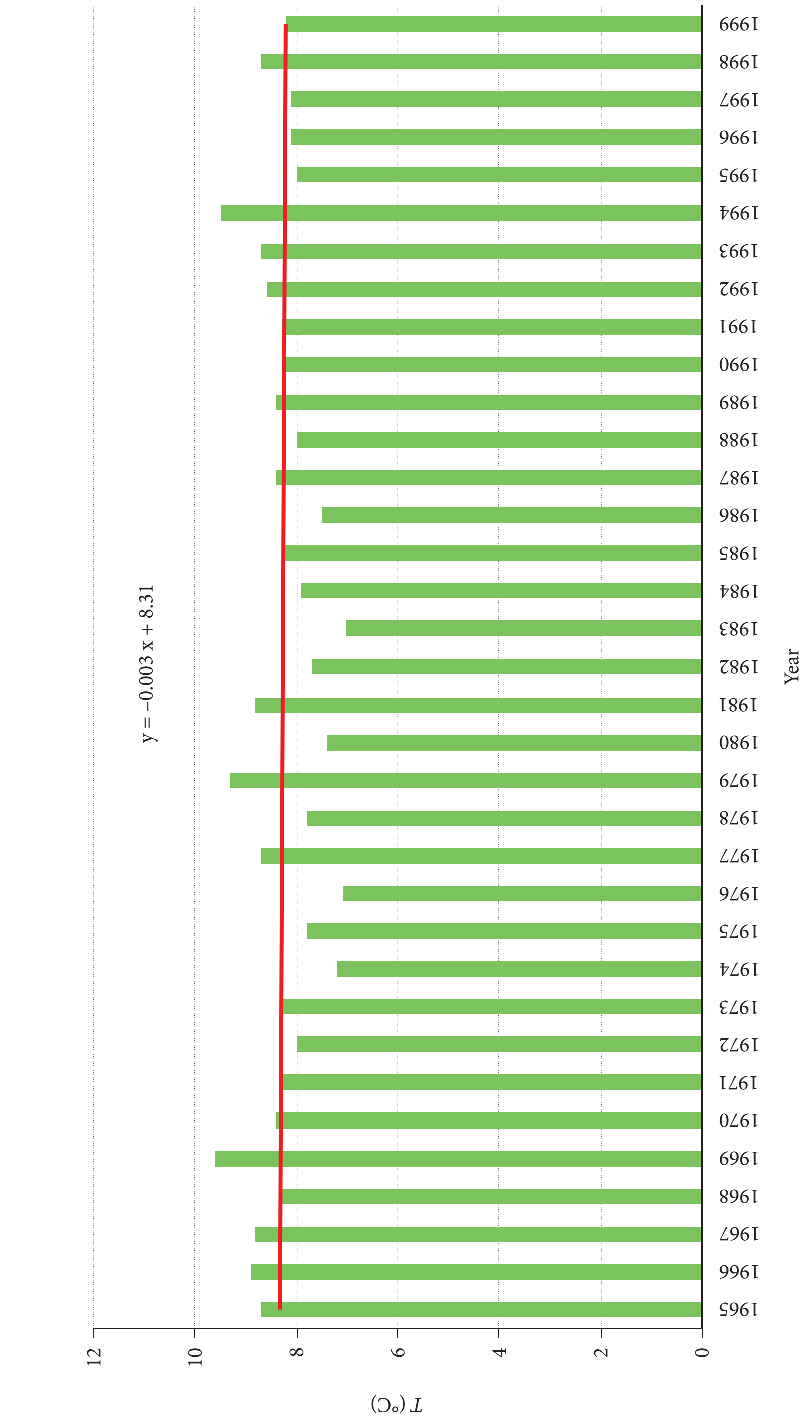


Figure 3: As in Figure 2, but for period P2.

Figure 4a


y = −0.003 x + 8.31
T (°C)
0
2
4
6
8
10
12
Year
1965
1966
1967
1968
1969
1970
1971
1972
1973
1974
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1996
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1998
1999

Figure 4b


y = 0.070 x + 20.41
Year
Tx (°C)
0
5
10
15
20
25
30
1965
1966
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1968
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1970
1971
1972
1973
1974
1975
1976
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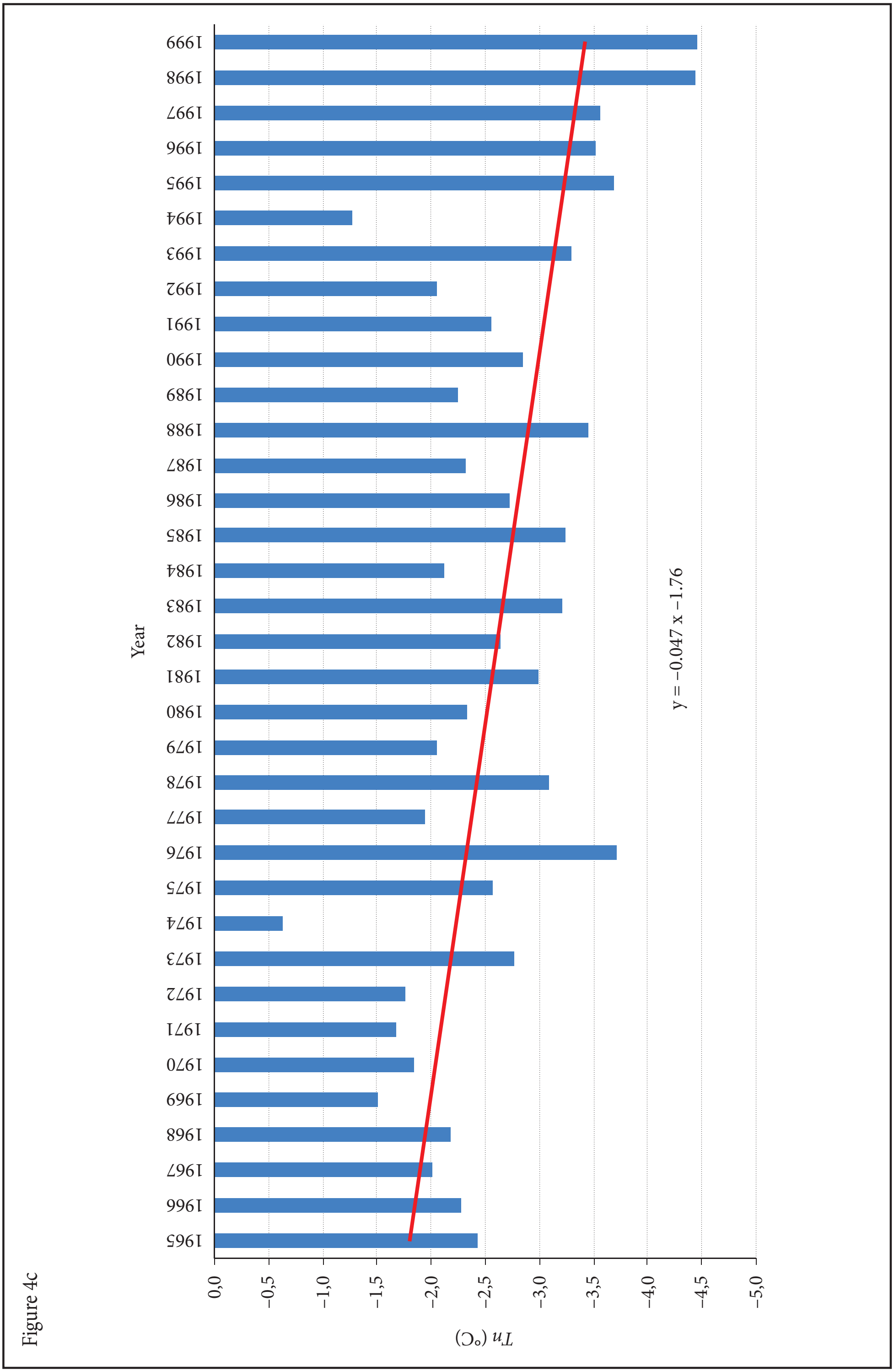

Figure 4: As in Figure 2, but at the Dragaš station.

The risk of rejecting the H_0 while it is true is 89%. Because the probabilities p in D-P2-T_x and D-P2-T_n are lower than the significance level, the H_0 should be rejected and the H_a should be accepted in both cases. The statement that there are trends is correct with a probability greater than 99%. Now, the trends are characterized as no trend, significantly positive, and significantly negative, respectively. It should be noted that in the case D-P2-T the Δy is equal to the standard error of the temperature measurement, and so it is also considered no trend.

5 Conclusions

The main results of the analysis of temperature trends in Kosovo are shown in Table 4.

Table 4: The main results of the analysis of trends.

Time series	Trend equation	Modified Mann–Kendall test
K-P1-T	*Negative trend*	*Negative moderate trend*
K-P1-T_x	*Positive trend*	*Positive moderate trend*
K-P1-T_n	*Positive trend*	*Positive significant trend*
K-P2-T	*Positive trend*	*Positive significant trend*
K-P2-T_x	*Positive trend*	*Positive significant trend*
K-P2-T_n	*Positive trend*	*Positive moderate trend*
D-P2-T	*Negative trend*	*No trend*
D-P2-T_x	*Positive trend*	*Positive significant trend*
DP-2-T_n	*Negative trend*	*Negative significant trend*

Based on the trend equations, positive trends were found in six and negative trends were found in three time series. After applying the Mann–Kendall test, significantly positive trends were confirmed in four time series, a moderately positive trend was found in two time series, and a significantly negative trend, moderately negative trend, and no trend were found in a single case each.

From the results presented above, it is very difficult to derive an overall general rule, but some conclusions can be drawn. First, positive temperature trends dominate. All of them could be explained by the effects of global warming on Kosovo. This impact is most evident in the case of representative time series K-P2-T, which covers the 1980s and 1990s, when the effect of global warming was first detected in the region (Gavrilov et al. 2016). On the other hand, the representative case K-P1-T was also influenced by global warming, but no positive trend was noted. This can be explained by impacts from the 1960s and 1970s, when there were no signs of global warming (Hardy 2006).

In the case of the Dragaš mountain station, the results were very diverse. There, all three trends were found: positive, negative, and no trend. This case, as well as a detailed explanation of other cases, requires additional research.

In spite of the limited meteorological data available, the results presented provide insight into the climate dynamics of the region.

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POST-FIRE SUCCESSION: SELECTED EXAMPLES FROM THE KARST REGION, SOUTHWEST SLOVENIA

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A young shoot at the base of a flowering ash scrub that had been scorched in a wildfire.

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Post-fire succession: Selected examples from the Karst region, southwest Slovenia

ABSTRACT: Forests in Submediterranean Slovenia are threatened by wildfires every year. The article presents the main characteristics of post-fire regeneration in the Karst area. The rate of succession was studied by comparing two burned sites with different periods after the last fire. Field plant sampling was used to determine the plant cover and species composition on each site. Vegetation characteristics were contrasted with nearby unburned sites. We found that the plant species composition of burned areas is similar to that of areas unaffected by wildfire, and that the monitored site has been colonised by specific pioneer plant species five years after the wildfire.

KEY WORDS: biogeography, succession, wildfires, pioneer plant species, Kras plateau, Submediterranean Slovenia

Popožarna sukcesija: Izbrani primeri rastlinske sukcesije na Krasu

POVZETEK: Gozdove obsredozemske Slovenije vsako leto ogrožajo požari. V prispevku predstavljamo glavne značilnosti obnavljanja rastlinskega pokrova po gozdnih požarih na Krasu. Preučevali smo hitrost sukcesije s primerjavo dveh različno starih pogorišč. S terenskim popisom smo določili pokrovnost posameznih rastlinskih plasti in vrstno sestavo. Značilnosti rastja na izbranih pogoriščih smo primerjali tudi z nepogorelimi zemljišči v bližini na enakih rastiščnih pogojih. Ugotavljamo, da je vrstna sestava rastlinstva na pogorišču podobna kot na nepogorelemu zemljišču in da so pet let po požaru na pogorišču naseljene določene pionirske rastlinske vrste.

KLJUČNE BESEDE: biogeografija, sukcesija, gozdni požari, pionirske rastline, Kras, obsredozemska Slovenija

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1 Introduction

The Submediterranean Slovenia is the country's most fire-threatened area due to the climatic, vegetation and anthropogenic factors. Wildfires usually affect the ground and soils, field and shrub layers in a woodland (Jakša 2002). After the event, the vegetation cover regenerates by the process of succession (Lovrenčak 2003).

This paper presents the characteristics of post-fire succession in selected burned areas of the Karst region. Species composition of the various burned areas was examined and typical plant species were determined. Vegetation covers of two burned sites with different periods since the last fire were contrasted. In addition, vegetation characteristics of the burned sites were compared to nearby unburned sites with similar habitat conditions. Changes in plant cover density and species composition through time were noted, as well as the presence of pioneer species.

There has been a limited research on the dynamics of post-fire succession in Slovenia. Kovač (2012) examined three burned areas in Slovenian Istria that were affected by fire in a three-year interval. The vegetation of burned sites consisted mainly of pioneer species. The field layer plant cover density was found to positively correlate with the period since the last fire. Geršič et al. (2014) compiled the characteristics of plant cover regeneration in specific environments – on point bars, rockfall material, screes, construction pits and burned areas. They found a widespread presence of pioneer species. Time was highlighted as the most important factor of succession.

Studies of post-fire succession in Mediterranean ecosystems in France (Capitanio and Carcaillet 2008) and California (Harvey and Holzman 2014) have shown that the highest species diversity on burned sites occurs two years after the wildfire. In Spain it was found that the most common species on burned sites are those that are adapted to wildfires (*Quercus coccifera, Brachypodium retusuin*) (Pausas et al. 1999). In South African Mediterranean-climate ecosystems the field layer cover is greatest one year after the wildfire, while the shrub layer requires more than three years for regeneration (Rutheford et al. 2011). Australian ecosystems recover after longer periods; the shrub and tree layers reach the pre-fire cover after 30 years of succession (Gosper, Yates and Prober 2013).

2 Succession and pioneer species

Ecological succession is the process of vegetation cover regeneration following considerable changes in the environment. The process consists of a time specific sequence of animal and plant species replacing each other in a given area (Lovrenčak 2003; Kladnik, Lovrenčak and Orožen Adamič 2005).

The most common classification of succession types is based on the starting position. Primary succession takes place in areas where there are no soils, plants or animals (Kladnik et al. 2008). Secondary succession is a more common process that takes place in areas which had already been populated. Certain or most of the species in the community have been removed by a specific extraordinary event. However, other species along with the soil remain, so regeneration does not initiate on completely bare soil (Tarman 1992). Among others, secondary succession takes place on burned areas (Tivy 1993).

Succession progresses over a distinctive sequence of stages. Characteristic plant and animal species are present at each successional stage. The early stages are dominated by fast-growing species that are adapted to harsh habitat conditions and rapidly proliferate (Tarman 1992). These pioneer species stabilise the habitat with their extensive root systems and improve soil characteristics by adding organic material. In this way, colonisation of new species is enabled (Lovrenčak 2003).

In the Submediterranean Slovenia, the majority of the most characteristic plant species have pioneer features. The wider study area has specific habitat conditions, species that thrive here require more light and heat, and can withstand limited rainfall as well as dry, shallow, skeletal soils. Hop hornbeam (*Ostrya carpinifolia*), flowering ash (*Fraxinus ornus*) and whitebeam (*Sorbus aria*) are plant species that often grow together on carbonate bedrock. They frequently form associations with autumn moor grass (*Sesleria autumnalis*, Dakskobler, Kutnar and Zupančič 2014). Other pioneer species, which have modest habitat requirements and therefore promptly colonise degraded areas are common juniper (*Juniperus communis*), *Paliurus spina-christi*, blackthorn (*Prunus spinosa*), blackberry (*Rubus spec. div.*) and wild asparagus (*Asparagus acutifolius*) (Figure 1) (Kovač 2012).

3 Wildfires

Wildfires are defined as uncontrolled burning in the forest environment, spreading rapidly and causing damage (Pravilnik o varstvu gozdov 2009). Climate has the largest influence on their emergence and spread. Wildfires are most common in arid, warm, sunny and windy areas (Pečenko 2005).

In Slovenia, wildfires are primarily a disturbance in the environment. They affect social, environmental and economic functions of forests. Aesthetic value of forested land is reduced. Forest animals, especially the micro- and mesofauna in the soil, are threatened. Species composition of the vegetation is changed. Timber resources are lost, which reduces financial profits from forests. Infrastructure located in forests as well as property in nearby settlements is at risk (Jakša 2006).

Wildfires have significant effects on soil characteristics. A large proportion of organic material is burned therefore the organic horizons on burned sites are usually thinner (Urbančič 2002). Immediately after the wildfire nutrient availability increases due to the elements found in ashes and the release of minerals from the soil (Hernández, García and Reinhardt 1997). On the other hand, the removal or reduction of the vegetation cover leads to decreased water retention, faster runoff, soil erosion and nutrient leaching which impedes succession (Gimeno-Garcia, Andreu and Rubio 2000; 2007). To improve soil characteristics and accelerate succession some studies suggest adding compost to burned sites (Cellier et al. 2014).

Slovenian forests are classified into four levels of potential fire risk – very high, high, medium, and low (Jakša 2006). Of the fourteen forest management areas (GGO) Sežana is the most fire endangered (Poročilo … 2014). The high fire risk of the Submediterranean Slovenia stems from physical as well as human geographical factors. The climate, with high temperatures and dry season, plays an important role. The carbonate bedrock with great permeability reduces water retention, thus increasing drought and the probability

Figure 1: Wild asparagus.

of forest fire occurrence. Strong winds, especially bora, contribute to the rapid spread of fires. Anthropogenic influence on the increased fire risk is manifested in the form of changes in natural vegetation; plantations of Scots pine (*Pinus sylvestris*) and black pine (*Pinus nigra*), both very susceptible to fires. The fire risk of the study area is further increased by transport corridors passing through, most notably the railway (Jakša 2002).

4 Methodology

The rate of vegetation regeneration is influenced by several factors including soil, climate, slope, aspect, elevation, wind exposure, and various anthropogenic impacts such as afforestation (Geršič et al. 2014). This paper deals exclusively with the role of time; the study sites were chosen accordingly. The time period between wildfires and field observations was chosen according to similar research on ecological succession in the Mediterranean (Lloret 1998; Meira-Neto 2011). The Slovenian Forest Service provided the fire inventory, from which Kamarija, burned in 2009, and Podgovec, burned in 2013, were selected (Figure 2). The location of the older burned site was compared against locations of fires in later years to ensure that the selected site was not subsequently affected by fire. It was verified that the same forest association was present at both locations, suggesting similar habitat conditions and thus allowing a comparison of plant cover primarily with respect to time. No post-fire reconstruction was carried out at any of the selected locations. Direct influence of anthropogenic factors on succession was therefore minimised.

In June 2014 four plant samplings were carried out – one on each selected burned site and one on an unburned site close to each study site (Figure 3; Figure 4). Vegetation characteristics of the unburned sites are assumed to be indicative of those of the burned study sites prior to the fire. The assumption is based on the comparable level and circumference of trees on sampling plots, indicating similar habitat conditions (Tivy 1993). Comparing the results of plant monitoring on burned sites with those on unburned sites allows an insight into the changes in land cover and species composition. The Braun-Blanquet method of plant sampling (Braun-Blanquet 1932) was used to determine abundance, cover and unity of each plant species

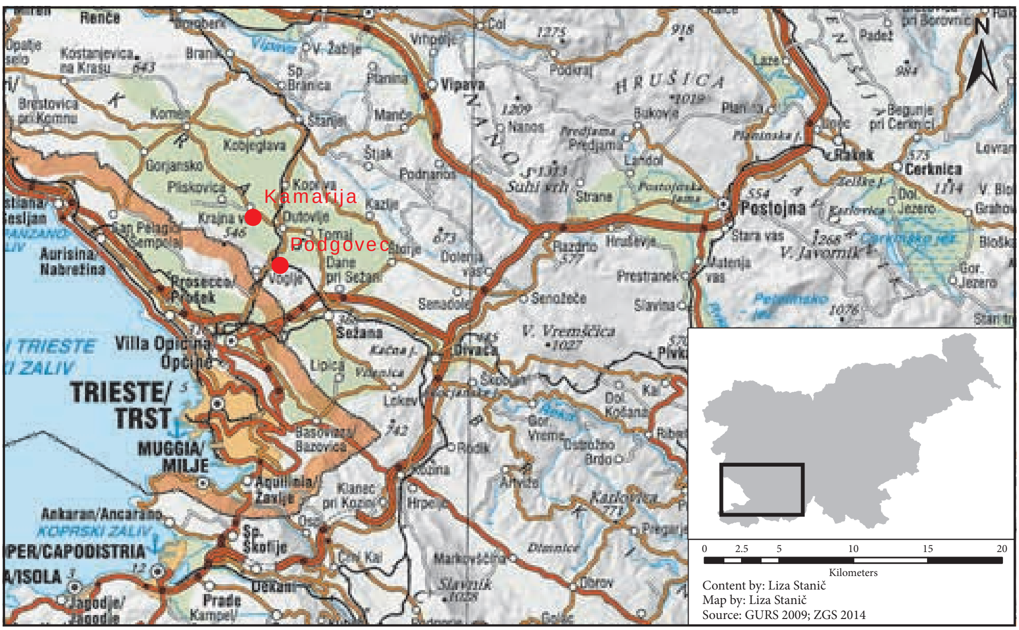

Figure 2: Location of study sites.

present (Lovrenčak 2003). The method is enables quick and accurate vegetation sampling as well as an analysis of species-habitat relationships (Wikum and Shanholtzer 1978). Species were identified using botanical identification keys (Pintar and Wraber 1990; Lippert 2000; Fletcher 2007; Schauer 2008; Lang 2013).

Figure 3: Locations of sampling plots at Kamarija.

Figure 4: Location of sampling plots at Podgovec.

5 Characteristics of selected burned sites

The study burned sites are located in the GGO Sežana in the south-western Slovenia. They lie on the Karst Plateau, where the bedrock is made of permeable Cretaceous limestone (Jurkovšek 2014). The terrain is levelled and no surface watercourses are present (Natek and Natek 2008). The climate is Submediterranean with high summer daytime temperatures and droughts due to the permeable bedrock. Owing to its location on the border between Mediterranean and continental influences, the region is characterised by strong winds, most notably the north-eastern bora wind (Senegačnik 2012). The most common soil types are redzinas, chromic cambisols and the region's typical red soil (*terra rossa*). Natural vegetation has been almost completely removed by intensive logging in the past. Systematic attempts to afforest the barren surface with black pine (*Pinus nigra*) began in the 19th century (Urbančič, Ferlin and Kutnar 1999; Zupančič and Žagar 2008). Efforts have been successful and today anthropogenic black pine plantations are one of the most common forest associations in the Karst region (Senegačnik 2012).

The forest association on both study sites was found to be hop hornbeam with *Sesleria autumnalis* (*Seslerio-Ostryetum*) which was at the oldest development stage prior to the fire (ZGS 2009–2013; 2014). This forest association is typical for karst as it thrives on dry, sunny and warm sites with shallow soils on carbonate bedrock (Dakskobler, Kutnar and Zupančič 2014). The older burned study site is Kamarija. It is located north of the town of Sežana, approximately 500 m south of the village Krajna vas along the Dutovlje–Pliskovica road. The second burned study site is Podgovec, which is located northeast of Sežana, 1 km southwest of the village Kreplje along the Sežana–Dutovlje railway line. Selected characteristics of the burned areas are presented in Table 1.

Table 1: Selected characteristics of burned study sites (ZGS 2009–2013; 2014).

Burned area	Kamarija	Podgovec
Location	45° 45' 50.48'' N 13° 48' 24.01'' E	45° 44' 5.9'' N 13° 49' 55.11'' E
Altitude (m)	265	260
Exposition	NW	N
Slope (°)	5	6
Date of fire event	14/04/2009	22/07/2013
Extent of burned area (ha)	2.25	2
Cause of fire	Unknown	Communications (train)
Type of fire	Surface	Surface
Post-fire reconstruction	No	No

6 Vegetation characteristics of studied burned sites

The results of the vegetation monitoring on burned sites were compared with the results from unburned sites nearby. Plant cover characteristics were examined by determining the species composition, abundance, cover and unity according to the Braun-Blanquet method.

6.1 The Kamarija burned site

The Kamarija burned site is separated from the comparative unburned site by a firebreak and a distance of 245 m. From this it can be assumed that the comparative unburned site was not affected by the fire that burned the study site (Figure 5).

The stoniness amounts to 5% on both sampling plots. The comparison of tree height and breast height circumference returns no significant differences between the burned and unburned site (Table 2). Similar tree heights and circumferences on both sites suggest analogous habitat conditions (Tivy 1993), justifying the comparison between the two sites. The differences in vegetation characteristics can be largely attributable to effects of the fire.

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Figure 5: Kamarija burned site (left) and unburned comparative site (right).

Table 2: Comparison of the breast height circumferences and the heights of trees on the Kamarija burned site and unburned comparative site.

	Burned site	Unburned site
Mean tree circumference (cm)	up to 50	50–100
Mean tree height (m)	10–20	10–20
Greatest tree circumference (cm)	155	97
Greatest tree height (m)	24	20

The comparison of vertical vegetation layers covers reveals differences between sampling plots (Table 3). The biggest discrepancies between the burned and unburned sites are in the shrub layer covers – 5% on the burned site compared to 30% on the unburned site. Small differences were recorded in the tree layer covers.

Table 3: Comparison of vertical vegetation layer covers on the Kamarija burned site and comparative unburned site.

		Burned site	Unburned site
Cover of specific vertical vegetation layers on sampling plots (%)	Tree layer	50	60
	Shrub layer	5	30
	Field layer	95	95
	Total	150	185

The burned site tree layer is dominated by flowering ash (*Fraxinus ornus*) and sessile oak (*Quercus petraea*). Both species are also present on the unburned site, but black pine (*Pinus nigra*) has the greatest cover, abundance and unity. The shrub layer consists of similar species as the tree layer with the addition of common juniper (*Juniperus communis*). On the burned site, blackberry (*Rubus spec. div.*) and common privet (*Ligustrum vulgare*) were also recorded in the shrub layer.

The herb layer species composition is similar on both sampling plots. The most common species on both sites is tor-grass (*Brachypodium pinnatum*). *Cirsium pannonicum* is also present in an equal extent on both sampling plots. Other abundant plant species on the burned site are common tormentil (*Potentilla erecta*) and orchard grass (*Dactylis glomerata*). In contrast, the abundant species on the unburned sites are yellow salsify (*Tragopogon dubius*), *Leucanthemum ircutianum*, meadow clary (*Salvia pratensis*), purple-globe clover (*Trifolium alpestre*) and hedge bedstraw (*Galium mollugo*).

6.2 The Podgovec burned site

The fire on the Podgovec burned area occurred 11 months prior to the vegetation monitoring. The plot chosen to provide the comparative vegetation characteristics is located 280 m away from the study site and

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Figure 6: Podgovec burned site (left) and unburned comparative site (right).

separated by a railway line. Due to these characteristics it can be assumed that the comparative site was not affected by the fire (Figure 6). Traces of fire are clearly visible on the burned site – tree trunks are scorched to a height of 3.5 m, the forest floor is covered with remains of charred twigs and cones.

The stoniness on the burned site is 15% compared to 10% on the unburned site. There are no notable differences in tree height and circumference between the two sampling plots (Table 4). This suggests similarity of habitat conditions, allowing for a meaningful comparison of vegetation characteristics.

Table 4: Comparison of the breast height circumferences and the heights of trees on Podgovec burned site and unburned comparative site.

	Burned site	Unburned site
Mean tree circumference (cm)	over 100	50–100
Mean tree height (m)	over 20	over 20
Greatest tree circumference (cm)	142	128
Greatest tree height (m)	30	26

The analysis of differences in tree height and circumference was followed by the comparison of specific vertical vegetation layers covers (Table 5). The difference in tree layer cover between the burned and unburned site is minor. As result of the fire, the shrub layer is considerably sparser. On the burned site its cover amounts to only 5%, while on the unburned site it is 30%. Field layer cover is also noticeably lower on the burned than on the unburned site. From the comparison with the unburned site it can be assumed that prior to the fire the field layer covered almost the entire sampling plot, while following the fire its cover is reduced to less than one third. The moss layer covers 5% of the unburned site but is not present on the burned site.

Table 5: Comparison of vertical vegetation layer covers on the Podgovec burned site and comparative unburned site.

		Burned site	Unburned site
Cover of specific vertical vegetation layers on sampling plots (%)	Tree layer	50	60
	Shrub layer	5	30
	Field layer	30	95
	Moss layer	0	5
	Total	85	190

The analysis of species composition revealed that black pine (*Pinus nigra*) dominates the tree layer on both sampling plots. The species has a lower cover on the burned site (50%) compared to the unburned site (65%) due to fire damage to lower branches. The burned site shrub layer consists mainly of blackthorn (*Prunus spinosa*) and flowering ash (*Fraxinus ornus*). All scrubs have bare scorched branches with no leaves.

Some flowering ash scrubs have young shoots at the base. The shrub layer is more diverse on the unburned site. In addition to the blackthorn and flowering ash, there are common juniper (*Juniperus communis*), blackberry (*Rubus spec. div.*) and sessile oak (*Quercus petraea*). The burned site field layer is patchy, comprising tor-grass (*Brachypodium pinnatum*), blackberry (*Rubus spec. div.*) and wild asparagus (*Asparagus acutifolius*). On the comparative sampling plot the field layer is more uniform. Besides the species present on the burned site, it is made up of *Melittis melissophyllum*, *Helleborus odorus* and ivy (*Hedera helix*).

7 Findings about post-fire vegetation regeneration

The results of vegetation monitoring demonstrate that ecological succession of burned areas occurs rapidly. The fire-affected Podgovec site can be clearly distinguished from unburned surrounding areas. The extent of the fire is clearly demarcated by a sparse field layer, scorched tree trunks and charred plant remains on forest floor. Three years after a wildfire Kovač (2013) found advancing vegetation recovery, however the burned site could still be clearly distinguished from unburned sites. The Kamarija site, which had been burned five years before the monitoring, can hardly be differentiated from adjacent unburned areas. The differences become apparent only after analysing the results of vegetation monitoring. Five years of ecological succession are therefore sufficient for plant cover regeneration to such an extent that burned sites are visually indistinguishable from the surrounding area. A possible explanation for the quick recovery is the wildfire type that occurred on study sites because the surface fire damaged only the field and shrub layers. Studies in Spain showed that if all vegetation layers are removed the colonisation of tree individuals takes at minimum 25 years (Röder et al. 2008). In Mediterranean-climate ecosystems the field layer regenerates after two years (Pausas et al. 1999; Rutheford et al. 2011), and the shrub layer after 10–15 years (Capitanio and Carcaillet 2008).

Analysis of vertical vegetation layers suggests that the cover is greater on older burned areas. The total vegetation cover is 85% at the Podgovec site compared to 150% at the Kamarija site. These differences arise mainly due to the covers of field layer. Both of the burned area plot sites have similar tree and shrub layer covers – 50% and 5% respectively. The field layer, on the other hand, covers 30% of the plot site at Podgovec and 95% at Kamarija. This points to the conclusion that the field layer cannot regenerate to the pre-fire state in one year. However, in five years the field layer returns to its original extent, while the shrub and tree layer covers remain constant. The comparison of vertical vegetation layers covers at the Kamarija site with unburned nearby areas suggests that five years are not sufficient for the regeneration of tree and shrub layers.

In addition to vegetation layers covers, this paper examines burned area species composition, focusing on the presence of pioneer plant species. Vegetation sampling found similar species on burned sites and nearby unburned sites. This is in line with studies showing demonstrating that species composition of burned sites is affected by adjacent sites (Keeley, Fotheringham and Baer-Keeley 2005). Typical species of burned sites in Slovenian Istria are aspen (*Populus tremula*), flowering ash (*Fraxinus ornus*) and downy oak (*Quercus pubescens*) (Geršič et al. 2014). Our monitoring found a different species composition. On the Podgovec burned site the following pioneer species were detected: flowering ash (*Fraxinus ornus*), blackthorn (*Prunus spinosa*), wild asparagus (*Asparagus acutifolius*) and blackberry (*Rubus spec. div.*). The same species were also present on the comparative plot. Well-known pioneers flowering ash (*Fraxinus ornus*) and common juniper (*Juniperus communis*) were found both on the Kamarija burned site and the nearby unaffected area. Hop hornbeam (*Ostrya carpinifolia*), blackberry (*Rubus spec. div.*) and common privet (*Ligustrum vulgare*) are exceptions because they were recorded only on the Kamarija burned site but are not present on the comparative unburned site.

8 Conclusion

Wildfires frequently threaten specific areas particularly in Submediterranean Slovenia. Nevertheless, few geographic studies of post-fire plant succession have been conducted. This paper presents the main findings derived from field plant sampling on two selected burned areas in the Karst region. The sampling was carried out using the Braun-Blanquet method. To assess the changes in vegetation characteristics on burned areas compared to the state before the wildfire, plants were sampled on comparable unburned areas nearby. Species composition and plant cover densities of individual vertical vegetation layers were recorded.

The surface fire affected the selected areas. This type of wildfire damaged the ground, field and shrub vegetation layers. The tree layer remained largely intact except for the lowest branches. The time span between burned areas discussed is five years. In this time, the field layer regenerated to the extent comparable to the unburned area. The plant cover density of the shrub layer remains more modest than before the wildfire even after five years.

The plant species composition of burned areas is similar to that of areas unaffected by wildfire. Five years after the wildfire the monitored site has been colonised by specific pioneer plant species such as hop hornbeam (*Ostrya carpinifolia*), blackberry (*Rubus spec. div.*) and wild privet (*Ligustrum vulgare*). Due to specific habitat conditions with dry, warm and sunny climate, and shallow, rocky soils, many common Submediterranean plant species are classified as pioneers. It is therefore typical for both burned and unburned areas to contain pioneer plant species. Furthermore, surface fires have little effect on higher vertical vegetation layers so there is little change in the insolation of the site. Consequently, there is no mass colonisation of pioneer species, only individual plants are present.

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THE GEOGRAPHICAL POSITION OF THE TOWN OF RASA BASED ON PORPHYROGENITUS AND MEDIEVAL MAPS

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Detail from an anonymous military map of the Balkans from 1395 (Oračev 2005).

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The geographical position of the town of Rasa based on Porphyrogenitus and medieval maps

ABSTRACT: The town of Rasa was mentioned in the tenth-century work *De administrando imperio* by Constantine VII Porphyrogenitus. The significance of this town in the Middle Ages is indicated by the fact that this toponym appears on old maps created by the greatest European cartographers from the fifteenth to nineteenth centuries. Based on cartographic and historical geographical sources, this paper considers various perceptions and texts connecting the town of Rasa with today's town of Ražanj or with the medieval Serbian capital Ras. The subject treated is historical social geography. Five types of sources were used for the historical geography of the Balkans: old maps, chronicles, geographical nomenclature, archeological findings, and ethnographic findings. Based on written sources, geographical names, and geographical logic, the authors provide their own conclusions about the geographical position of the town of Rasa.

KEY WORDS: geography, old maps, geographical names, Rasa, Ras, Serbia

Geografska lega mesta Rasa na podlagi Porfirogenetovih zapisov in srednjeveških zemljevidov

POVZETEK: Mesto Rasa je prvič omenjeno v delu De administrando imperio, ki ga je v 10. stoletju napisal Konstantin VII. Porfirogenet. Na pomembnost mesta v srednjem veku kaže dejstvo, da se ta toponim pojavlja na zemljevidih, ki so jih med 15. in 19. stoletjem izdelali največji evropski kartografi. Na podlagi kartografskih in zgodovinskih geografskih virov so v članku obravnavana različna mnenja in besedila, ki Raso povezujejo z današnjim mestom Ražanj ali s srednjeveško srbsko prestolnico Ras. Glavna tema je zgodovinska družbena geografija. Za zgodovinsko geografsko obravnavo Balkana so avtorji uporabili pet vrst virov: stare zemljevide, kronike, geografska poimenovanja, arheološke najdbe in etnografske izsledke. Na podlagi pisnih virov, geografskih imen in geografske logike avtorji predstavijo lastne ugotovitve o geografski legi mesta Rasa.

KLJUČNE BESEDE: geografija, stari zemljevidi, geografska imena, Rasa, Ras, Srbija

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1 Introduction

Localization of geographic places mentioned in historical sources is an important goal of historical geographical research (Gašperič 2007; 2010; Kladnik and Pipan 2008; Vuolteenaho and Berg 2009; Vuolteenaho and Ainiala 2010; Douglas 2014; Fuchs 2015). In Constantine Porphyrogenitus' work *De administrando imperio*, chapter 32 contains the first mention of the town of Rasa. Namely, in the second Serbian-Bulgarian conflict in »the later period of the reign of Boris around 887 AD,« Boris had made peace with the Serbs, »who escorted him to the border, to Rasa« (Greek: ἑωζτήζ ῾Ράσης; Vizantijski izvori … 2007, 52). Some authors are uncertain whether this refers to Ras or Rasa. This study uses cartographic and historical sources to determine the location of Rasa, which Porphyrogenitus mentioned as a border town between Serbia and Bulgaria. This is an important question because in the toponymy of medieval Serbia there is the phonetically similar toponym *Ras*, which was the capital of the medieval Serbian state of Raška, which also has not been precisely located (Grčić and Grčić 2012; 2014).

2 Theoretical framework

The development of historical geography has raised awareness of four sources used in that discipline: 1) old chronicles, 2) ethnography, 3) geographic nomenclature, and 4) archaeology (Grčić and Grčić 2012; 2014). The Polish academy member Tadeusz Kotarbiński, who created »practicology« (or the »science of good work«), recommends that one not observe an object constantly through the same window, but look at it each time from another perspective (Trubačov 2006). This means that one should perceive the meaning of a certain toponym and its logical connection with the geographical area, ethnography, linguistics, written historical documents, cartographic sources, and archeological artifacts. The value of toponyms as a historical source lies in their relationship with the territory; that is, with the geographical map. Here arises a general question posed by Harley (1990): should a map be understood in a traditional way, as a reflection of the real world, or in the postmodern sense, as graphic language that needs to be decoded at the appropriate time and in a spatial context? In the second case, which is more appropriate for modern conceptions, the map should be considered within the context of historical facts, geographical principles, and maps of a given space and time. Without sufficient evidence, especially cartographic evidence, researchers can only point to some assumptions. For example, maps of the Roman provinces transmitted knowledge and expression of remembrance of political traditions more effectively than historical texts (Ćirković 1991).

3 Methods

Maps have long been very important to historical geography and the history of cartography, but they were rarely treated as a historical source in the reconstruction of the past (Gašperič 2007; 2010; Kladnik and Pipan 2008). In the development of cartography, there is a visible division between the »decorative« and »scientific« phases of mapping, but Harley (1990) recognized this division as a myth. Old maps have many pieces of information that are not precise and do not represent the only real picture of reality. Maps are socially constructed images of real space in social, political, and cultural contexts and a mirror of the skills and perceptions of the cartographer. This means that a particular map has to be returned to the past and situated in its proper period and place, or even culture (Fürst-Bjeliš and Zupanc 2007). When discussing a map as a text, Harley (1990) points out three aspects of the context: 1) the context of cartographer, 2) the contexts of other maps, and 3) the context of society. For this reason, it is necessary to use a comparative method and geographical logic in attempting to identify the Rasa mentioned by Porphyrogenitus in the tenth century. This toponym is studied by comparing selected maps from different times and cultures (see Table 1).

In addition to maps, we examined texts by Constantine Porphyrogenitus, the priest of Doclea (Duklja), and some Byzantine and church documents from Antiquity and the Middle Ages. We also considered the opinions of some prominent scholars about the genesis and geographic position of the toponyms *Ras* and *Rasa*.

Table 1: Toponyms on old maps denoting the position of Rasa near today's town of Ražanj.

Cartographer	Map name, place, and year of publication	Toponym
anonymous*	*Military map of the Balkans, 1395–1396	Rossia
JacoboCastaldo*	Romanie (quae olim Thraciae dicta), Vicinuorumq(ue) regionum, uti Bulgariae, Walachiae, Syrfiae etc descriptio, 1584	Rezuna
Gerard Mercator*	Walachia. Servia. Bulgaria. Romania; Duisburg, 1589	Resigne
G. Cantelli*****	Map of Serbia (Rome, G. Rossi), 1689	Razena alt (ats), Rasna
Giacomo Cantelli da Vignola*	La Bulgaria e la Romania com Parte di Macedonia, Roma, 1689	Rasna
Pierre Mortier****	Carte Nouvelle de la Mer Mediterranee, Amsterdam, 1694	Rasena
Johann Georg Schreiber*	Carte von Romanien mit dennes Dardanelen, Bulgarien und Servien. Leipzig, end of the seventeenth century	Raszna
MatthäusSeutter*	Transylvaniæ, Moldaviæ, Walachiæ, Bulgariæ nova et accurata delineatio; eighteenth century, Augsburg	Razena
Guillaume Delisle*[1]	Imperii Orientalis et circumjacentium regionum sub Constantino Porphyrogenito et ejuspraedecesforibusDescriptio, made after 1718	Rhazen
Christoph Weigel*	Regiones Danubiæ, Pannoniæ, Dacia, Moesiæ cum Vicino Illyrico, studio Christoph; Nuremberg, 1719	Razena
Guillaume Delisle*	Nova et accurata Regni Hungariæ Tabula, ad usum Serenissimi Burgundiæ Ducis, first quarter of the eighteenth century	Razena
MatthäusSeutter***	Regnorum et Provinciarum Dalmatia, Croatia, Sclavonia, Bosnia, Servia, Istria et Reip, 1709	Rasena
anonymous*	Parte della Transilvania, Parte della Banato, Parte della Servia, Parte della Bulgaria, Valachia Imperiale, Valachia Thurca, 1717–1737	Rasna
Johann Matthias Hase*	Hungariæ, Propriæ, Croatie, Dalmatiæ, Bosniæ, Serviæ, Bulgariæ, Cumaniæ, Principatum: Transsylvanniæ, Despotatus: Walachiæ, Moldaviæ; Nuremberg, 1744	Rasen, Rasna
Antonio Zatta*	Turchiad'Europa. Divisa Nelle sue Provincie e Governi. Di nuova Proiezione; Venice, 1782	Rozena
F. Müller*****	Map of Serbia, Vienna, Artaria, 1788	Razena, Ratzana

Sources: * Oračev 2005; *[1] Ehrenberg, E. R. 2006 (National Geographic); **Nikolić 1983; *** Marković 2002; **** Schüler 2010; ***** Srejović 1991.

4 Research findings

4.1 Historical geography of Rasa

According to Castellan (1999) »*between 867 and 874, the Serbs were under the control of the Byzantine church. The Serbs, who settled in the territory of Raška, between the Drina and Morava Rivers* …«. Near Varvarin (the village of Gornji Katun) was found one of the oldest monuments of Slavic literacy in Serbia and in the Balkans (from the ninth or tenth century): the Temnić inscription (Ivić 1986; Stojanović 1913). In a relatively small area between Stalać and Ražanj, on the slopes of the Mojsinje Mountains (*Mojsinjske planine*) and Poslon Mountains (*Poslonske planine*), there are a large number of churches and monasteries (including the ruins of seventy churches and hill forts); this area is known as Holy Mount Mojsinje (*Mojsinjska Sveta gora*). St. Roman's Monastery, which was founded in the second half of the ninth century, located seven kilometers south of the town of Ražanj (in the Niš District), also has significant cultural and historical value. The monastery was mentioned in a grant issued by Byzantine Emperor Basil II to the Archbishopric of Ohrid in 1020, in which it is recorded as *Sfenteroman* (Janićijević 1998; Živić 2006; Dumić, Đokić and Stević 2006). A charter issued by Byzantine Emperor Basil II to the Archbishopric of Ohrid in 1020, and confirmed by Emperor Michael Palaeologus in 1272, mentions among other things Raška or the Raska eparchy or diocese (Greek: τὸν δὲ ἐπίσκοπον Ράσον – tòn dè ἐpisкopon Rason). The mere fact that the town was the seat of a bishop indicates that it was a remarkable town in a good transport position. Some Bulgarian and Russian authors from the second half of the nineteenth century thought that this referred to Ras near today's town of Novi Pazar on the Raška River, which flows into the Ibar (Golubinskij 1871; Drinov 1971).

Based on the *Escorial Taktikon* – a list of offices that arose from the need to administer the newly conquered provinces of Bulgaria at the time of John Tzimiskes (969–975) in the official administration of Byzantium Stanković (2002) points out that to the west there was an administrative unit with its center in Ras. The existence of this administrative unit remained recorded only thanks to a seal by John, the *katepan* of Ras (Nesbit and Oikonomides 1991). In Greek, a *katepanat* was a large territory in a border zone that included several *themes* (administrative units) in which civilian and military power was exercised by a *katepan.* The *katepan* (or *dux*) was a title carried during the Roman and Byzantine period by military commanders in a province (Touati 2007). The *theme* of Morava was also established; this was led by Adralest Diogenes and was located near the confluence of the Morava and Danube Rivers, at the site of the ancient fort called Horreum Margi (Stanković 2002; Pirivatrić 1997). According to Živković (2007), Byzantine seals (Protospatharios John, *katepan* of Ras, as well as the seal of Adralesta Diogenes, a protospatharios and strategist of Morava), are the most reliable indicator that Byzantine reign was established in this border area.

The town of Rasa, mentioned at the end of the ninth century, is identified by some authors with Ras, the capital of Stefan Nemanja's Serbia in the second half of the twelfth century (Novaković 1877). Only at the end of the nineteenth century did Ras (i.e., Apostles Peter and Paul Church, which was known to be located in Ras) appear on maps drawn near Novi Pazar (the Austrian military map from 1900). In 1859, the Russian historian Alexander Hilferding, on his way through Old Serbia, thought that he recognized the town of Ras about seven kilometers west of Novi Pazar, in the ruins known as Gradina near Pazarište, near where the Sebečevska River empties into the Raška River. »*I have no doubt that these ruins are in fact the old town of Ras, about which a lot was said in ancient Serbian history*« (Hilferding 1868 cv: Hilferding 1972, 134). According to Ćirković, »*although the arguments were insufficient, many scholars (Konstantin Jireček, Stojan Novaković, Jovan Cvijić) agreed with Hilferding's opinion, and so over time identifying Ras with one of the many fort ruins was generally accepted as unproblematic*« (Ćirković 1997, 425). It is usually assumed that Ras was several kilometers from Novi Pazar, at a place called Pazarište or Eski Pazar (i.e., 'old Pazar'). »*Here, however, are no ruins*« (Dinić 1978, 80). Kalić raises the possibility that the place called Race referred to Arsa (Kalić 1988). According to Ćirković, »It is more likely that this Rasa in the country of Michael or Vlastimir, the successors of Boris, is identical to the fortress (Greek: φρούριον) at Arsa (Greek: Αρσα), which according to the narratives of Procopius was rebuilt by Emperor Justinian in the province of Dardania« (Ćirković 1997, 424). However, the attention of European medieval cartographers was directed toward a town with a similar name, which was located near the present town of Ražanj.

4.2 The toponym Rasa on old geographic maps

The old Roman military road (Latin: *Via Militaris*) known as the Moravian road led through the Roman town of Arsena, where Justinian built a fortress (Jireček 1959). Along the route of the public road (Latin: *Via Publica*), in the village of Novi Bračin north of the town of Ražanj, there was an ancient settlement called Præsidium Dasmini. The ancient settlements of Præsidium Dasmini and Præsidium Pompeiare shown on the Tabula Peutingeriana, a Roman itinerary map (SegmentumVII; Figure 2). In the centre of the northern part of the Aleksinac Basin was Mutatio Cametas, today's town of Ražanj. Felix Kanitz mentioned this as an important point on the route of the ancient Moravian road (Rašković 2002).

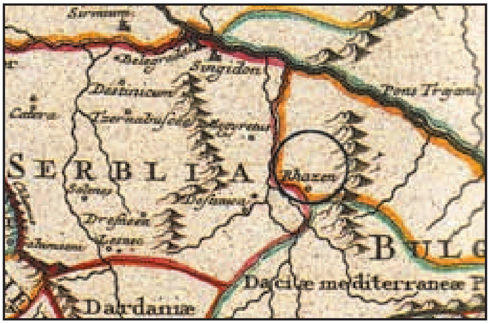
Separating the last syllable from the word *Arsena* yields the name *Arsa*. It can be assumed that the name *Rasa* is a translation of the Greek word *Arsa*; today's Raša River in the Istria Peninsula in northwest Croatia was called Arsa in Roman times. The Slavic name *Rasena* or *Rasna* undoubtedly inherited the ancient name of the town, *Arsena*. It seems, however, that the ancient toponym *Arsena* signified some kind of art or skill. The etymology of the word *rasa* can be connected with a place of ecclesiastical authority. According to the Bulgarian terminology dictionary (Bălgarski tolkovski rechnik 2013), *raso* refers to the black, wide, long upper garments of an Orthodox priest. In Greek, *rason* designates the large wide-sleeved clothing worn by priests and Byzantine church monks (Touati 2007). According to the Klaić dictionary (1970), *ras* means 'prince'. Thus, the name *Raška* could mean 'principality'. Mihailo Dinić ruled out the possibility that the name of the mediaeval state of Raška came from the name of the town of Ras (Dinić 1966).

The place called Rasa was not precisely localized, its name is only known in the form in which it appears in Porphyrogenitus' work (Greek: Ράσης). Porphyrogenitus reported that Rasa was a border crossing between

Serbia and Bulgaria. The map by the prominent French cartographer Guillaume Delisle, »Eastern Empire and Neighbouring Regions According to Constantine Porphyrogenitus«, shows Rasa (German: Ratzen) on the Serbian-Bulgarian border, but on the Bulgarian side (Grčić and Grčić 2012, 8). According to Dinić (1966), it should not be excluded that Porphyrogenitus' Rasa belonged to Bulgaria. In any case, it is a border fortress between the two countries (Grčić and Grčić 2014).

Figure 1: Part of the military map of the Balkans (Oračev 2005).

Figure 2: Fragment of the *Tabula Peutingeriana* (Segment 7; Sectors 3, 4) (Weltkarte des Castorius, genannt die Peutingersche Tafel 1888).



3.1. Rhazen (Guillaume Delisle, Eastern Empire and surrounding regions according to Constantine Porphyrogenitus, 1718).

3.2. Rasena (Guillaume Delisle, Map of the Hungarian Kingdom, first quarter of the eighteenth century).

3.3. Rasen, Rasna (Johann Matthias Haas, Map of Hungary and part of Croatia, Dalmatia, Bosnia, Serbia, Bulgaria, 1744).

3.4. Razena (Mattheus Seutter, Map of Transylvania, Moldavia, Walachia, Bulgaria, beginning of the eighteenth century).

3.5. Raszna (Johann Schreiber, Map of Romania with the Dardanelles, Bulgaria and Serbia, end of the seventeenth century).

3.6. Razena alt (ats), Rasna (Giacomo Cantelli da Vignola, Map of Serbia, 1689).

Figure 3: Details of several medieval maps showing what is today Ražanj (Vignola 1689; Delisle 1711; Haas 1744).

For this discussion, the military map (Figure 1) is of particular importance. It is the work of an anonymous author and is kept by the National Library in Paris in the Pauli Sanctini manuscript (Codex Latinus Parisinus, register number 7239). This map shows a large part of the Balkan Peninsula, from Belgrade to Istanbul. Estimated on the basis of the Ottoman flags, the possible time of creation of this map is 1395 or 1396 (Beševliev 1963; Oračev 2005). Fortified towns are represented in the form of vignettes. North of the city of Niš is shown a fortified town called Rossia (or Rassia; Figure 1). On this map, the name *Rossia* is printed on the approximate territory of today's town of Ražanj, as well as on many other old maps (Table 1). On this map, the town of Rasa is shown as a border town in Serbia, and on the other side of the gorge is written *Bulgaria*. In the fourteenth century in a nearby gorge, between Mounts Ozren and Rtanj, was the Bulgarian-Serbian border (Jireček 1959). The map is striking with its cartographic projection because it reveals some parallels with the Roman itinerary map *Tabula Peutingeriana* (Figure 2).

There are almost no old maps showing the Morava River from the end of the fourteenth century until the twentieth century that do not show a place called *Rasen*, *Rasena*, *Razena*, *Rozena*, *Rasna*, *Raszna*, *Resigne*, *Rhazen*, and finally *Ražanj* (Table 1 and Figure 3). Medieval maps are characterized by the similarity of the location of this place in regard to the relief and river flows (Figure 3). Some data from this and other old medieval maps can possibly provide the key for understanding the localization of the ninth-century border town of Rasa.

5 Conclusion

The historiographical text by Byzantine Emperor Constantine VII Porphyrogenitus, *De administrando imperio*, provides a testimony about the geography of settlements in the Balkan Peninsula in the second half of the ninth century and first half of the tenth century. This article addresses the border town of Rasa. Many scholars (Dinić, Ćirković, Kalić) have doubted the traditional theory of the precise location of the place. The issue may be resolved by old maps. Particular support in this regard may be maps created by prominent cartographers from the end of the fourteenth century to the end of the eighteenth century. This paper points to Ražanj, which could be the border town of Rasa (Rasen), which was mentioned by Porphyrogenitus as a place near the Serbian-Bulgarian border.

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SPECIAL ISSUE

Agriculture in modern landscapes: A factor hindering or facilitating development?

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AGRICULTURE IN MODERN LANDSCAPES: A FACTOR HINDERING OR FACILITATING DEVELOPMENT?

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Suburbanization at the expense of farmland: the example of the Ljubljana Marsh.

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Agriculture in modern landscapes: A factor hindering or facilitating development?

ABSTRACT: Agriculture plays an important role in both protecting and developing farmland. In Slovenia, the main reasons for this loss are urbanization and the implementation of large development projects that require the destruction of fertile farmland. About 3000 ha of farmland has been lost each year since Slovenia's independence. The importance of agriculture and farmland is touched upon in this special issue of *Acta geographica Slovenica*. The authors focus on management of farmland, analyse the development potential for agriculture, observe the changes in the landscape by remote sensing, soil quality and its pollution, and land cover as an element of biodiversity. They draw attention to the lack of participation in spatial planning procedures and the question of the importance of agriculture and jobs in this sector in national economy. This introductory paper brings a short analysis of how the issue of farms' spatial constraints and moving farm structures to new locations is perceived by municipal offices, nature parks, and the Slovenian Chamber of Agriculture and Forestry and its regional offices.

KEY WORDS: agriculture, urbanization, spatial planning, less-favorable areas, limiting factors, karst, Slovenia, European Union

Kmetijstvo v sodobni pokrajini: zaviralec ali pospeševalec razvoja?

POVZETEK: Kmetijstvo ima pomembno vlogo pri varovanju in razvoju kmetijskih zemljišč. Od osamosvojitve dalje je Slovenije vsako leto izgubila približno 3000 ha kmetijskih zemljišč. Glavni razlogi za njihovo izgubo so urbanizacija in izvajanje velikih razvojnih projektov, ki zahtevajo uničenje plodnih kmetijskih zemljišč. Pomena kmetijstva in kmetijskih zemljišč smo se dotaknili tudi v tej posebni izdaji revije Acta geographica Slovenica. Avtorji se osredotočajo na upravljanje kmetijskih zemljišč, analizirajo razvojni potencial kmetijstva, opazujejo spremembe v pokrajini z daljinskim zaznavanjem, obravnavajo kakovost in onesnaževanje prsti ter rabo zemljišč kot element biotske raznovrstnosti. Opozarjajo na pomanjkljivo sodelovanje pri prostorskem načrtovanju in na vprašanje pomena kmetijstva oziroma delovnih mest v tem sektorju za nacionalno gospodarstvo. Uvodni članek prinaša kratko analizo o tem, kako občine, naravni parki in Kmetijsko-gozdarska zbornica Slovenije ter njeni regionalni uradi zaznavajo vprašanje prostorskih omejitev kmetij in premikanje struktur kmetij na nove lokacije.

KLJUČNE BESEDE: kmetijstvo, urbanizacija, prostorsko planiranje, območja z omejenimi dejavniki za kmetijstvo, omejitveni dejavniki, kras, Slovenija, Evropska unija

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1 Introduction

The importance of farmland and protecting has been a widely debated issue in Slovenia in recent months. The main reason for this is the planning of certain business development projects, the siting of which will destroy high-quality farmland. According to agricultural experts, this will cause irreparable damage to Slovenian agriculture and food security. Let us mention only two such development projects. The first is the construction of an auto paint shop in the Municipality of Hoče–Slivnica, where a large number of new jobs supposedly justifies the destruction of over 80 ha of high-quality and highly fertile farmland. The second is the planned construction of the Third Development Axis, the aim of which is to strengthen the economy of secondary urban centers (Nared and Razpotnik Visković 2016). Its northern section from Velenje to Šentrupert is planned to cross 110 ha of Slovenia's highest-quality farmland.

Both cases have certain points in common: they are both development projects of national and regional importance, the implementation of which requires the destruction of fertile farmland. This is also the main reason for the strong opposition from local civil initiatives, environmental organizations, and individuals. They all draw attention to the lack of participation in spatial planning procedures for siting such projects (Nared et al. 2015) and the insufficient assessment of alternative solutions. The issue of insufficient inclusion of individuals and local initiatives in preparing municipal planning documents (which is even more apparent with national spatial plans) was also highlighted by the Court of Auditors in its recent audit of spatial planning in Slovenia (Revizijsko … 2017).

This raises the question of the importance of agriculture and jobs in this sector in the current national economic strategy. Slovenia's Development Strategy (Strategija … 2005) does not even mention the word *agriculture*, even though there were 69,902 farms in Slovenia in 2016 (Kmetijska … 2016); something similar applies to the 2050 Vision of Slovenia (Slovenija … 2017). Such developments have a long-term effect on the overall national economy because, among other things, they also affect biodiversity and forest and water resources. Moreover, the new jobs and economic development promised by the planned projects mentioned above indirectly threaten not only the production of food and national food security, but also jobs in agriculture that are tied to cultivating the farmland that is now threatened.

The Alumni Club of the Department of Agronomy at University of Ljubljana's Biotechnical Faculty responded to these recent events with the roundtable Protecting Agricultural Land (Kako prenesti varovanje … 2017), which was held in early May 2017. At this roundtable, participants discussed the farmland protection system over time, presented future changes including the new methodology for defining farmland of the highest quality, highlighted the importance of urbanization as the main reason for the loss of farmland, and examined the role of agriculture in this.

The importance of agriculture and farmland is also touched upon in this special issue of *Acta geographica Slovenica*. The authors emphasize that high-quality management of farmland involves more than just defining the regulations and the ratio between areas allocated for urban growth and those allocated for rural development (Markuszewska 2017). It is vital to first evaluate the development potential for agriculture in various areas and develop tools that make this possible (Pažek et al. 2017). In this as well as in observing changes in the landscape, land use, and land cover, extensive databases such as NDVI, Corine Land Cover, and the Slovenian Register of Current Agricultural and Forest Land Use have proven helpful for over a decade, but they need to be used with caution, taking into account the pitfalls hidden in the methodological changes in capturing data over time (Foški 2017; Jovanović, Milanović and Zorn 2017). In terms of protecting high-quality farmland, usually only data on area are used, while neglecting two other aspects: first, soil quality and the impact of its pollution on other landscape elements, especially water (Ilić and Panjan 2017), and, second, land cover, which is a vital element of biodiversity, nature conservation, and protection against natural disasters (Polenšek and Pirnat 2017).

2 Agriculture and farmland

Agriculture plays an important role in both protecting and developing farmland, considering that there have been constant spatial tensions between agricultural and rural activities in recent decades, usually resulting in a more or less permanent loss of farmland. Urbanization is the main reason for this loss in Slovenia. Since Slovenia's independence, 70,000 ha of farmland (or 3.45% of the country's territory) has been built up, and the current municipal planning documents envisage another 57,000 ha to be earmarked for the construction of housing, business and commercial districts, and transport infrastructure (Kako prenesti varovanje … 2017). In addition, farms also have increasing spatial needs for expanding and modernizing their activities (Razpotnik Visković 2017). Today's farmyards and the structures in them are unable to meet modern technological needs and regulations (Knific and Bojnec 2015). Farms inside settlements are becoming increasingly spatially constrained, with areas for relocation or mere expansion usually only available on the edges of the settlement (i.e., on farmland; Razpotnik Visković 2015), where urbanization is also spreading.

The target research project Selecting Farm Structure Sites and Solving Spatial Conflicts (Internet 1) revealed how the issue of farms' spatial constraints and moving farm structures to new locations is perceived by municipal offices, nature parks, and the Slovenian Chamber of Agriculture and Forestry and its regional offices. A full 192 municipalities – or 90% of all Slovenian municipalities, accounting for 90% of Slovenian territory and 90% of the total Slovenian population – responded to the online questionnaire prepared as part of this project. Such a wide response already indicates that the spatial constraints on Slovenian farms are a very relevant topic (Polajnar Horvat and Smrekar 2015). A full 85% of the responding municipalities confirmed that their farmers were dealing with spatial constraints and that this was a serious development issue. In twenty-eight municipalities, this problem was not indicated. These were mainly hilly municipalities with an exceptionally low share of developmentally promising farms.

On the other hand, only 37% of municipalities had allocated areas for relocating or expanding promising farms in their spatial plans. Considering that as many as 85% of the municipalities acknowledged a spatial constraint problem, this share was modest and lower than expected. The areas envisaged for relocating or expanding promising farms are important not only from the viewpoint of these farms' economic progress, but also in terms of reducing social tensions within settlements. Lower quality of life due to agricultural activity (noise, odors, mud on the roads, and so on) in (sub)urban settlements (Tiran 2016) is one of the main reasons for disagreements among residents (Guštin and Potočnik Slavič 2015). The majority of municipalities considered suitable adjustments to their spatial plans to be the primary method for resolving such disputes. By adopting suitable planning documents, development can be directed to more suitable areas, thus preserving the highest-quality farmland.

An important measure in terms of developing farmland is not only the relocation of farms and the construction of large farm buildings, but also the construction of auxiliary farm structures. The Agricultural Land Act (Zakon o kmetijskih … 2011) provides that in their planning documents local communities may allow the construction of simple farm and forestry outbuildings and other structures on farmland for which a building permit is not required (e.g., hayracks, sheds, greenhouses, or barns). Municipalities assess the suitability of selecting sites for auxiliary farm structures very differently. The main problems observed include inappropriate dimensions and location, inappropriate designs, and disproportionate visual impact. A major problem highlighted by the municipalities is the fact that these structures are not being used for agriculture, but as vacation houses, workshops, camper garages, or even housing. It is surprising that farmers were the main developers in only 55% of municipalities; elsewhere, non-farmers predominated or the ratio was half-and-half. The current situation primarily results from a lack of inspection and inadequate activity by inspection services.

In their interviews, the representatives of agriculture and forestry institutes highlighted another issue: municipalities provide very different support for the construction of farms and the development of agricultural activity on farmland. They believe this is not fair because the same law applies to all of Slovenia.

Seventy-eight per cent of municipalities reported that they strategically support the construction of farm structures on farmland, whereas the rest were against it. Reservation toward construction on farmland was expressed in four urban municipalities (Maribor, Nova Gorica, Murska Sobota, and Ptuj) and many municipalities with well-developed tourism (Ankaran, Bled, Bohinj, Brda, Rogaška Slatina, Šmarješke Toplice, Tolmin, and Zreče). In contrast, municipalities with a high share of developmentally promising farms (Cerklje na Gorenjskem, Mozirje, Sveti Jurij ob Ščavnici, and Vrhnika) were in favor of such construction. Here it must be added that the lack of support for farm construction on farmland does not mean that these municipalities are against agricultural activity or that they hinder its development; such a standpoint can merely contribute to more long-term protection of farmland, which is also called for by agricultural experts themselves.

3 Papers in the special issue

This special issue begins with a paper on the conflicts between legal policy and rural area management in Poland (Markuszewska 2017), which describes the consequences of rural transformation as witnessed in central and eastern Europe and reflected in many adverse effects that have an impact on the environment and activities in it, and hence also long-term economic development. Spatial management is encumbered due to a lack of strategies and legal documents acknowledging the importance of the development of rural areas, especially where they come in contact with urban areas or in areas of infrastructure use. This is where conflicts arise, the most common consequence of which is a continuous decrease in high-quality land suitable for agriculture. The author proposes a mechanism for coordinated spatial planning and planning of agricultural activities that would reduce the probability of conflicts.

In her paper »The (Non)usefulness of the Register of Current Agricultural and Forest Land Use for Monitoring Processes in Urban Areas,« Mojca Foški (2017) discusses changes in urban land use as a key indicator of spatial processes in Slovenia. She reports that in Slovenia it is only possible to monitor this phenomenon by using the agricultural and forest land use register, and that the methodology for capturing these types of data has changed so much that the register does not reflect the actual changes in urban areas. This means there is no systemic and up-to-date data source available to monitor actual changes in urban areas, where extensive use (undeveloped islands within settlements) often occurs, degraded areas form in settlements, and various conflicts arise, especially on the edges of urban and suburban settlements, where they adjoin agricultural and forest land.

The paper »Forest Patch Connectivity: The Case of the Kranj–Sora Basin, Slovenia« (Polenšek and Pirnat 2017) focuses on an important but often overlooked cultural landscape element: patches of forest, trees, and shrubs. These areas form an important agricultural landscape element in terms of biodiversity, nature conservation, and protection against natural disasters (e.g., wind). Urbanization and farming exert pressure on these parts of the landscape, resulting in reduction of their area and spatial connectivity. The authors argue that the connectivity of such areas is just as important for the functioning of a natural system as their area; this is especially true for minor agricultural land use types such as forests. This paper features an original methodological approach to studying this issue and proposes certain solutions useful for long-term planning of the use of agricultural landscapes.

The paper »Multi-Criteria Assessment of Less-Favored Areas: The National Level« deals with less-favored areas for agriculture (Pažek et al. 2017). These areas are highly relevant for agriculture in Europe because they account for as much as 65% of farmland. In Slovenia, this percentage is even higher (73%), covering mountainous areas (72.3% of Slovenia's total area), special vulnerable areas (10%), and other less-favorable areas with permanently infertile soil (4%), with karst land not taken into account (Ciglič et al. 2012). The authors present the complex multi-criteria decision-making model DEXi, which makes it possible to assess the most suitable farming method with an emphasis on sustainability. The model can be applied to the analysis of individual farms as well as regional analyses and agricultural policy. The agricultural landscape is a complex system, in which diverse agricultural activities are impacted by many other landscape processes, which creates conflicts and represents a constant management challenge. The use of models, such as the one presented in this paper, may help solve these issues.

The paper »The Use of NDVI and Corine Land Cover Databases for Forest Management in Serbia« (Jovanović, Milanović and Zorn 2017) also examines conflicts within the landscape, but from a different starting point. It presents the use of remote sensing and Corine land use data for managing forests in the Serbian municipalities of Kuršumlija and Topola. Because of the finding that the official data on the forest area in Serbia are deficient and differ from those in the Corine database, the authors present the use of a normalized vegetation index for calculating the forest area. This method is based on satellite vegetation data and provides fairly accurate results, which will facilitate the management of forest areas in this area, where illegal tree felling is common. This is most likely the reason for the calculated values being lower than the official ones. The authors recommend that the method be used for all geographically similar areas (e.g., in the Balkan Peninsula) or other areas that face illegal activities and where accurate official data sources are often unavailable.

Nitrogen and phosphorus pollution is common in agricultural landscapes and is especially alarming in protected areas. The paper »Nitrogen and Phosphorus Pollution in Goričko Nature Park« (Ilić and Panjan 2017) deals with the long-term impact of diffuse and point sources of pollution on the quality of ecosystems. The authors carried out a comparative analysis by monitoring surface watercourses. They established elevated levels of nitrogen and phosphorus compounds in the water. Long-term pollution is indicated by the increasing levels of these pollutants, which is especially alarming due to the modest thermal and discharge potential of rivers. The results of the analysis have wider implications because this is not an isolated case, but a predominant situation in agricultural landscapes that should receive greater attention.

4 Conclusion

The papers in this special issue elucidate the topics described above, each in their own way. Examples from various countries show that spatial planning is a complex process in agricultural landscapes. A large number of stakeholders and diverse long-term impacts at various levels, from legislative to economic, make it difficult to manage these landscapes and cause frequent conflicts. Many of these could be solved through better land-use planning or by directing activities and, first and foremost, through better inclusion of stakeholders in all decision-making processes. This entails planning, preparing, and adopting strategic documents and municipal planning documents, and better harmonization of business, tourism, agricultural, and other strategies. The intensive development of farmland, which has been common in Slovenia since its independence, calls for more decisive protection of this land, reigning in urbanization tendencies, and efforts to raise awareness about the importance of farmland for the survival and secure future of communities. Or, in the words of Franklin D. Roosevelt: »The nation that destroys its soil destroys itself.«

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CONFLICTS BETWEEN LEGAL POLICY AND RURAL AREA MANAGEMENT IN POLAND

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Agricultural landscape, the environs of Poznań.

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Conflicts between legal policy and rural area management in Poland

ABSTRACT: This paper refers to the issue of the damaging consequences of the ongoing rural area transformation in Poland in a dynamically developing economy, with a simultaneous lack of adequate planning tools of countryside management. Lack of strategic documents recognise the importance of rural area development leads to irreversible changes, presented on the basis of the issue of farmland merging and the depletion of farmland resources. As a solution guaranteeing comprehensive rural management, agrarian arrangement plans of communes (AAPC) and agrarian arrangement projects of villages (AAPV) have been proposed.

KEY WORDS: rural geography, spatial planning policy, farmland merging, de-farming, agrarian arrangement plans of communes, agrarian arrangement projects of villages, rural area, Poland

Neskladje med pravno politiko in upravljanjem podeželja na Poljskem

POVZETEK: Avtorica v članku obravnava problematiko škodljivih posledic trenutne preobrazbe poljskega podeželja, ki se odvija v dinamičnem gospodarstvu ob hkratnem pomanjkanju ustreznih načrtovalskih orodij za upravljanje podeželja. Pomanjkanje strateških dokumentov, pomembnih za razvoj podeželskih območij, povzroča nepopravljive spremembe, ki so v članku predstavljene na podlagi problematike združevanja kmetijskih zemljišč in njihove izgube. Kot rešitev, ki zagotavlja celovito upravljanje podeželja, avtorica predlaga oblikovanje načrtov kmetijske ureditve občin in projektov kmetijske ureditve vasi.

KLJUČNE BESEDE: geografija podeželja, politika urejanja prostora, združevanje kmetijskih zemljišč, deagrarizacija, načrti kmetijske ureditve občin, projekti kmetijske ureditve vasi, podeželje, Poljska

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1 Introduction

In Central and Eastern European countries, since the beginning of the 90's of the past century, when instruments of market economy were set in motion, an enormous change in the use of agricultural areas has been observed. Unfortunately, in most cases, improper practices in the decision-making process about spatial planning are observed. However, it must be explained that a strong desire for land consumption expressed by individuals has enforced legislators to create laws enabling rapid economic development.

This situation can be observed in Poland. When it comes to countryside development, in Poland the legal guidelines of spatial planning leave much to be desired (Markuszewska 2012). Although agricultural matters are included in many strategies (Figure 1), no planning documents related to agrarian space constantly operated by farmers have yet been elaborated. Yet, not only elaborations about the agronomic utilisation of rural areas are missing, but also documents concerning village renewal and rural heritage protection. In addition, existing legal acts protect poorly against the irretrievable decline of soil resources whilst also not supporting agriculture modernisation in the scope of the improvement of agrarian structure. Not to mention the lack of any legal policy system of rural area development, integrating the various levels of administrative bodies responsible for the decision-making process.

This paper discusses the problem of the faulty planning and management system of rural areas in Poland. The aim was to present conflicts between faulty legal policy and negative changes in rural area being a result of implementation of that legislation. On the one hand, remark was concentrated on the issue of the fragmentation of the agrarian structure. On the other hand, attention was put on the de-farming phenomenon. Finally, suggestions to improve decision-making policies in the field of the management of rural area have been proposed.

2 Methods

The faulty planning system of rural areas development, with respects to weaknesses of the legal ground as well as the competence divergence of administrative bodies, is presented in this paper. Several major questions related to rural landscape dynamics and management were identified and were kept as the centre of reflection and comparison:

- What are the weak points of rural area development at a local level?
- To what extent does the existing spatial planning and management framework take into account the aspect of agrarian production space modernisation as well as farmland resources protection?
- Are there any opportunities for slowing down the rate of the negative consequences of controversial policy implementation?

The data were gathered from legislation (legal acts referring to the procedures for farmland merging and de-farming) and statistics (describing changes in farmland merging since 1945 as well as agricultural land de-farming since 1990). Open interviews with 20 officials, responsible for local and regional planning, were conducted. Additionally, in order to describe the wider context of the research, branch literature was also taken into consideration. As a result, several solutions for improving the current situation in the planning and management of rural areas have been presented.

3 Results

3.1 Stewardship of production space in relation to farmland merging

When considering the improvement of agriculture efficiency, one of the rural policy guidelines and an aspiration of the Polish government since the system's transformation, there has been a total rebuild of the agrarian structure. Agrarian structure, defined as a state of agricultural production units, is classified into different groups according to land ownership and land fragmentation.

In Poland, a characteristic feature of agrarian production space is land fragmentation, often referred to patchwork fields. Patchwork fields mean that farmland of one ownership is split up into a large number of tiny plots scattered between varied landowners with a complicated arrangement. Land fragmentation is described by the plot distribution pattern, this could be: a small average-sized farm (7 ha), a relatively

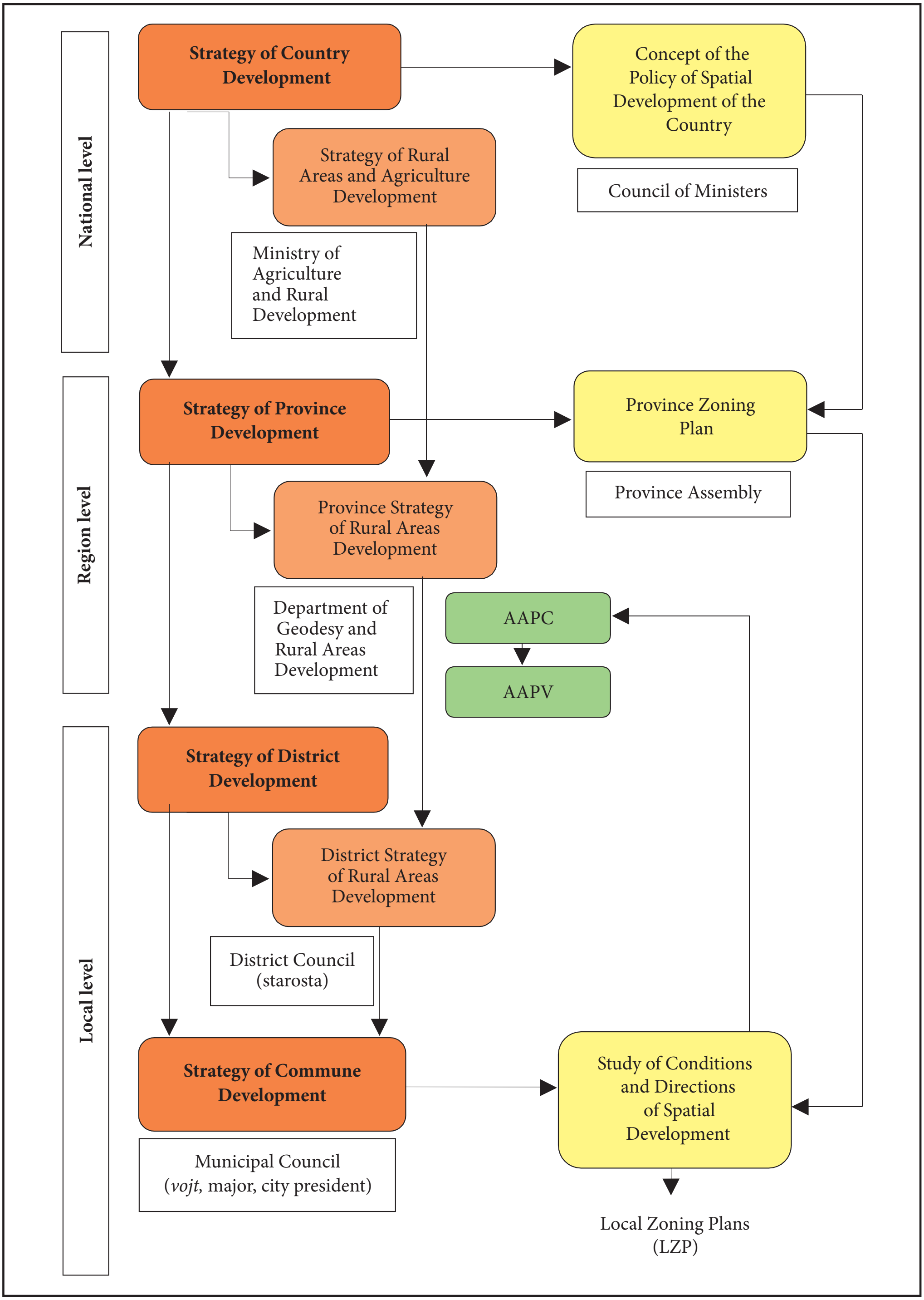

Figure 1: Selected strategic and planning documents drawn up by different administrative bodies. Strategic documents are marked by red colours, whereas planning documents in yellow.

high number of land plots per farm (8 pieces) and a small average size of individual plot (0.6 ha). Additionally, the distance between the farm and the cultivated fields can be considerably remote, sometimes reaching up to 3 and even 4 km (Woch 2006; Woch et al. 2011). As for spatial distribution, the most unfavourable agrarian structure occurs in south-eastern Poland. However, also in other parts of the country this problematic field mosaic contributes to a serious cultivation inconvenience.

In a situation like this, the carrying out of land consolidation can solve the farmland fragmentation issue. Additionally, comprehensive land consolidation includes not only the merging and exchanging of arable land, but also the modernization of rural area. For this reason, farmland consolidation can be a great tool for both, production space upgrading and countryside renewal. But even though these profound changes lead to rural area modernisation, farmland merging is conducted very rarely in Poland.

Analysing the effectiveness of land consolidation work in the post-war period, several re-parcelling stages can be distinguished. Between 1945 and 1967 farmland merging work covered 560,000 hectares of agricultural land. Until 1980, increased activity was observed – 3,676,000 hectares of land were merged. In the years 1981–1988, consolidation activities decreased noticeably, and during that period only 444,000 hectares of land were merged. Further, through the economic transformation, between 1989 and 1998, a steady decline in land consolidation was still evident, as only 228,000 hectares of farmland were merged.

There are several reasons explaining the decreasing interest in land consolidation work, among which the most important are: adverse legislation, declining funds and farmers unwillingness to cooperate (Woch 2006; Wierzchowski 2007; Markuszewska 2013). Nevertheless, for a better understanding of the weaknesses of the land consolidation process, legislation review has been undertaken.

First of all, the competences of the public administration are divided between various tiers; some of the responsibilities of land consolidation are under local authorities and yet others are under regional ones (Act on Land Consolidation and Exchange – Ustawa o scalaniu … 1982; Act on Local Government – Ustawa o samorządzie … 1990; Act on Province Government – Ustawa o samorządzie … 1998). For example, head of the district government (Pl. *Starosta*) at landowners' formal request, issues a positive opinion on farmland re-parcelling and simultaneously prepares a decision on the initiation of the land consolidation process. Later, a land consolidation project is drawn up by the surveyor-designer from the province government. Despite the fact that the project is drafted by the surveyor-designer, it is head of the district government who is entrusted to approve the document. Additionally, the discrepancy in the administrative competences has not only a detrimental effect on legal processes, but also makes civil servants less involved in the farmland merging procedures.

Before the public administration reform in 1998, the authorisation to conduct farmland merging procedures was at commune level, whereas after the reform this process is controlled by district and provincial levels (Act on Regulations Implementing the Act Reforming Public Administration – Ustawa-Przepisy … 1998). As a result the commune authorities have been disregarded, which should not happen, because there are commune officers who are responsible for planning and development at the landscape level, and farmland merging is a vital aspect of that process.

Another aspect is the separation of merging-exchanging work from post-re-parcelling development. As a result, merging-exchanging work, based on a land consolidation project, concerns land parcel consolidation and relocation, is fully completed by the geodesy department of the province government. In turn, post-consolidation development, including road construction, drainage ditch implementation is under the supervision of the head of the district government who selects a contractor during the tendering procedure.

On the other hand, currently in force Act on Land Consolidation and Exchange (Ustawa o scalaniu … 1982) gives a too powerful role to the land consolidation committee, represented mostly by landowners. For example, the decisions of the head of the district government can be undermined at any time and procedures or decisions may be easily prosecuted by the administrative court. Before 1982, when that law was implemented, these activities were limited. Even the pre-war regulatory Act on Land Consolidation (Ustawa o scalaniu … 1923) restricted the power of the merging committee when it slowed down the merging work. In such a case it was possible to dismiss all members and to appoint new ones collected from the land consolidation authorities not landowners. Nowadays it is impossible, even if the advisory group exceeds its power.

Furthermore, the provisions of the Act allow for the temporary suspension or even abandonment of the merging activity at the request of only one landowner, regardless of the progress of the work, and surprisingly, that person is not fined for any investments already executed. In comparison, again with reference to the pre-war act, Act on Land Consolidation (Ustawa o scalaniu … 1982), which imposed the following limitation: interruption of any ongoing land consolidation processes was only possible if the application was submitted by two-thirds of the participants, and only the persons responsible for the procedure deferment would bear the cost of any work previously conducted.

3.2 Farmland resources hazard with regard to urban sprawl

According to the Act on Agricultural and Forest Land Protection (Ustawa o ochronie … 1995), farmland is subjected to legal protection, which means that the use of farmland for non-agricultural purposes is generally restricted. Nevertheless, in certain situations the Act enables de-faming, which means that agricultural land can be intended for non-agricultural purposes. However, overuse of that regulation can lead to the depletion of farmland resources.

For a better understanding of the negative consequences of de-farming process, a brief review of the legislation is given below.

In 1966 the first legal act Resolution of the Ministers' Council on Agricultural Land Protection (Rozporządzenie … 1966) came into force. One of the principles emphasised that, »*for non-agricultural purposes*« can only be assigned to the poorest soils (5th or 6th classes). Although, good farmland quality (1st–4th classes) could be de-farmed, but only when there was a lack of substitute soils in a given area or when the non-farming allocation was justified for particularly important national reasons.

However, shortly afterwards, the legislation required streamlining and therefore new legal acts were introduced: Act on Agricultural and Forest Land Protection (Ustawa o ochronie … 1971), Act on Land Consolidation and Exchange (Ustawa o scalaniu … 1982). Here the limitation of agricultural land allocation for non-farming purposes was much more restrictive, and additionally, the power over decisions to be taken was given to the province governor (Pl. *Wojewoda*), with the objective of discouraging parties from seeking to obtain de-farming decision.

The presently enforced law, approved in 1995 – the Act on Agricultural and Forest Land Protection (Ustawa o ochronie … 1995), maintained most of the previously established regulations, and additionally, imposed the obligation of the marking of non-agricultural land allocation in local zoning plans. Moreover, in the cases of 1st–4th class soils being de-farmed, the Minister of Rural Development was given authority. The amendment of 2008 made the Act more liberal and washed out all previously existing limitations. First of all, for issuing the administrative decision on de-farming, the Marshal from the provincial government was given entitlement. Secondly, only in relation to the de-farming of the 1st–3rd classes of agricultural land, was the obligation to obtain a decision required, and only when the area exceeded 0.5 hectare. This means that such approval was unnecessary in the cases of farmland which 4th–6th class soils, regardless of the size of the area proposed to be de-farmed. Moreover, no permission was requisite for the non-agricultural use of the 1st–3rd classes of farmlands located within administrative boundaries of towns. Finally, the obligation to move the humus layer of 1st–4th soil classes has been withdrawn. Undoubtedly, this policy relaxation has worked against the protection of farmland resources. For example, simply taking into account the area of farmland in towns, theoretically 1 million hectares of agricultural land has supposed to have been irreversibly lost.

This harmfully operated legal regulation has been limited according to the newest alteration of 2013. The new rules indicate that only the Mayor (Pl. *Wójt*) is authorised to submit an application for de-farming, naturally on the request of landowners (previously it was directly under landowners' power). Furthermore, in relation to the de-farming of agricultural lands of 1st–3rd classes, only the Minister of rural development is authorised to take the decision (previously, the power was under local government). What is also important, according to the Act on Spatial Planning and Development (Ustawa o planowaniu … 2003) in order to obtain de-farming permission for future building investments, several requirements must be fulfilled, such as: access to public roads, access to water infrastructure and electricity network, and sometimes sewage and the gas system.

According to statistical data, in the years 1990–1994, between 5,000 and 7,000 hectares of agricultural land were de-farmed each year. In the next period, between 1995 and 2003, the intensity of this process slightly decreased, because every year between 1,000 and 3,000 hectares were allocated for non-farming purposes. However, in the years 2004–2013 the activity increased: from 3,000 to more than 5,000 hectares were de-farmed annually. Another disturbing matter is the quality of de-farmed soils. The best quality of soils, those including 1st–3rd classes, covers about 26%, however, the first two classes take only 3%. Even if the legal provisions emphasize that only wastelands or the poorest soils should be designated for non-agricultural purposes, the conducted analysis revealed that since 1995 the greatest percentage of de-farmed soils covered the richest soils (Environment 2013).

The loss of farmland is particularly evident in the range of influence of urban areas, where on the one hand, there is an easy access to »fresh land«, and on the other hand, easy access to urban services.

3.3 Rural area management – searching for a good solution in a long-term perspective

The above studies revealed the strong need to improve the existing controversial body of laws as well as to elaborate documents relating to the management of agrarian space, with the emphasis put on comprehensive rural area development, tailor-made for social demands. As for documentation, agrarian arrangement plans of communes (AAPC) and agrarian arrangement projects of villages (AAPV) can fulfil that requirement. However, AAPC and AAPV are kinds of so-called »economic programs«, not »planning documents«, which excludes them from the decision-making process of spatial planning. Also, there is no legal obligation to draw up these documents. The underestimation of AAPC or AAPV is proved by the fact that only in one province, the Lower Silesia Province, did the regional government decide to implement agrarian arrangement plans of communes for practical actions to deal with the issue of farmland fragmentation.

With regards to the agrarian arrangement plan of commune, the main goals are: the provision of comprehensive and multifunctional development of rural areas, the boosting of farms' effectiveness and improvement of general living conditions, all this with the simultaneous protection of the natural environment and the preservation of cultural heritage. Accordingly, AAPC is a document clarifying the current stage of a rural area development based on its existing natural potential, people resources, cultural values, as well as presenting scenarios for future changes. The range of agrarian arrangement work proposed to be implement in the AAPC, includes in particular:

- improvement of the plot distribution pattern by the reduction of land fragmentation,
- modernization of the agrarian structure by the construction of new infrastructure networks including between-fields roads, drainage ditches,
- an increase in soil productivity by conducting anti-erosion activities and farmland reclamation,
- preservation of landscape by the designation of protected areas and forestation of poor quality farmland,
- implementation of non-farming purposes by the designation of land for the development of new residential, service purposes,
- revitalization of village by the renewal of existing buildings, implementation of public utility infrastructure, road renovation and plumbing system installation.

Among the information related to the characterisation of a plot distribution pattern, the subsequent data are given: the number of parcels in individual farms, size of the individual parcels, and distance between the farmstead and the arable land. Due to this fact, AAPC stands out from other local strategic documents as a useful tool in the assessment of land consolidation demand (Analiza zapotrzebowania … 2010). The guidelines of the AAPC constitute directives on the drafting of the AAPV. It is suggested that the most beneficial way of AAPV utilisation can be the drawing up of Projects for farmland merging and Projects for village renewal.

During the procedure of AAPC and AAPV elaboration, an important role is played by the local community; village leaders and farmers as well as the commune council. This way of proceeding, involving all parts of the decision-making process, allows for the working out of commonly accepted findings, which then streamlines the implementation of the agrarian arrangement work.

As for the practical application of AAPC, assessment of land consolidation demand in the Lower Silesia Province has been conducted. Based on the AAPC, several elaborations have been prepared by the Department of Geodesy and Cartography (the unit of province government), among which, the most important are: the Analysis of demand for land consolidation work in communes, the Study of demand for land consolidation work in the province as well as the Database of land consolidation objects (Analiza zapotrzebowania … 2010). It is important to emphasise that for the creation of a proper base for information flow, the Analysis among all sides (landowners and administrative bodies of local and regional governments) involved in land consolidation process, has been disseminated (Markuszewska 2013).

4 Discussion

The paper presents the conflicts between legal policy and rural area management and development in the context of the failure of farmland merging and the depletion of farmland resources in Poland. However, this situation is comparable to other countries of Central and Eastern Europe. The land fragmentation issue in Central and Eastern Europe has been widely discussed, for example by van Dijk (2003; 2007), Pasakarnis et al. (2013), King and Burton (1982). Other authors focused on the problem of the degree of fragmentation of agricultural land, which is a big obstacle to the development of modern farming as well as, like similarly in this paper, putting the emphasis on the complicated procedures of farmland merging and the role of the comprehensive approach to the land consolidation process (Kabat and Hagedorn 1997; Sarris et al. 1999, Voltr 2000; Skalenicka and Salek 2008; Vijulie et al. 2012). On the other hand, ongoing urban sprawl and intensive urbanization of rural areas lead to the depletion of farmland resources, which in respect to Central and Eastern European countries should raise particular interest, bearing in mind the role of agriculture in the national economies. This environmental harmful consequence, resulting from unregulated legal policy in many of the post-communist countries of this region of Europe, in several papers has been stressed. It is worth mentioning several examples: Matthew (2000), Hirt (2008), Łowicki (2008), Bălteanu and Popovici (2010), Suditu (2012).

5 Conclusion

On the basis of findings discussed in this paper, it has been proved that the problematical situation with management and development of rural areas in Poland is affected, inter alia, by the following reasons a lack of reasonable legal tools for rural area management, a lack of a harmonised policy with a comprehensive approach to the multifunctional development of rural areas, a lack of clarified goals of rural policy that is expected to be achieved by local and regional authorities, and a lack of long-term perspective in the decision-making processes on rural area development. All these aspects lead to disastrous environmental and economic consequences, such as for example, the loos of non-renewable soil resources, rural traditional landscape degradation and rising costs of living. However, a lack of strategic documents focusing on areas where agrarian production is the main purpose of farming development, means that the AAPC and AAPV can gain favour as complementary documents to existing ones, which has been proved above.

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THE (NON)USEFULNESS OF THE REGISTER OF EXISTING AGRICULTURAL AND FOREST LAND USE FOR MONITORING THE PROCESSES IN URBAN AREAS

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Urban land use, which covers all built-up areas, areas with infrastructure facilities, and other areas that permanently changed from a natural to a built environment, is in general increasing in all countries and environments.

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The (non)usefulness of the Register of Existing Agricultural and Forest Land Use for monitoring the processes in urban areas

ABSTRACT: The changing of urban land use is the key indicator of spatial processes at work. The only systemic data source in Slovenia that can be employed to monitor land use changes is the Register of Existing Agricultural and Forest Land Use. The hypothesis that the Register is not suitable for monitoring urban land use changes was tested by comparing the data in the »built-up and related land« category for 2002, 2005, 2009, 2011, and 2013. The analysis was carried out at the level of Slovenia, and the results were interpreted in relation to small testing areas in NE Slovenia. We found that the methodology of data capture varied to such a degree that the data fail to reflect the actual changes in urban areas.

KEY WORDS: spatial planning, land use, urban land use, spatial monitoring, Register of Existing Agricultural and Forest Land Use, Slovenia

(Ne)uporabnost Evidence dejanske rabe kmetijskih in gozdnih zemljišč za spremljanje procesov na urbanih območjih

POVZETEK: Spreminjanje urbane rabe prostora je ključni pokazatelj prostorskih procesov. Edini sistemski vir podatkov v Sloveniji, ki je lahko namenjen tudi spremljanju sprememb rab prostora, je Evidenca dejanske rabe kmetijskih in gozdnih zemljišč. Hipotezo, da evidenca ni ustrezna za spremljanje sprememb urbane rabe prostora, smo preverjali s primerjavo podatkov kategorije »pozidana in sorodna zemljišča« v letih 2002, 2005, 2009, 2011 in 2013. Analizo smo opravili na ravni Slovenije in rezultate interpretirali na manjših testnih območjih severovzhodne Slovenije. Ugotovili smo, da se je metodologija zajema podatkov tako spreminjala, da podatki ne odsevajo dejanskih sprememb na urbanih območjih.

KLJUČNE BESEDE: prostorsko načrtovanje, raba zemljišč, urbana raba, spremljanje stanja prostora, Evidenca dejanske rabe kmetijskih in gozdnih zemljišč, Slovenija

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1 Introduction

Knowing the situation and trends of land use and land cover changes is essential in order to make informed decisions concerning spatial planning, land management, and economic planning. The changes in land use and land cover are indicative of natural processes (e.g. transition from agricultural to forest land use) or human activities (e.g. transition from agricultural to urban land use). Land use changes are often reflected in changes to land cover, as land cover and land use are often correlated (Arnold et al. 2014; Antrop 2005; Ellis 2010; Tavares, Pato and Magalhaes 2012), except for land use changes in urban areas. In urban space only a small proportion of changes is detected as a change in land cover (e.g. change of a brownfield into a park), while changes from housing to services can only be detected by having insight into social and economic activities in the study area. It is accordingly important to distinguish between *land use* – defining the purpose of using the Earth's surface (INSPIRE 2013a; INSPIRE 2013b) – and *land cover* – defining the biological and physical cover of the Earth's surface (INSPIRE 2013a; INSPIRE 2014); by knowing land use and land cover we are able to provide more accurate information about space (Hovenbitzer et al. 2014). Land use is split up into the existing land use, and intended or planned land use (INSPIRE 2013b). Existing land use is independent of legal provisions, which lay down the ways of acquiring ownership and the rights thereof, and can be generally recorded on the ground (Metodologija … 2013), unlike intended land use. Transitions into urban land use are mostly regulated by spatial planning documents.

A detailed review of the literature by Slovenian authors dealing with identifying and monitoring land use changes was undertaken by Gabrovec and Kladnik (1997). The studies until 1997, and also thereafter, focused on studying agricultural land use changes (Vrščaj 2007; Miličić and Udovč 2012; Lisec, Pišek and Drobne 2013) or landscape changes (Petek 2002; 2005; 2007; Petek and Urbanc 2004; Kladnik and Petek 2007), and through this lens they indirectly touch upon urban land use areas. Urban land use changes have been addressed by Bogataj and Drobne (2002), Krevs (2004), and Topole et al. (2006). Bole (2014, 2015) focused on identifying Slovenian traffic areas and how they are changing.

The data on the surface area of urban land for Slovenia could be acquired from the Statistical GIS Land Cover and Land Use database (Skumavec and Šabić 2005, SURS 2007), but since 2005 it is no longer updated, while already Krevs (2004) pointed out to its deficiencies.

The CORINE Land Cover (CLC) database of the European Environment Agency (EEA) (Corine … 2014) provides the data for Slovenia for 1995, 2000 and 2006, which are shown in the Environmental Atlas (Atlas … 2014) and the Urban Atlas (Urban … 2014). This grid density is too low (cell spatial resolution is 100 × 100 m) to identify the existing land cover changes in urban areas.

Many authors (Ilešič 1950; Medved 1970; Gabrovec and Kladnik 1997; Gabrovec, Kladnik and Petek 2000; Lisec, Pišek and Drobne 2013; Bole 2014, 2015) used land cadastre data. The Surveying and Mapping Authority of the Republic of Slovenia stopped updating these data, but instead acquires them from the records kept by other sectors (Metodologija … 2013).

The Register of Existing Agricultural and Forest Land Use (hereinafter: Register) is based on the method of visual interpretation of orthophotos (DOF) with a resolution of 1 m, and the result is a topologically correct vector database of existing agricultural and forest land use. Vector data for 2002, 2005, 2009, 2011, and 2013 are publicly accessible at the website of the ministry responsible for agriculture (Internet 1). Although the register was set up for agricultural policy needs, it was used in real property valuation (Zakon o množičnem vrednotenju … 2006), pursuant to the Spatial Planning Act (2007) and the Rules on Land Use and Legal Regimes Data (2008), as well as for showing the discrepancy between the existing and the planned land use and for calculating the environmental indicator TP03 Built-up Land (Kazalci okolja v Sloveniji 2014).

The data from the Register were used to test the hypothesis on the suitability of the register on monitoring urban land use changes and the processes therein. We compared the categories of »built-up and related land« (hereinafter: PiSZ) at different time points, i.e. for 2002, 2005, 2009, 2011, and 2013, and, based on the findings, we gave recommendations with a view to establishing better and more wide-scale use of the EDRKGZ.

2 Data and methodology

2.1 Data from the Register and interpretation keys

The data from the Register for 2002, 2005, 2009, 2011, and 2013 are freely available at the Ministry of Agriculture, Forestry and Food's website (Internet 1). The Register's timeline is presented in detail in the paper by Miličić and Udovč (2012). The key to understanding and interpreting data is to know the interpretation keys (hereinafter: IK) (Interpretation Key 1.0 2002; Interpretation Key 2.0 2004; Interpretation Key 3.0 2005; Interpretation Key 4.0 2006; Interpretation Key 4.1 2008; Interpretation Key 5.0 2009; Interpretation Key 5.2 2011; Interpretation Key 6.0 2013) with a comprehensive description of land use capture, illustrative examples, and size of the areas. There are major modifications in IK 2.0, 3.0, 4.0, 5.0, and 6.0, and only minor modifications in 4.1, 5.1, and 5.2, which relate to agricultural land and do not influence the PiSZ land use capture.

The IK structure from versions 2.0 to 6.0 remained the same. In IK (2004), the use of PiSZ is defined as land with buildings, roads leading to urban areas and houses, parking lots, mines, quarries and other infrastructures intended for human activities. This category includes undeveloped land that is inseparably connected with human activities, such as:

- industrial and domestic waste sites,
- abandoned land inside built-up areas,
- city parks and gardens,
- recreational areas,
- gardens and extensive orchards next to buildings if they are smaller than the minimum area prescribed, and appertaining land of buildings,
- weirs, embankments and bridges if larger than 25 m^2,
- hay barns fall within this category if they have a roof or are situated in land zoned for building,
- permanent buildings in agricultural land if they are larger than 25 m^2 (apiaries, barns, sheds, etc.),
- zones along motorways, sown with grasses, trees and shrubs, and enclosed by fencing, are part of the motorway,
- grass-covered areas at airfields and airports are included only if enclosed by fencing,
- rural roads and forest roads are included in agricultural and forest land, respectively,
- land within urban areas exceeding 5000 m^2 is excluded.

Changes regarding PiSZ land use capture were made to the following versions of interpretation keys:

IK 4.0, 2006: changed the criteria for connecting too small pieces of land to neighbouring land,

IK 4.1, 2008: all GERKs (Graphical Agricultural Unit of a Farm Holding) smaller than 5000 m^2 and meadow orchards in appertaining land of structures exceeding 5000 m^2 are excluded from PiSZ use; smaller pieces of land are excluded only if they are classified as a GERK,

IK 5.0, 2009: all roads, cart tracks, and ditches wider than 2 m are excluded from primary land use and classified as PiSZ,

IK 5.2, 2011: walled slurry pits larger than 25 m^2 are included under PiSZ land use,

IK 6.0, 2013: grass runway surfaces in small airfields are included under PiSZ,

The smallest surface area of PiSZ land use capture increased from 10 m^2 in 2002 to 25 m^2 in 2005, and then stabilised (Table 1). The number of polygons of PiSZ land use capture significantly increased, i.e. from 71,279 in 2002 to 171,165 in 2013, possibly indicating the increased level of data capture accuracy.

To understand the Register it is necessary to know the general instructions for data capture, where the emphasis is on the generalisation of linear structures narrower than 2 m, and the exclusion of details smaller than 2 m, the criteria of merging and connecting polygons that do not meet the minimum illustration criteria, and simplifications and positioning of lines. Since IK 2.0 (2004) onwards, the general instructions for data capture did not significantly change, and we feel that they did not affect the quality of data.

2.2 Methods

The analysis was carried out at the level of Slovenia, as well as at the level of small testing areas. At the level of Slovenia, the data for 2009, 2011 and 2013 are divided into four areas (Figure 1), and the polygons are designated as OB_ID_1, 2, 3, 4. The data of 2002 and 2005 are adapted to these territorial areas.

A detailed data analysis was conducted for NE Slovenia (area 4 designated as NES, Figure 1), where the A5 Maribor–Pince motorway section was built or upgraded.

Because the data for area 4 NES do not reflect the expected increase in PiSZ land use, a further analysis in selected testing areas was conducted:

- an analysis of three continuous and three dispersed rural settlements,
- an analysis of infrastructure installations (motorway, rural roads and cart tracks, railway, small airfields and energy facilities).

The analysis was performed in 0.5 × 0.5 km quadrants, where the DOFs of 2002 and 2013 show no considerable changes that could be reflected in PiSZ land use data. The selection of areas without any actual changes in space is essential, because then the data acquired would reflect both the methodological changes in data capture as well as the capturer's interpretive abilities. The data analysis and processing were performed by using the functions of merging, overlaying and clipping of vector data layers in *ArcMap 10.2* and *Excel* 2007.

Table 1: Basic characteristics of PiSZ land use category at various points in time (Interpretacijski ključi . . . MKGP, author's calculations).

Basic data	2002	2005	2009	2011	2013
Year of digital ortophoto image production as the source of data capture	1997–2002	2000–2003	2006	2010, 2011	2011, 2012, 2013
Minimum PiSZ land use capture area	10 m^2	25 m^2	25 m^2	25 m^2	25 m^2
No. of independent PiSZ and use polygons out of all polygons	71,279 (654,270) (10.8%)	79,340 (715,243) (11.1%)	140,226 (965,793) (14.5%)	170,250 (1,481,001) (11.5%)	171,165 (1,639,321) (10.4%)
Interpretation Key (version)	1.0	2.0, 3.0	4.0, 4.1	5.0, 5.1, 5.2	6.0, 6.1
Distinctive features in interpretation keys for PiSZ land use			All land **smaller** than 5000 m^2 and the land classified as GERK is excluded.	Cart tracks and rural roads wider than 2 m and walled slurry pits larger than 25 m^2 are captured.	The built-up and related land use includes grass-covered runways at small airfields.

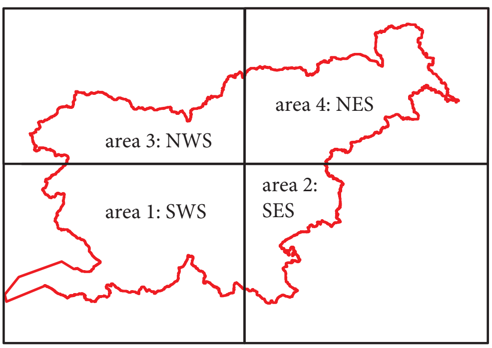


Figure 1: Data processing areas for the territory of Slovenia.

3 Results

3.1 Analysis of land use »built-up and related land« for the territory of Slovenia

The graphic calculation of PiSZ land use for each study area (Figure 1), and for the entire Slovenia is given in Table 2 and Figure 2. The proportion of PiSZ land use related to the surface of all land uses in the Register is also calculated. The surface of all land uses in the Register varied between 2,036,575 ha in 2002 and 2,032,710 ha in 2013, i.e. by 3.865 ha. The total surface of all land uses in the Register stabilised in 2011 and 2013, as there was only a 2-ha variation between the last two periods.

First, the PiSZ surface and proportion from the first data capture in 2002 until 2005 rose substantially from 108,473 ha to 114,456 ha (by 2983 ha) or 0.3%, and then in 2009 they decreased to the lowest level of 107,397 ha or a 5.28% proportion of all land uses. From 2011 to 2013, the PiSZ land use surface area grew by 363 ha or 0.02%.

Table 2: The graphic calculation of PiSZ land use per individual areas in Slovenia (Figure 1) and for the entire Slovenia in 2002, 2005, 2009, 2011 and 2013 (MKGP 2013; authors' calculation).

Year of the data from the Register analysed		2002		2005		2009		2011		2013	
Quantified graphic surface of all land uses in the Register (ha)		2,036,575		2,032,733		2,032,617		2,032,712		2,032,710	
		Built-up and related land (PiSZ)		Built-up and related land (PiSZ)		Built-up and related land (PiSZ)		Built-up and related land (PiSZ)		Built-up and related land (PiSZ)	
		(ha)	(%)	(ha)	(%)	(ha)	(%)	(ha)	(%)	(ha)	(%)
Study area	area 1: SWS	35,026	1.72	37,160	1.83	36,509	1.80	37,179	1.83	37,016	1.82
	area 2: SES	15,338	0.75	16,230	0.80	15,688	0.77	15,567	0.77	15,640	0.77
	area 3: NWS	15,382	0.76	16,067	0.79	14,889	0.73	15,913	0.78	16,096	0.79
	area 4: NES	42,727	2.10	44,999	2.21	40,310	1.98	40,173	1.98	40,443	1.99
	Slovenia	**108,473**	**5.33**	**114,456**	**5.63**	**107,397**	**5.28**	**108,832**	**5.35**	**109,195**	**5.37**

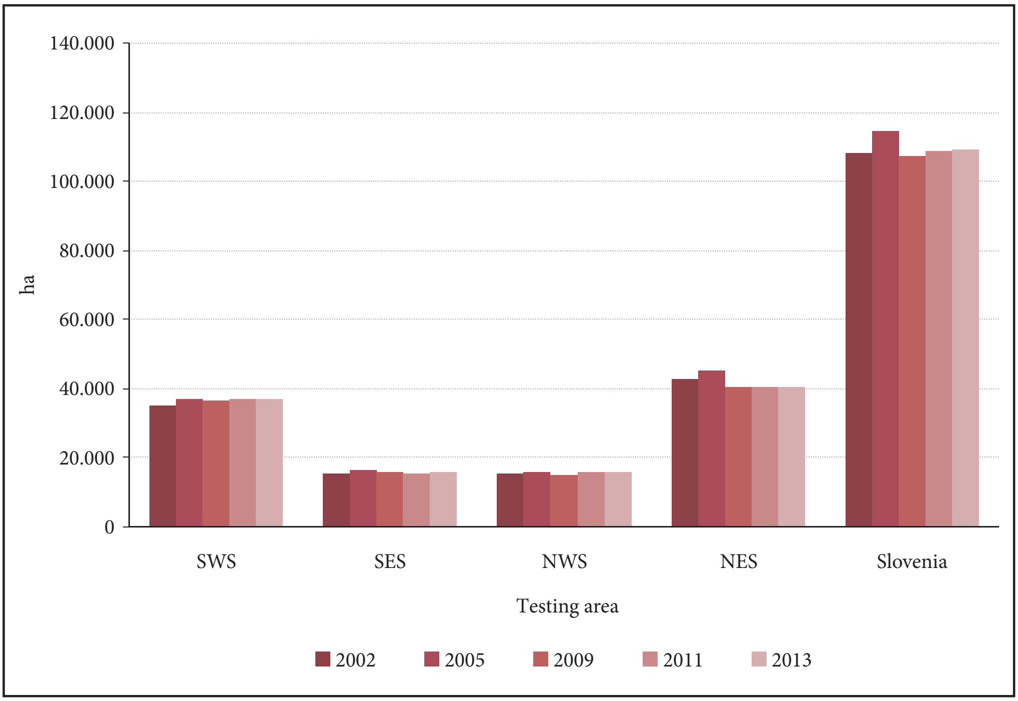


Figure 2: Illustration of PiSZ surface changing per individual study areas (Figure 1) in various periods (MKGP 2013; author's illustration).

Between 2002 and 2005 the data capture methodology's criterion regarding PiSZ increased from 10 m^2 to 25 m^2. It can be said that the accuracy of acquisition decreased, which probably affected the determination of the maximum PiSZ land use in the time period in question. Based on the reduced surface in 2009 we can conclude that in the previous observation cycle there was no significant urbanisation growth. The reduced surface in 2009 could result from the changed data capture methodology concerning agricultural land within urban areas, since until 2008 it only covered continuous agricultural land larger than 5000 m^2, while after 2008 also land smaller than 5000 m^2, complying with the criteria for capturing other types of existing use, and extensive meadow orchards smaller than 1000 m^2 if they are inscribed as GERKs.

3.2 Analysis of »built-up and related land« land use acquisition for NE Slovenia

During 2000–2009 the construction of the A5 Maribor–Pince motorway section was underway in area 4 NES (Figure 1). The Pomurje motorway branch consists of seven sections, and the connecting regional roads

Table 3: Built-up and related land associated to the A5 Maribor–Pince motorway section (Arh 2012).

Year	Built-up and related land (PiSZ), associated to the Maribor–Pince A5 motorway section (ha)
2002	0
2005	76
2009	198
2011	465

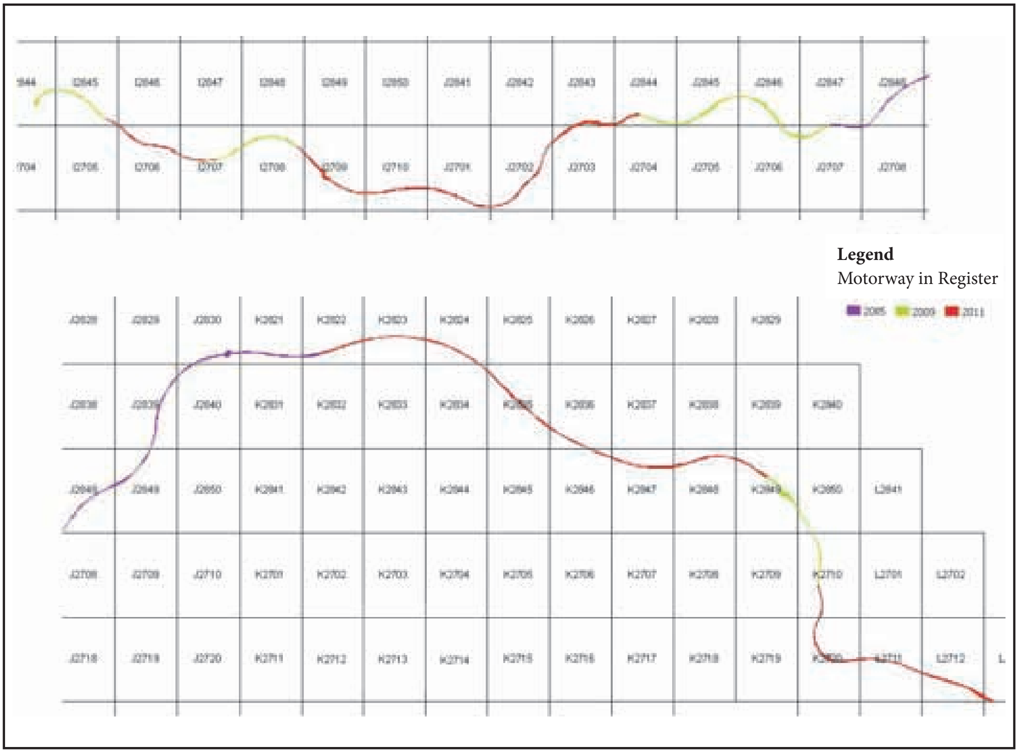


Figure 3: The progression of the A5 Maribor–Pince motorway construction in the Register by years, shown on the grid of sheets of the Basic Topographic Map (Arh 2012).

to Murska Sobota are included in the total length. The construction of the first motorway section Vučja vas–Beltinci in a length of 14.6 km started in 2000, and was put into service in 2002/2003, while the rest of the motorway of 71.2 km was completed between 2006 and 2008 (DARS 2006). As this was the only major building intervention in the 2000–2009 period, we analysed the PiSZ land use change in area 4NES. From the data from the Register we specifically excluded the motorway A5 branch (Figure 3) and graphically calculated the associated motorway area (Table 3).

The 2011 data from the Register show that the surface of the A5 Maribor–Pince section is 465 ha. From 2002 to 2011, the surface of PiSZ land use should increase by at least this amount, but this is not reflected in the data, as shown in Table 2 and Graph 1. On the contrary, in this period PiSZ decreased in area 4 NES, – the most among all Slovenian areas in question.

3.3 Analysis of PiSZ land use capture on the sample of settlements

We selected three dispersed and three continuous test settlements, and calculated, for 0.5 × 0.5 km areas, the graphic surface of PiSZ land use from the Register. The results are presented in Table 4 and Figure 4.

The decrease in PiSZ land use surface between 2011 and 2013 was established in three testing areas, even though, based on the results for the entire Slovenia, we thought that the data capture methodology had stabilised. In testing area 6 (Figure 5), the surface reduction was mostly due to the exclusion of extensive orchards in the settlements and at their edges. Extensive orchards in the settlements right next to housing and agricultural structures are the appertaining land of the structures and thus in spatial sciences considered as part of the built-up area.

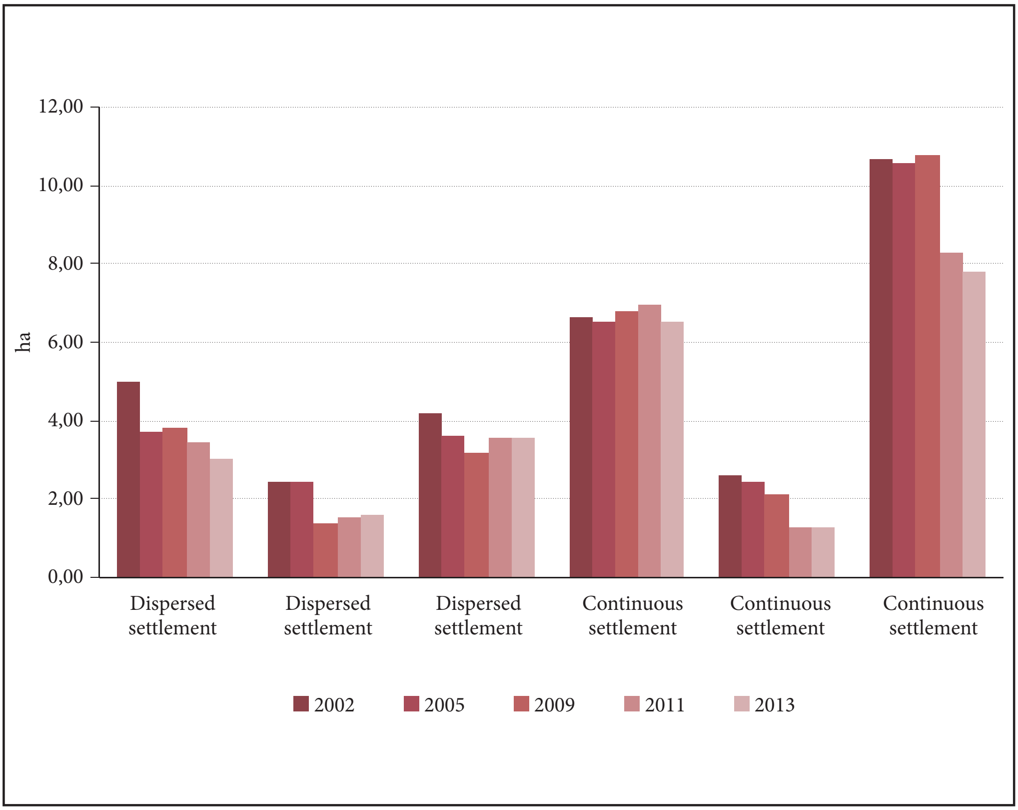


Figure 4: PiSZ use from the Register in testing areas of settlements (MKGP, author's illustration).

Table 4: PiSZ use from the Register in testing areas of settlements (MKGP, author's calculation).

	Testing area 1 dispersed settlement	Testing area 2 dispersed settlement	Testing area 3 dispersed settlement	Testing area 4 continuous settlements	Testing area 5 continuous settlements	Testing area 6 continuous settlements
Area centroid	Y: 578989 X: 165290	Y: 584012 X: 185752	Y: 614838 X: 157074	Y: 595499 X: 171530	Y: 613490 X: 159598	Y: 579040 X: 167805
						
	Built-up and related land (PiSZ) in the Register in testing areas 0.5 × 0.5 km					
	(ha)	(ha)	(ha)	(ha)	(ha)	(ha)
2002	4.986	2.417	4.221	6.647	2.576	10.677
2005	3.718	2.417	3.600	6.531	2.418	10.561
2009	3.815	1.357	3.174	6.807	2.144	10.753
2011	3.469	1.543	3.565	6.957	1.275	8.302
2013	3.021	1.568	3.565	6.514	1.275	7.792

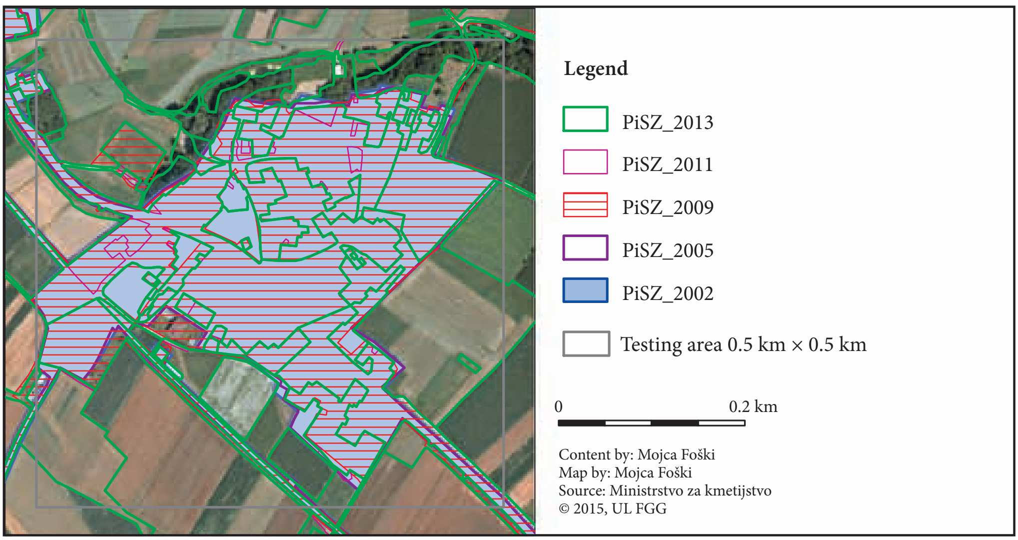


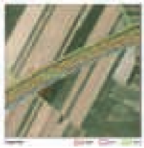
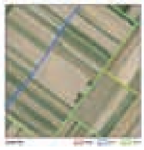
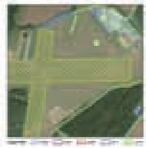
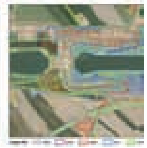
Figure 5: PiSZ use from the Register in the case of testing area 6 (MKGP, author's illustration).

3.4 Analysis of PiSZ land use acquisition for infrastructure

We randomly selected six testing areas of a size of 0.5 × 0.5 km with various infrastructure facilities and installations.

Even though there are no methodological changes in the interpretation keys concerning motorways, there are significant discrepancies in the surface area of PiSZ land use (testing areas 7 and 8 in Table 5, Figure 6). In the testing area of a small airfield (testing area 10) the impact of the changed data capture methodology

Table 5: PiSZ use from the Register in the area of infrastructures (MKGP, author's calculation) *In 2002 and 2005 there was no motorway yet, so the PiSZ land use was not captured.

	Testing area 7 motorway.	Testing area 8 motorway _2	Testing area 9 cart tracks/ rural roads	Testing area 10 small airfield	Testing area 11 railway	Testing area 12 power plant
Area centroid	Y: 588188 X: 166209	Y: 575096 X: 160374	Y: 596278 X: 164261	Y: 590505 X: 165752	Y: 589637 X: 170578	Y: 560870 X: 145147
						
	Built-up and related land (PiSZ) in the Register in testing areas 0.5 × 0.5 km					
	(ha)	(ha)	(ha)	(ha)	(ha)	(ha)
2002	0*	0.510	0	1.326	1.862	7.658
2005	0*	0.246	0	1.073	0.925	7.636
2009	4.039	2.124	0.282	1.499	1.336	6.530
2011	2.652	5.231	0.453	1.377	1.037	6.577
2013	2.917	2.998	0.363	6.749	1.064	7.931

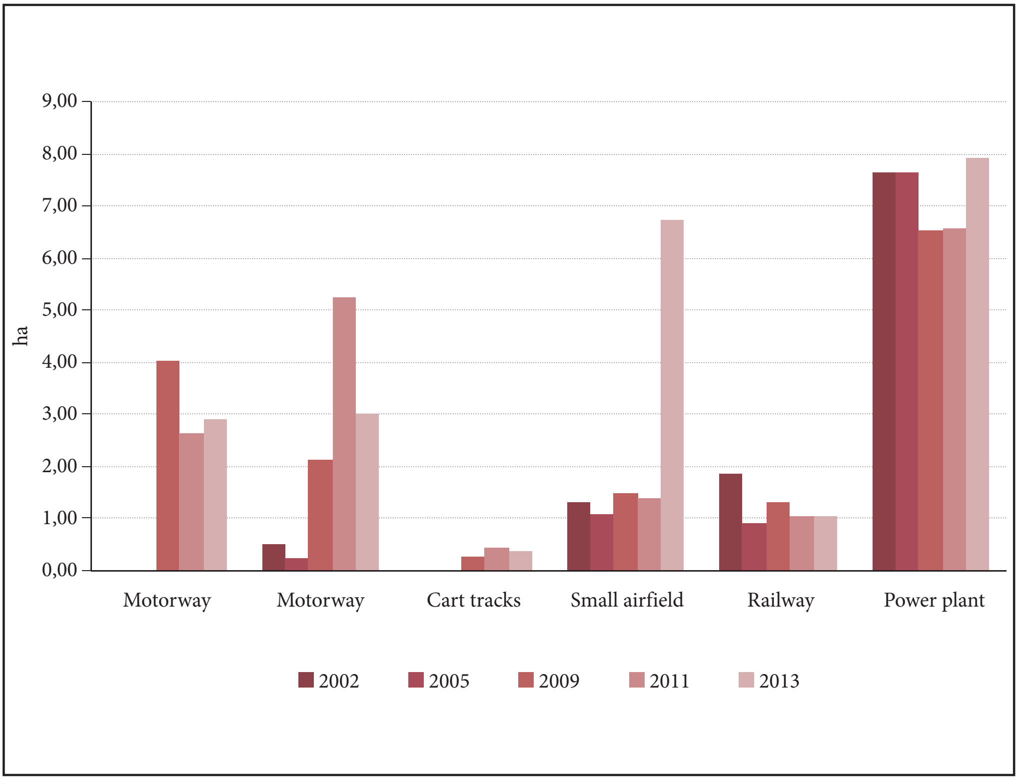


Figure 6: »Built-up and related land« from the Register in the area of infrastructures ((MKGP, author's illustration).

is evident (IK 6.0 2013), because the runway previously classified under the category of permanent meadows is now also classified as PiSZ. The surface changes in testing area 12 (power plant) cannot be attributed to the changed data capture methodology; we think that the discrepancy is the result of the capturer's interpretive abilities. The smallest discrepancies are associated with the railway area.

4 Discussion

Urban land use, which covers all built-up areas, areas with infrastructure facilities, and other areas that permanently changed from a natural to a built environment, is in general increasing in all countries and environments. We are certain that this is also the case in Slovenia, since SURS data (2013) show that, from 2007 to 2013, 29,972 building permits were issued for new spatial interventions. In Slovenia there are no in-depth analyses of the situation and trends concerning the urban area changes; Topole et al. (2006) and Bole et al. (2007) analysed several rural settlements, Ravbar (2007) noticed the trend of increasing settlement surfaces in suburban settlements and on urban outskirts, while Bole (2015) noticed the trend of increasing traffic surfaces.

The data from the Register for the level of Slovenia in the first three data capture campaigns (2002, 2005, 2009) vary considerably and indicate even a decrease in PiSZ surfaces, which is a rare occurrence, i.e. that urban land would be restored to its original use. Golobič (2013) reports only one such case, i.e. the Gorenjska motorway section between Črnivec and the Peračica viaduct, which the municipality converted back to agricultural land after the completion of the motorway.

After 2009 there are no major variations in PiSZ use, so the change in PiSZ land use could be the reflection of increased urbanisation. However, the results for testing area 4 of NE Slovenia (NES) (Figure 1) rejected this claim, as between 2005 and 2011 there was no considerable increase in surface area by 465 ha, i.e. the surface area of the newly built motorway A5 Maribor–Pince branch.

Urbanisation cannot be accountable for the rise by 0.02% or 360 ha of PiSZ land use from 2011 to 2013, because in the most recent period the analysis of 12 testing areas also revealed huge discrepancies in the data capture methodology. The increase in PiSZ areas is the result of methodological changes of settlement data capture (exclusion of agricultural land from settlements), capture of rural roads and cart tracks wider than 2 m, and some other types of land (the case of small airports). There is a general tendency that the PiSZ land use is captured increasingly closer to the structures, as also reported by Arh (2012). There is a particularly large discrepancy concerning dispersed settlements where the PiSZ land use is limited by many polygons. Land use by appertaining land of structures was not captured.

We can confirm the hypothesis that the existing Register is not suitable for determining urban land use areas and their changes, and also not for formulation of the indicator of urban land use changes in the territorial monitoring system (Poročilo … 2015). The deficiency of the Register for determining the areas zoned for development is also pointed out by Lampič and Repe (2012).

At the same time, we draw attention to the fact that its use for determining the discrepancy between the actual situation in space and the planned land use in the illustration of spatial situation in the Municipal Spatial Plan Preparation Procedure is unsuitable, even though the use of the Register is prescribed both by the Spatial Planning Act (2007) and the Rules on Land Use and Legal Regimes Data (2008). The discrepancies in the illustration of spatial condition may be due to the Register's shortcomings, and do not necessarily reflect the spatial potential; indeed, this can lead to professional errors.

Next to the spatial non-homogeneity of the source DOFs in various periods, as pointed out by Krevs (2004), we find that the data capture methodology is inhomogeneous as well, and that there are missing urban land use subcategories, which causes problems in data interpretation. Miličić and Udovč (2012), Mivšek et al. (2012), Lisec, Pišek and Drobne (2013), and Nastran and Žižek Kulovec (2014) also pointed out the deficiencies of the Register.

We propose that a single record be established, i.e. as those used in Austria (Land Information System Austria 2014), Germany (Hovenbitzer et al. 2014), Spain (Valcarcel et al. 2008) and the Netherlands (Hazeu 2014), which keep, maintain and interconnect data on land cover and land use in a single system. The integrated systems for establishing spatial and environmental monitoring, thus supporting spatial, economic and social planning and decision-making, are affected positively by the results of the project HELM (internet 2; HELM 2014), which dealt with the methodology of establishing a land use and land cover system, and the ongoing project EAGLE (EAGLE-Eionet … 2014).

5 Conclusion

Currently, the data from the Register are the only systemic and updated data source of the existing land use. By analysing records from the period between 2002 and 2013 we found that the methodological changes of urban use capture were so significant that the data do not reflect the actual urban land change. This is why the Register is unsuitable for spatial monitoring – the necessary component of spatial planning and its related activities. This means that it is necessary to establish a single system that would provide the data both on land cover and land use, and allow for monitoring of spatial and socio-economic spatial processes.

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FOREST PATCH CONNECTIVITY: THE CASE OF THE KRANJ-SORA BASIN, SLOVENIA

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Western part of the Kranj–Sora Basin viewed from Ambrož pod Krvavcem.

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Forest Patch Connectivity: The Case of the Kranj-Sora Basin, Slovenia

ABSTRACT: This article features a spatial analysis of forest patches, trees, and shrubs outside forests in part of the Kranj-Sora Basin in central Slovenia. Forest patch connectivity is explored using methods derived from graph theory. The graph nodes represent the forest patches and the edges between them represent the shortest connections calculated using a raster layer containing data on the resistance of individual land-use types. The contribution of an individual forest patch to habitat connectivity and availability is calculated using selected indicators. The findings show that the largest forest patches complemented by smaller patches constitute the basic connectivity tool. Thus, habitat size and close-to-nature structure are vital for the conservation of species over short distances. In conclusion, guidelines are presented for managing and mitigating the effects of further clearing the remaining natural vegetation.

KEY WORDS: forestry, geography, forest habitat patches, patch connectivity, graph theory, Kranj-Sora Basin, Slovenia

Povezanost gozdnih zaplat na primeru Kranjsko-Sorškega polja

POVZETEK: V prispevku obravnavamo prostorsko analizo gozdnih zaplat, dreves in grmov zunaj gozda na primeru dela Kranjsko-Sorškega polja v osrednji Sloveniji. S pomočjo metod, ki izhajajo iz teorije grafov, smo preverili povezanost gozdnih zaplat. Vozlišča grafa predstavljajo gozdne zaplate, povezave med njimi pa najkrajše povezave, ki smo jih izračunali na podlagi izdelanega rastrskega sloja, ki vsebuje upore posamezne rabe zemljišč. Prispevek posamezne gozdne zaplate k povezanosti in dostopnosti habitatov smo izračunali s pomočjo izbranih kazalnikov. Ugotovili smo, da so temeljno ogrodje za povezanost največje gozdne zaplate, ki jih dopolnjujejo manjše zaplate. Za ohranjanje vrst sta tako pri kratkih razdaljah najpomembnejši sta velikost in sonaravna zgradba habitata. Na koncu smo podali usmeritve za usmerjanje in blažitev učinkov nadaljnjih krčitev ostankov naravne vegetacije.

KLJUČNE BESEDE: gozdarstvo, geografija, gozdne habitatne zaplate, povezanost zaplat, teorija grafov, Kranjsko-Sorško polje, Slovenija

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1 Introduction

According to traditional landscape-ecology theory, a landscape consists of a matrix as the predominant land-use type, in which other uses are distributed as patches and corridors (Forman 1995). In agricultural landscapes, forest habitat patches are extremely important for ensuring biodiversity. Landscape structure analyses have a significant impact on both the landscape division criteria (Petek 2005) and the understanding of changes occurring within a landscape. Habitat reduction and fragmentation are among the main reasons for biodiversity decline (Collinge 1996; Bailey 2007). Several studies have shown that the entire area of the habitat regardless of its spatial distribution is a dominant factor influencing the survival of a particular species. When the total habitat area within a landscape falls below 50% (Flather and Bevers 2002; Crouzeilles et al. 2014) or, as reported by Andren (1994), below 30%, the distribution of habitat patches becomes equally important as the habitat area. The concept of habitat connectivity makes it possible to understand and measure the interconnected ecological impacts of habitat loss and fragmentation (Laita, Kotiaho and Mönkkönen 2011). The aim of this study is to determine whether the forest habitat patches in the selected study area are functionally connected and to identify the most important connecting forest patches that contribute the most to maintaining forest patch connectivity.

1.1 Habitat patch connectivity and graph theory

Over the past decade, a number of habitat patch connectivity studies have relied on mathematical graph theory and the network theories derived from it (Bunn et al. 2000; Zetterberg, Mörtberg and Balfors 2010; Saura et al. 2011; Zetterberg 2011; Mazaris et al. 2013). In graph theory, graphs make it possible to combine population processes with spatial patterns and their connectivity at both the level of landscapes and individual patches (Urban and Keitt 2001). A habitat patch connectivity analysis using graph theory methods makes it possible to assess the functional connectivity of individual patches (Laita, Kotiaho and Mönkkönen 2011). In this way one can assess the spatial importance of habitats and their connectivity (Bunn et al. 2000).

1.2 Habitat patch connections

The findings of several studies show that matrix heterogeneity has a strong impact on movement between habitat patches (Ricketts 2001; Russell, Swihart and Feng 2003; Revilla et al. 2004). The matrix is composed of various elements that have different effects on the spatial movement of species. Some land-use types represent barriers that are difficult to cross (e.g., rivers and freeways), whereas others make movement easier, often by providing shelter and food. This determines the resistance – that is, how demanding a specific land-use type is for crossing. Based on this, effective distances are calculated; they represent the shortest functional connections between habitat patches. From the biological perspective, identifying resistance is the most important step in calculating effective distance (Adriaensen et al. 2003).

Methods derived from graph theory were used to calculate the effective distance, whereby the graph nodes were the forest patches and the graph edges with the least resistance for species movement between them were the shortest effective distances (Polenšek 2015).

The predominantly flat northeastern part of the Kranj-Sora Basin was selected as the study area, as shown in Figure 1. This area is strongly affected by intensive farming (Rejec Brancelj 2001) and urbanization. The study area covers 10,423.65 ha, of which the forest covers 3,901.46 ha or 37.4%; in the flat part of the study area forest coverage is even smaller (27.7%). Across the entire study area, the forest is fragmented into 150 patches, ranging in size from 0.25 ha to 718.97 ha (Polenšek 2015).

2 Methods

2.1 Connectivity indicators

Proceeding from graph theory, researchers specializing in landscape ecology and other related disciplines have developed a number of indicators for assessing patch connectivity in landscapes. Bodin and Saura (2010)

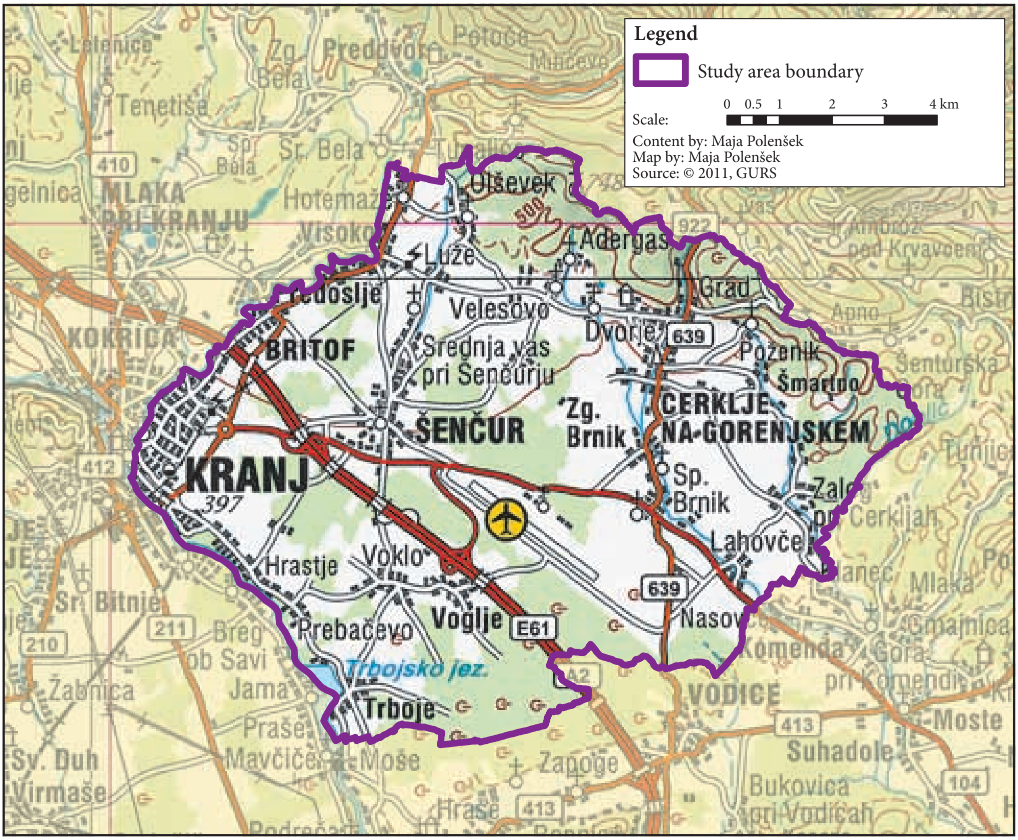

Figure 1: Study area.

suggested the indicators *IIC* and *PC* and their three fractions, and the indicator *BC* to calculate habitat connectivity and availability. These indicators should provide a sufficiently broad picture of habitat connectivity and availability without the unnecessary duplication of indicators.

The Betweenness Centrality (*BC*) indicator is a centrality measure, which means it measures how often a specific node lies on the shortest path between all pairs of nodes. It is expressed with the following equation (Zetterberg 2011):

$$BC_k = \sum_i \sum_j \frac{g_{ij}(k)}{g_{ij}} \qquad (1)$$

g_{ij} = the number of the shortest paths between i and j,
$g_{ij}(k)$ = the number of the shortest paths actually crossing node k.

Bodin and Norberg (2007) successfully used this indicator to identify the connecting patches between habitat patches. The Integral Index of Connectivity (*IIC*) is expressed as (Pascual-Hortal and Saura 2006):

$$IIC = \frac{\sum_{i=1}^{n} \sum_{j=1}^{n} \frac{a_i a_j}{1 + nl_{ij}}}{A_L^2} \qquad (2)$$

where a_i and a_j are the areas of habitat patches i and j, nl_{ij} is the number of all the links on the shortest path between patches i and j, and A_L is the total landscape area (the habitat and the matrix).

IIC is based on a binary connectivity model, which means that two patches are either connected or not (e.g., because the distance is too great) with no intermediate modulation of the connection strength (Saura and Pascual-Hortal 2007).

The Probability of Connectivity (*PC*) indicator is a measure that reflects the availability of a given habitat within a landscape. It is defined as the probability that two randomly placed points within the landscape fall into habitat areas that are reachable from one another (interconnected) given a set of *n* habitat patches and the direct connections between them (p_{ij}; Saura and Pascual-Hortal 2007). It is expressed with the following formula:

$$PC = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} a_i a_j p_{ij}^*}{A_L^2} = \frac{PCnum}{A_L^2} \tag{3}$$

where a_i and a_j are the areas of habitat patches *i* and *j* (they can also refer to some other patch characteristic such as quality, core area, habitat suitability, etc.), A_L is the total landscape area (the habitat and the matrix), and p_{ij}^* is the maximum product probability of all possible paths between patches *i* and *j*.

The significance of an individual habitat patch is computed from the variation in *PC* (dPC_k) or *IIC* ($dIIC_k$) caused by the removal of each individual element from the landscape (Saura and Rubio 2010):

$$dPC_k = 100 \cdot \frac{PC - PC_{remove,k}}{PC} = 100 \cdot \frac{\Delta PC_k}{PC} \tag{4}$$

where dPC_k is the importance of element *k* for maintaining overall habitat availability in the landscape, *PC* is the metric value in the original intact landscape where all elements including *k* are present, and $PC_{remove,k}$ is the metric value after the removal of *k*.

The dPC_k (or $dIIC_k$) values can be composed of three distinct fractions considering the different ways in which a certain landscape element *k* can contribute to habitat availability and connectivity in the landscape (Saura and Rubio 2010):

$$dPC_k = dPCintra_k + dPCflux_k + dPCconnector_k \tag{5}$$

- $dPCintra_k$ is the habitat connectivity or availability within patch *k* that depends on patch characteristics such as habitat area or quality (e.g., the state of its conservation) and is independent of how patch *k* may be connected to other patches;
- $dPCflux_k$ is the area-weighted dispersal flux through the connections of patch *k* to or from all of the other patches in the landscape when *k* is either the starting or ending patch of that connection or flux. It depends on the attribute of patch *k* and its position within the landscape network. It measures how well patch *k* is connected to other patches rather than how important that patch is for maintaining connectivity between the rest of the patches;
- $dPCconnector_k$ is the contribution of patch or link *k* to the connectivity between other patches as a connecting element between them. It depends only on the topological position of a patch or link in the landscape network.

2.2 Producing a resistance digital data layer

Forest animals that also feed on farmland were used as hypothetical species for determining the relative resistance of individual land-use types. Resistances used by Adriaensen et al. (2003) were used as a basis and adjusted to individual land-use type (Table 1). A smaller number indicates lower resistance for crossing a certain land-use type, and a larger number indicates higher resistance. Forestland has the lowest resistance and represents the graph nodes. The woody growth outside the forest was assigned the same resistance as the forest areas, but it does not form nodes because its area is too small. Regardless of the crop type, farmland was assigned a slightly higher resistance because it mostly does not provide the same shelter as forest areas. Infrastructural areas were divided into highways, state roads, and major municipal roads that differ from one another largely by the volume of traffic and the average vehicle speed. With regard to freeways, passages were also taken into account (primarily underpasses in this case). Freeways, urban land,

and bodies of water, which represent a relative rather than absolute barrier for many animal species, were identified as land types that are the most difficult to cross. In determining the resistance of land-use types that are the most difficult to cross, the findings of Driezen et al. (2007) were taken into account. They show that the distinct difference between the resistances of land-use types that are more difficult to cross and those that are easier to cross is vital in determining resistance.

Table 1: Cell resistance by individual land-use type (Polenšek 2015).

Land-use type	Cell resistance
Forestland (habitat)	1
Trees and shrubs (woody growth)	1
Farmland	5
State roads	20
Municipal roads	10
Urban land	200
Bodies of water	200
Freeways	200
Freeways (municipal road underpass)	50
Freeways (forest road underpass)	30
Freeways (bridge across a river)	20

The land-use vector digital data layer (Grafični podatki RABA … 2012) was converted into a raster data layer with a 1 × 1 m cell size using ArcMap/ArcInfo10.0 in order to correctly capture the line elements and the smallest woody growth (individual trees). The reviewed land-use raster data layer was exported into GEOTIFF format.

2.3 Computing forest patch connectivity

The edge-to-edge inter-patch connections were computed using the *Graphab* 1.1 software package (Foltête, Clauzel and Vuidel 2012), which makes possible calculations across larger areas with a high raster resolution. This software computes the least-cost distances by using Dijkstra's algorithm (Foltête, Clauzel and Vuidel 2012). The movement cost was computed by adding up all of the cell costs within a connection. A connection is measured from the center of the neighboring cell, whereby its cost corresponds to half of the sum of both cells' costs. In the case of a diagonal movement between two cells, the cost sum is multiplied by (Drielsma, Manion and Ferrier 2007).

2.4 Habitat connectivity and availability

The indicators were computed using *Conefor* 2.6 (Saura and Torné 2009) based on the data charts exported from the *Graphab* 1.1 software package (Foltête, Clauzel and Vuidel 2012). Computations were made for inter-patch distances ranging from 100 to 20,000 m at 100 m intervals. For every distance, the relative contribution of the intra, flux, and connector fractions for the *dIIC* and *dPC* indicators was calculated (Saura and Rubio 2010):

$$\theta PCfraction = \frac{\sum_{k=1}^{n} dPCfraction_k}{\sum_{k=1}^{n} dPC_k} \qquad (6)$$

Based on an analysis of distances up to 20,000 m across the entire landscape, the distances with the greatest changes in the *dPC* and *dIIC* metric values were identified.

2.5 The most important connecting patches

Baranyi et al. (2011) established that the indicators *BC*, *dIICconnector*, and *dPCconnector* are the most successful among the thirteen indicators most commonly used for identifying the most important connecting patches. They are used to assess not only how well a specific patch is connected with other patches, but also how important it is for maintaining connectivity.

The method of ranking forest patches by priority in terms of their contribution to connectivity was adopted from Lee, Woddy, and Thompsonu (2001), whereby forest patches were ranked by individual indicators (*BC*, *dIICconnector*, and *dPCconnector*). Then their rankings were added up, based on which a new cumulative ranking was defined. For selected movement distances, forest patches were ranked in *IBM SPSS Statistics 21* such that a ranking of 1 was ascribed to the forest patch with the highest score for individual indicator. All of the three indicator rankings by individual forest patch were added up and based on the ranking sums the forest patches were ranked such that the highest ranking was ascribed to the patch with the lowest-ranking sum.

Forest patches were divided into three groups according to their contribution to connectivity: connecting patches with high impact, connecting patches with low impact, and patches with no impact on connectivity. Based on the indicator-based forest-patch contribution to connectivity within various distances of movement, the first twenty forest patches within the same ranking were ranked under the first group. These patches contribute the most to connectivity according to all three indicators. The second group included forest patches that still have some impact on connectivity in terms of the indicators selected. The last group included those that do not contribute anything to connectivity in terms of any of the three indicators selected.

3 Results

The study area includes 150 forest patches that are connected with 268 functional links. The number of links depends on the longest possible movement distance: the longer the distance, the more links between the forest patches. The threshold where the number of links no longer increased was recorded at a distance of 14,400 m. The distances ranged between 4 and 14,361 m and the median distance was 2,289 m.

3.1 Forest-patch contribution to maintaining habitat connectivity and availability within various movement distances

The changes in *dIIC* and *dPC*, which depend on the longest possible distances, are presented in Figure 2. The *dIIC* scores change incrementally, with the highest score being reached at distances of up to 2,900 and

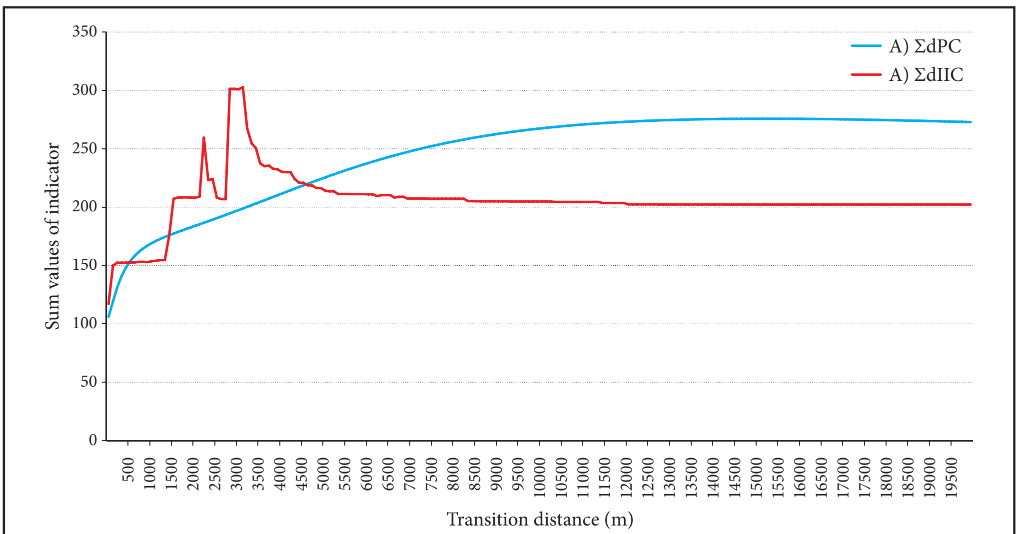

Figure 2: Sums of indicator changes.

3,000 m, and the second-highest scores being reached at distances of up to 200, 1,500, and 2,300 m. The *dPC* scores do not show such distinct variations as *dIIC*. The highest score is achieved at a distance of up to 15,500 m. Slightly greater changes in the *dPC* indicator are evident within distances of up to 700 or 800 m and 7,300 m. Within these distances, the importance for connectivity is the greatest, and the role of patches in maintaining the connectivity of the overall forest-patch network decreases with the increase in distance.

Individual relative fraction contributions for *dIIC* are presented in Figure 3. Within movement distances of up to 100 m, the majority of forest patches are not connected with one another, which is reflected in both the large number of graph components and the high contribution of the *dIICintra* fraction. The contribution of *dIICintra* already decreases significantly within distances of up to 200 m, whereas the contribution of *dIICflux* increases. Within distances of up to 1,500 m, the contribution of *dIICconnector* increases. A major increase in *dIICconnector* then occurs within distances of up to 2,300 m. The *dIICconnector* fraction contributes the most within distances between 2,900 and 3,200 m. Within distances up to 5,100 m, the fraction ratio slowly stabilizes at two-thirds of *dIICflux* and one-fifth of *dIICconnector*, and the remainder pertains to *dIICintra*.

The contributions of the *dPC* fraction are presented in Figure 4. Similarly, the *dPCintra* fraction predominates within short movement distances, whereas *dPCflux* predominates within distances of up to 500 m. Within distances of up to 8,200 m, the ratios slowly stabilize, with one-third pertaining to *dPCconnector*, 9% to *dPCintra*, and the rest to *dPCflux*.

3.2 The most important connecting patches within the movement distances selected

Based on the changes in *dIIC* and *dPC* scores within various distances, the distances where both indicators feature the greatest changes in habitat connectivity and availability were selected. Thus, five distances were selected: 800, 1,500, 3,000, 7,100, and 15,500 m. In Figure 5, forest patches are ranked into three groups by their importance for maintaining connectivity between other forest patches within all five distances.

The area of the twenty most important connecting patches increases with the greatest possible distance, so that they cover 44% of the forest in the study area within distances of up to 800 m, and 86% within distances of up to 15,500 m (Table 2). Forty-one most important connecting patches were identified within all of the distances examined in greater detail. Eight forest patches are important within all distances and eighteen patches only occur within one distance. The areas of important connecting patches range from 0.62 to 718.98 ha, with larger patches predominating.

In addition to the twenty most important forest patches identified, other forest patches also contribute to maintaining connectivity to some degree. With the increase in distance, their number increases from 42 to 70% of all forest patches and, vice versa, their total area decreases from 51 to 13% of the total forest area. A part of the forest patches does not have any impact on connectivity. Just under half (45%) of such patches are within short distances, but they cover only 5% of the total forest area. Their number decreases significantly with distance: to at least as little as one-sixth of all forest patches or 1% of the forest area.

4 Discussion

The Integral Index of Connectivity (*dIIC*) most clearly shows the critical distances because it uses a binary connections model, in which the connection either exists or does not. However, this index divides the landscape

Table 2: Forest patches ranked by importance as connecting patches within various distances ($n = 150$).

	Forest patches					
	Most important connecting patches		Less important connecting patches		Without impact on connectivity	
Distance (m)	*n*	ha	*n*	ha	*n*	ha
800	20	1,728.27	63	1,991.61	67	181.58
1,500	20	1,838.22	71	1,910.21	59	153.03
3,000	20	2,777.40	95	1,067.75	35	56.31
7,100	20	3,371.04	103	482.36	27	48.06
15,500	20	3,355.27	105	499.28	25	46.92

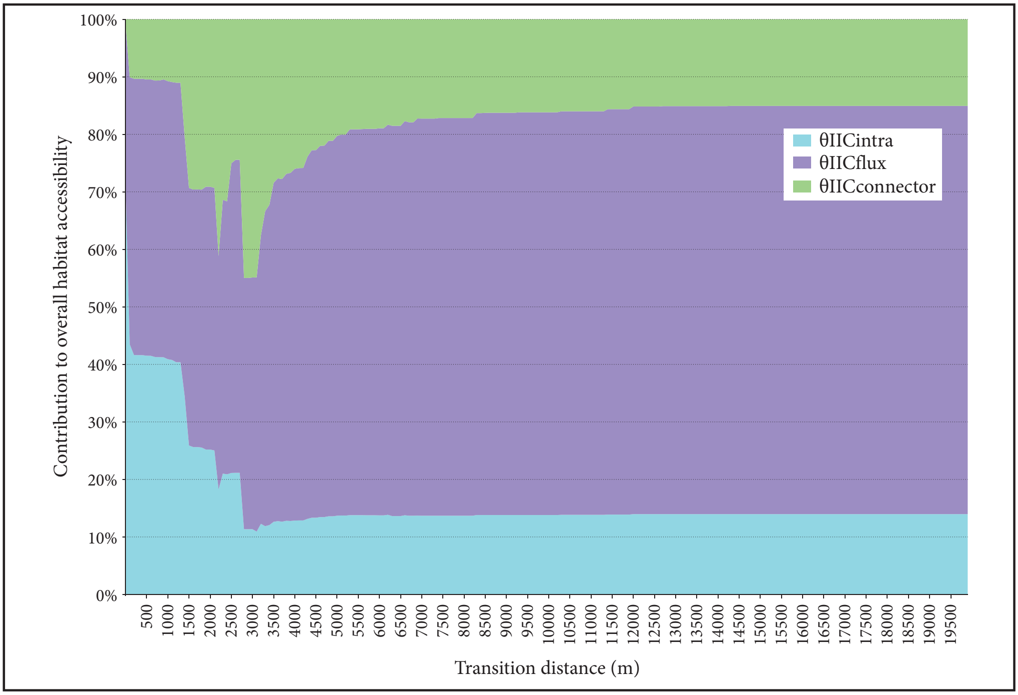

Figure 3: Relative contribution of an individual dIICk fraction.

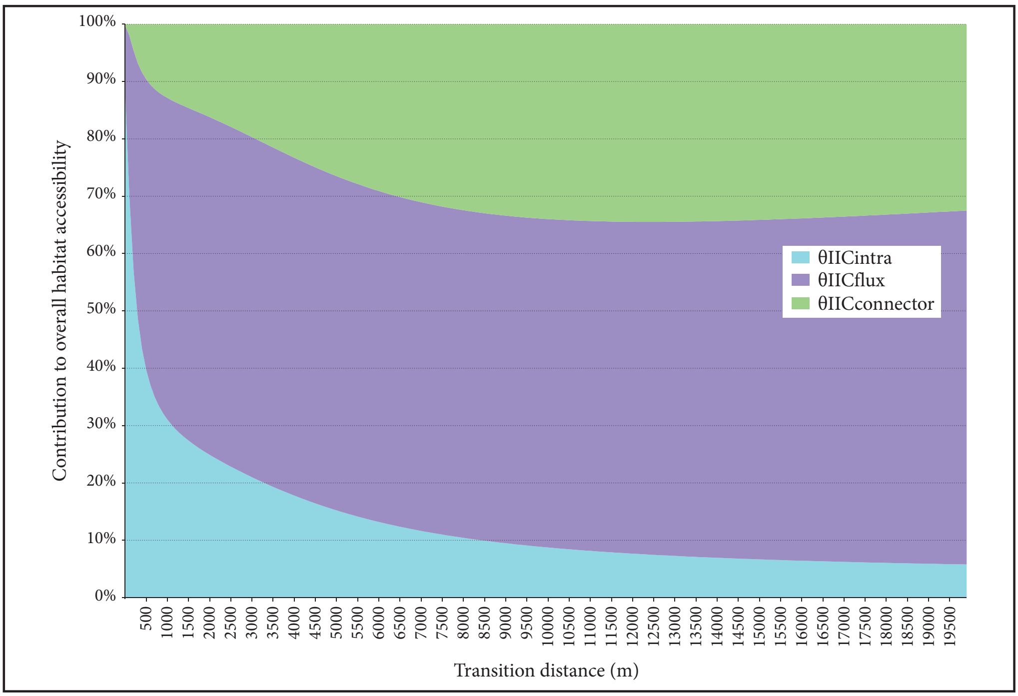

Figure 4: Relative contribution of an individual dPCk fraction.

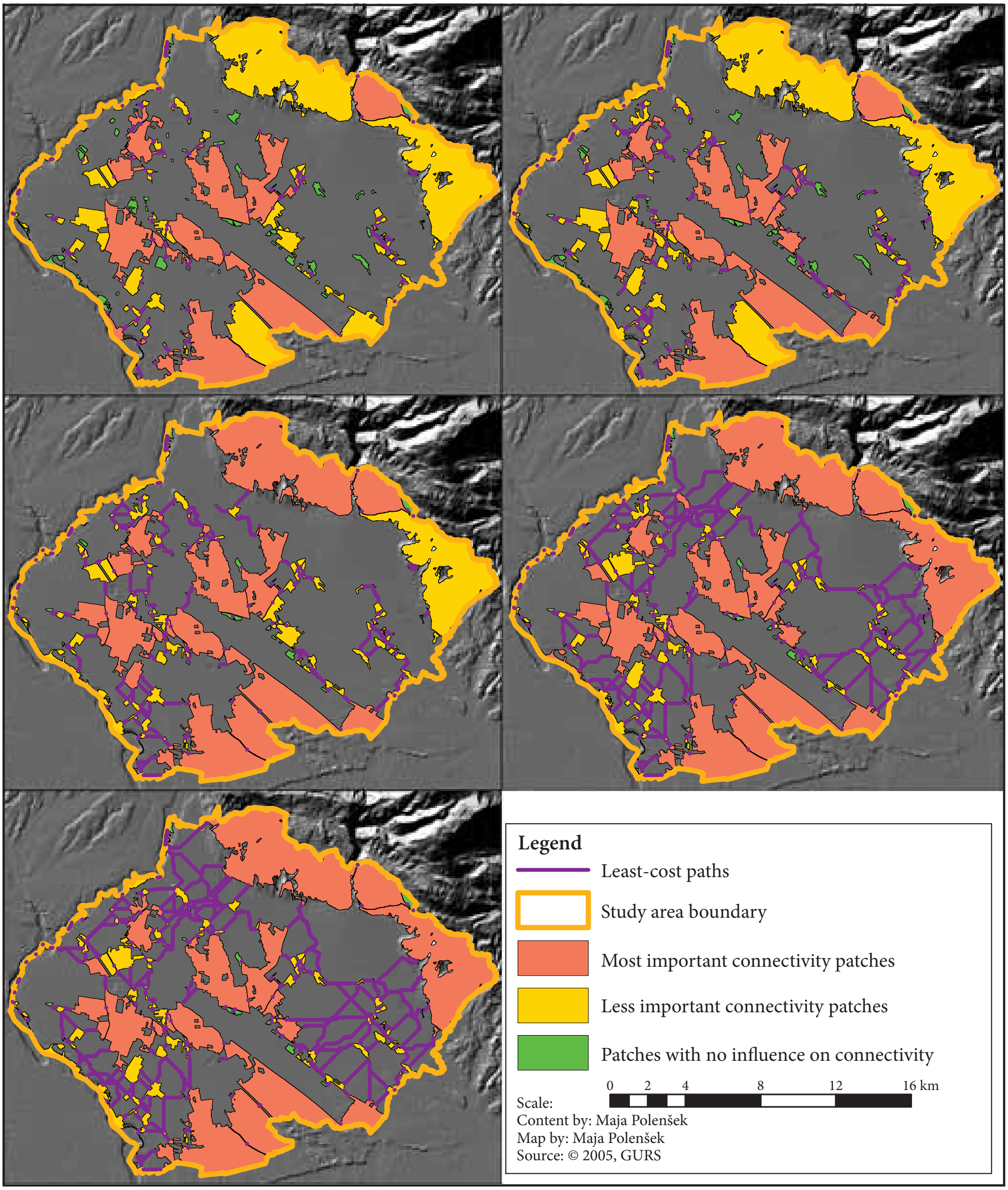

Figure 5: Forest patches by importance.

network into two unconnected parts (Bodin and Saura 2010). With the Probability of Connectivity (*PC*) indicator, the critical distances are much less clear because it uses a probability model, in which the loss of a connecting patch only reduces the amount of flux. Unlike *dIIC*, thanks to the probability model *dPC* also detects changes in landscape network connectivity within longer distances.

Within short distances, the share of connected patches is small, resulting in a higher share of completely isolated patches. The land-use types that are more difficult to cross have a greater impact on movement than those easier to cross. In the case at hand, the negative impact of roads and settlements within short distances is greater than the positive impact of woody growth. The spatial distribution of patches does not play a significant role. The importance of habitat patch connectivity increases rapidly with the increase in the longest possible distance. Within medium distances, the connecting patches are the most important, enabling the connectivity of more remote patches. Contrary to short distances, the areas within the matrix that are easier to cross (in this case, woody growth) have a greater impact. Within longer distances, forest patches again lose importance as connecting patches because of the increased number of direct connections. Remote patches also become interconnected and depend less on the connecting patches. The selection of the most important connecting patches that contribute the most to maintaining habitat connectivity and availability compared to other forest patches showed that large forest patches in particular are the most important because the movement distances increase significantly with their loss. At the same time, they are complemented by smaller forest patches, whose distribution contributes to better connectivity of remote forest patches. A comparison of selected movement distances showed that within all of the distances examined the most important connecting patches do not change significantly.

In Europe, a new 2014–2020 agricultural policy is under preparation, which also includes a green component, for which a third of subsidy funds will be earmarked (Overview of CAP … 2013). This green component will also include areas with ecological significance. Based on the study presented here, as well as other studies, it is recommended that these areas also include habitat-significant forest patches, especially those whose area, close-to-nature structure, and spatial distribution are vital to maintaining spatial connectivity. This especially applies to intensively cultivated landscapes with a small share of natural vegetation, which should include a wide range of forest patches and woody growth typical of individual landscapes.

5 Conclusion

Based on the findings presented here, the main guidelines for maintaining forest-patch connectivity in future clearing of forests in agricultural landscapes can be summed up as follows:

- Individual forest-patch characteristics such as habitat size and close-to-nature structure are the most important for species conservation over short distances;
- Priority should be given to conserving the largest forest patches, especially those with a higher share of core area;
- Priority should be given to conserving all of the most important connecting patches, especially those with the most natural structure;
- When clearing part of a patch, this should be done in a way that divides its shape and affects its core environment as little as possible;
- Forest patches that make it possible to conserve the most vital functions should be maintained;
- Another goal is to conserve larger forest patches, even though their current structure has been severely altered. It is much easier to manage the development of existing forest areas than to plan new ones on predominantly intensively farmed land.

All of these guidelines also have solid support in established literature on landscape ecology (Forman 1995) because the pattern of large natural vegetation patches with corresponding connections is considered the most suitable support for biodiversity conservation in agricultural landscapes.

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MULTI-CRITERIA ASSESSMENT OF LESS FAVOURED AREAS: A STATE LEVEL

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Less Favoured Areas (LFAs) where production conditions are difficult.

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Multi-criteria assessment of less favoured areas: A state level

ABSTRACT: The paper present a multi-criteria decision DEXi model for assessment of less favoured areas (LFAs). The tool enables easier assessment of farming in different areas of Slovene LFAs with respect to criteria of sustainability. Analysis of LFAs and final integration of the assessment of LFAs depend upon various criteria. In this paper we analyze individual LFAs and farming systems in these areas at the state level with respect to criteria of sustainability and farming potential.

KEY WORDS: geography, less favoured areas, agricultural policy, multi-criteria decision analysis, DEXi

Večkriterijska ocena območij z omejenimi možnostmi za kmetijsko dejavnost: stanje v državi

POVZETEK: V prispevku je predstavljen večkriterijski odločitveni model DEXi za oceno območij z omejenimi možnostmi za kmetijsko dejavnost (OMD). Razvito orodje omogoča oceno načina kmetovanja s poudarkom na kriteriju trajnostnosti v različnih OMD območjih. Analiza OMD območij in modelna integralna končna oceana kažeta na odvisnost več kriterijev. Pri oceni posameznega OMD območja in načina kmetovanja na nivoju Slovenije imata tako pomembno vlogo kriterij trajnosti in potencial posamezne analizirane kmetije.

KLJUČNE BESEDE: geografija, območja z omejenimi možnostmi, kmetijska politika, večkriterijska odločitvena analiza, DEXi

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1 Introduction

The proportion of the total utilized agricultural area (UAA) classified as less favoured areas (LFAs) has raised from 33% to 65% in European Union in the last two decades. A substantial amount of the utilized agricultural area is classified as mountain areas (MacDonald et al. 2000). This situation is also seen in Slovenia, where 491.000 hectares or 72.3% of the UAA are located in mountainous and hilly areas (LFAs). Almost two-thirds of it is in permanent pasture, and arable land accounts for less than 30%. The proposed European Union indicators for defining areas less suitable for agriculture (there are eight European criteria) in Slovenia are not entirely appropriate because taking them into account would omit some distinctly and clearly unsuitable areas, i.e. karst areas (Ciglič et al. 2012). However, as other European Union Alpine regions, Slovenia is characterized by one of the most difficult conditions for agricultural production in Europe. Overutilization of agricultural land is becoming a serious problem, although the reasons for overutilization are not the same everywhere. Efforts to combat overutilization and understanding of the background to the problem are of particular importance for improvement of agricultural land quality (Borec et al. 2004). The current rural development European policy includes significant evolution of support schemes for LFAs. Agricultural production in LFAs is usually extensive and less suited for different farming systems and agri-food production. Some authors have suggested development strategies for LFAs based on interdisciplinary research of the coupling of human and natural systems approaches (Ruben et al. 2005). Sheate et al. (2008) examined the sustainability of various scenarios for reconciling biodiversity conservation with declining agriculture use in mountain areas of Europe. Their methodology was grounded in baseline of ecological and socio-economic data. Terluin et al. (1995) examined agricultural incomes in LFAs from an economic perspective. In their scenario, income was based on the typology of European countries and the relationship of regional gross domestic product per inhabitant and farm net value added per annual work unit. They confirmed that within the analyzed geographical areas, farmers in LFAs receive a higher amount of direct income subsidies than farmers in regions not classified as LFAs. The links between size, subsidies and performance for Slovenian farms were presented by Bojnec and Latruffe (2013). The study concludes that Slovenian farms have always been small and highly subsidized. Further, a conception of developmental types of mountain is presented regarding the state of developmental potentials on farms by Kerbler (2003). Assessment of farming potential on individual LFA is usually related to multiple criteria (Pažek et al. 2010). Tiwari et al. (1999) asserted that the rural reality system is complex and that the use of economic or environmental criteria alone may be insufficient. Multiple competitive criteria are likely to influence the decision-making process. A decision model must be able to evaluate all the options when considering those factors influencing the decision. A multi-criteria decision analysis approach was used in this paper to assess different organizational and planning decisions in farm management, such as the DEXi methodology (Bohanec et al. 1995; Bohanec, Zupan and Rajkovič 2000; Pažek et al. 2006; Rozman et al. 2006; Bohanec, Džeroski and Žnidaršič, 2004; Bohanec et al. 2007; Pavlovič et al. 2011, Pažek, Rozman and Irgolič 2012a). The theoretical background of hierarchical multi-attribute decision models is based on the dissection of a complex decision problem into smaller and less complex subproblems. In this context, the DEXi method uses qualitative variables and utility functions in the form of decision rules and provides qualitative assessments of alternatives. Subproblems are represented by variables, which are organized into a hierarchy (Pažek et al. 2012b).

The aim of this paper is to present a DEXi multi-criteria decision support tool for assessment of LFAs and farming systems in these areas at the state level.

2 Materials and methods

The DEXi method is a combination of traditional multi-attribute decision-making processes and specific elements of expert system and machine learning techniques (Bohanec 2003). Computer program for multi-attribute decision making is called DEXi. It is aimed at interactive development of qualitative multi-attribute decision models and the evaluation of options. This is useful for supporting complex decision-making tasks, where there is a need to select a particular option from a set of possible ones so as to satisfy the goals of the decision maker (Bohanec 2014). Variables are connected by utility functions. Utility functions in DEXi are adjusted to qualitative variables and, therefore, represented by »if/then« decision rules (elementary decision rules), which are usually given in a tabular form. The DEXi method can be used for solving various decision problems regarding real-world decisions (Bohanec et al. 1995; Bohanec and Rajkovič 1999; Bohanec, Zupan and Rajkovič 2000; Bohanec et al. 2006).

The DEXi models are developed by defining:

- attributes (a): qualitative variables that represent decision subproblems (for instance farm size, as demonstrated in Table 1);
- scales: ordered or unordered sets of symbolic values that can be assigned to attributes (for instance for farm size: small to 6.00 ha, average (between 6.00 and 7.00 ha) and big (farm size is over 7.00 ha; as demonstrated in Table 2);
- tree of attributes: a hierarchical structure representing the decomposition of the decision problem;
- utility functions: rules that define the aggregation of attributes from bottom to the top of the tree of attributes.

In the evaluation and analysis stage, DEXi facilitates:

- description of options: defining the values of basic attributes (terminal nodes of the tree);
- evaluation of options: a bottom up aggregation of basic attributes values based on utility functions;
- analysis of options: »what-if« analysis, »plus-minus-1« analysis, selective explanation and comparison of options, and
- reporting: graphical and textual presentation of models, options and evaluation results.

The hierarchical model structure for the assessment of LFAs that represents the decomposition of the decision problem into subproblems, was defined by the policy decision maker expert group of the Agency of the Republic of Slovenia for agricultural markets and rural development (AKTRP 2012; Irgolič 2011). The main criteria included in the model structure are: description of the farm, farm holder age structure,

Table 1: Hierarchical model structure for assessment of LFAs.

Attribute (a)
Final assessment
├ **Farm description**
├─ ├ Farm size
├─ ├ Usage type of agricultural land
├─ ├ Number of assigned points
├─ └ Amount of LFA payments
├ **Social structure**
├─ ├ Farm holder´s age
├─ ├ Successor or not
├─ └ Successor´s age
├ **Amount of natural handicap payments**
├─ ├ Number of payment entitlements
├─ ├ Value of payment entitlements for arable land
├─ ├ Value of payment entitlements for pasture
├─ └ Amount of payment entitlements
├ **Amount of agri-environment payments**
├─ ├ Organic farming
├─ ├ Integrated crop production
├─ ├ Implementation of other agri-environmental measures
├─ └ Amount of payments
└ **Amount of direct payments**
── ├ Amount of protein crops payments and nuts payments
── ├ Amount of additional payments for milk
── └ Amount of additional payments for beef

amount of natural handicap payments, amount of agri-environmental payments, and amount of direct payments. Aggregate criteria were divided into groups of criteria (as seen in Table 1) and in the final evaluation of the LFAs areas: other areas, hill areas, karst areas, steep slopes, and mountain areas.

The attributes at the lowest level are basic descriptors of options (in our case individual LFAs), These represent model inputs and must be provided by the decision maker. Table 2 presents the sets of scales that were defined for all attributes in the model.

The decision rules are presented in a so-called complex form, with headings displaying approximate weights assigned to the attributes (second row in Table 3). The so-called »weight-based strategy« of defining decision rules was used. In terms of the subattributes and the number of points assigned, if the value of the assessment points by the agency for the observed farm was less than 310, this subattribute was assigned the discrete value »bad« by the the DEXi model. If the farm was awarded between 311 and 350 points, then the discrete value was »good.« Finally, if the farm received more than 351 points, the discrete value assigned by the DEXi model was »excellent.« The symbols »≤«, »≥« define value intervals for the relevant attribute. The asterisk »*« defines any possible value. The relative importance of the attributes was expressed by weights (as seen at the top of Table 3). These weights were estimated by DEXi using a linear regression method (according to Rozman et al. 2009), where DEXi interpolates the values of previously undefined rules in the table. Linear coefficients respond to the required weights, and its surface lies as close as possible to the initially specific subset of rules (Pavlovič et al. 2011). In practical use, this means the higher the weight, the more important the attribute.

After each attribute was assigned to a scale, the utility functions were defined (Table 3). The utility functions evaluate and define individual attributes with respect to their immediate descendants in the hierarchy. The utility function procedure was derived for each level in the hierarchy (partial utility function for aggregate attributes and overall utility function for the whole model, except for the lowest level in the

Table 2: Basic structure of the decision model, with sets of values (scales).

Attribute (a)	Scale
Final assessment	INAPPROPRIATE; RATHER INAPPROPRIATE; APPROPRIATE; EXCELLENT
├ Farm description	BAD; GOOD; EXCELLENT
│ ├ Farm size (ha)	SMALL; AVERAGE; BIG
│ ├ Usage type of agricultural land	Meadows; Plantations; Fields
│ ├ Number of assigned points (points)	< 310; 310–350; > 350
│ └ Amount of LFA payments (€)	< 500; 500–1000; > 1000
├ Social structure	BAD; GOOD
│ ├ Farm holder´s age (years)	> 55; 40–55; 18–25; 25–40
│ ├ Successor or not	No; Yes
│ └ Successor´s age(years)	> 55; 40–55; 18–25; 25–40
├ Amount of natural handicap payments	Bad; Good; Very good
│ ├ Number of payment entitlements	< 6,5; 6,5–7,5; > 7,5
│ ├ Value of payment entitlements for arable land (€)	< 380; 380–400; > 400
│ ├ Value of payment entitlements for pasture (€)	< 160; 160–180; > 180
│ └ Amount of payment entitlements (€)	< 1000; 1000–1500; 1500–2000; > 2000
├ Amount of agri-environment payments	Bad; Good; Excellent
│ ├ Organic farming (%)	< 2; 2–4; 4–6; > 6
│ ├ Integrated crop production (%)	< 2; 2–4; 4–6; > 6
│ ├ Implementation of other agri-environmental measures (%)	< 20; 20–30; 30–40; > 40
│ └ Amount of payments (€)	< 1200; 1200–1600; 160–2000; > 2000
└ Amount of direct payments	Bad; Good
├ Amount of protein crops payments and nuts payments (€)	< 150; 150–250; > 250
├ Amount of additional payments for milk (€)	< 500; 500–1000; > 1000
└ Amount of additional payments for beef (€)	< 650; 650–750; > 750

hierarchy). According to Pavlovič et al. (2011), for each attribute y, whose descendants in the hierarchical tree of attributes are $x_1, x_2, \dots x_n$, the corresponding utility function *f* defines the mapping:

$$f\colon x_1 \times x_2 \times \dots x_n \rightarrow y,$$

where $x_1, x_2, \dots x_n$ and y denote values in the domains of the attributes $a_1, a_2, \dots a_n$ and y. These rules define the mapping of four subattributes and the assessment of the cumulative descriptive attributes of the farm in the overall final assessment of the LFAs according to defined decision rules.

Table 3: Example of decision rules, with a utility function of the presented case.

	Decision rules				
	Farm size	Usage type of agricultural land	Number of assigned points	Amount of LFA payments	Farm description
	26%	26%	31%	17%	
1	SMALL	Meadows	< 310	*	BAD
2	SMALL	Meadows	*	< 500	BAD
3	SMALL	*	< 310	< 500	BAD
4	≤ AVERAGE	≤ Plantations	≥ 310–350	≥ 500–1000	GOOD
5	*	≤ Plantations	310–350	≥ 500–1000	GOOD
6	≤ AVERAGE	Plantations	*	≥ 500–1000	GOOD
7	*	Plantations	≤ 310–350	≥ 500–1000	GOOD
8	*	≥ Plantations	< 310	≥ 500–1000	GOOD
9	≤ AVERAGE	Plantations	≥ 310–350	*	GOOD
10	≤ AVERAGE	≥ Plantations	≥ 31–350	< 500	GOOD
11	*	Plantations	310–350	*	GOOD
12	*	≥ Plantations	310–350	< 500	GOOD
13	AVERAGE	≤ Plantations	*	*	GOOD
14	AVERAGE	*	*	< 500	GOOD
15	≥ AVERAGE	≤ Plantations	≤ 310–350	*	GOOD
16	≥ AVERAGE	*	< 310	*	GOOD
17	≥ AVERAGE	*	≤ 310–350	< 500	GOOD
18	*	Fields	≥ 310–350	≥ 500–1000	EXCELLENT
19	BIG	*	> 350	*	EXCELLENT

The single line in Table 3, i.e., single decision rule, defines the value of the final assessment of LFAs for one combination of values of the former four attributes. The description of the farm, amount of natural handicap, and agri-environmental payments can take three different discrete values (part of the decision rules for the farm description attribute with the utility function is presented in Table 3), and the age structure and amount of direct payments can take two different values. Consequently, there are 108 possible combinations ($3 \times 3 \times 3 \times 2 \times 2$) and thus 108 decision rules.

In the next step, the attribute values for each options were placed in the DEXi evaluation table, and the evaluation analysis of the LFA assessment was evaluated.

Data for specific criteria compiled by the Agency of the Republic of Slovenia for agricultural markets and rural development were used. The sample size was 42.856 Slovenian farms that are registered and financial supported by the government through different environmental programs, including support for farming in LFA areas (D – 8.413 farms, H – 13.193 farms, K – 5.975 farms, S – 2.269 farms and V – 13.006 farms). The average value of attributes from this database was used as input in the DEXi multi-criteria model (attributes at the leaves of the hierarchical tree as presented in Table 1).

3 Result and discussion

The following Slovenian LFAs were included in the analysis (Irgolič 2011): hill areas (H), karst areas (K), steep slopes (S), other areas (D), and mountain areas (V). Numerical and qualitative data compiled by the Agency of the Republic of Slovenia for Agricultural Markets and Rural Development were employed. The data were divided into five aggregate attributes (Table 4) according to the utility function, and an integrated assessment of a particular LFA was performed at the end as the last step in the analysis.

The classification of particular areas was enabled by the multi-criteria decision model. The developed DEXi model shows that the mountain areas were assigned a value of »excellent,« the best possible outcome. As seen in the integrated assessment (Table 4 and Figure 1), most of the main attributes in this scenario were assigned the highest value, except the attribute amount of agri-environmental payments, where the utility function was assigned a value of »good.« This outcome is expected because there are more than 6% of organic farms in mountain areas (awarded the highest discrete value) but less than 2% of integrated farms (awarded the discrete value bad). Consequently, the implementation of other agri-environmental measures by those farms is between 30–40%, and the total amount of payments are €1.200–1.600/farm. Both attributes intervals are assigned a neutral value in the model. The karst areas and steep slopes received the worst assessments score (Figure 1 and Figure 2). Other areas and hill areas were evaluated as »appropriate,« as seen in Table 4.

According to the lowest value assigned to two attributes in the assessment (amount of agri-environmental and direct payments in the karst areas, where meadows predominate (33.133 ha meadows in comparison with 9.791 ha of fields), the karst areas (K) results with the inappropriate final assessment. Steep slopes (S) areas were assessed as »rather inappropriate.« In the hierarchical model, the farm description attribute was assessed as »excellent.« Besides the subattribute »usage type of agricultural land« where meadows predominate, all other subcriteria were assigned the highest discrete value.

In contrast to the karst areas, the neutral value (»very good«) was determined by the amount of natural handicap payments attribute. On the other site, two main attributes received the worst assessment (»bad«), i.e., the amount of agri-environmental payments (weight 38%) and the amount of direct payments (weight 11%).

The same integrated assessment was determined for the other areas and hill areas. In both alternatives, the assessment of the attributes was the same. The description of farms in both areas was »excellent,« the age structure criteria was assigned the value »good« (age of farm holder was between 40 and 55 years, the farm has a successor), and amounts of both attributes were assessed as »good.«

The DEXi software also enables »what-if analysis.« For instance, one might consider how the overall assessment can be improved. Table 5 shows the sensitivity (so called ± 1 analysis) for the areas K that was originally assessed as »inappropriate«. The analysis shows, for example, which attributes considerably affect the evaluation of areas *K*. When attribute Number of payment entitlements or Integrated crop production increase the overall assessment of areas K improves to »rather inappropriate«.

The final assessment of the areas confirmed that selecting specific types of farming and other socio-economic parameters in a particular LFA depends on various criteria, which were taken into consideration in the multi-attribute decision model.

The developed model enabled a final assessment of the LFAs based on the defined attributes and the decision rules within the defined utility functions for the observed problem. Moreover, the results show that the developed decision model could be a suitable methodological tool to aid the practical evaluation of different farming systems in LFAs and aid future political decision making. As this seems the use of program desirable for many practical problems such as assessment of the service quality that embeds many qualitative attributes or that cannot be easily numerically quantified further study should be particularly focused on the integration of qualitative and quantitative modeling techniques in the assessment of service quality as well as the inclusion of direct farm activities in the DEXi tree. However, despite the use of qualitative data only, we found that the approach fulfilled most of our expectations and revealed considerable advantages in comparison with other approaches. In particular, we emphasize the use of the qualitative multi-criteria DEXi model, which was suitable in a field where judgment prevails, thus making it difficult to give numeric answers. This kind of model is comprehensible to a wide range of users in the evaluation process.

Table 4: Integrated final assessment of LFAs.

Attribute (a)	EVALUATION RESULTS				
	D	H	K	S	V
Final assessment	APPROPRIATE	APPROPRIATE	INAPPROPRIATE	RATHER INAPPROPRIATE	EXCELLENT
Farm description	EXCELLENT	EXCELLENT	GOOD	EXCELLENT	EXCELLENT
Farm size (ha)	AVERAGE	SMALL	AVERAGE	BIG	BIG
Usage type of agricultural land	Fields	Fields	Meadows	Meadows	Meadows
Number of assigned points (points)	> 350	310–350	< 310	> 350	> 350
Amount of LFA payments (€)	500–1000	500–1000	> 1000	> 1000	> 1000
Social structure	GOOD	GOOD	GOOD	GOOD	GOOD
Farm holder´s age (years)	40–55	40–55	40–55	40–55	40–55
Successor or not	Yes	Yes	Yes	Yes	Yes
Successor´s age(years)	40–55	40–55	40–55	40–55	40–55
Amount of natural handicap payments	Good	Good	Good	Very good	Very good
Number of payment entitlements	6,5–7,5	< 6,5	6,5–7,5	> 7,5	> 7,5
Value of payment entitlements for arable land (€)	< 380	> 400	380–400	> 400	> 400
Value of payment entitlements for pasture (€)	< 160	> 180	160–180	> 180	> 180
Amount of payment entitlements (€)	> 2000	1000–1500	1500–2000	> 2000	1500–2000
Amount of agri-environment payments	Good	Good	Bad	Bad	Good
Organic farming (%)	< 2	2–4	2–4	2–4	> 6
Integrated crop production (%)	> 6	2–4	< 2	< 2	< 2
Implementation of other agri-environmental measures (%)	20–30	20–30	< 20	20–30	30–40
Amount of payments (€)	> 2000	< 1200	1200–1600	1200–1600	1200–1600
Amount of direct payments	Bad	Bad	Bad	Bad	Good
Amount of protein crops payments and nuts payments (€)	150–250	> 250	150–250	< 150	150–250
Amount of additional payments for milk (€)	< 500	< 500	< 500	500–1000	> 1000
Amount of additional payments for beef (€)	> 750	< 650	< 650	> 750	650–750

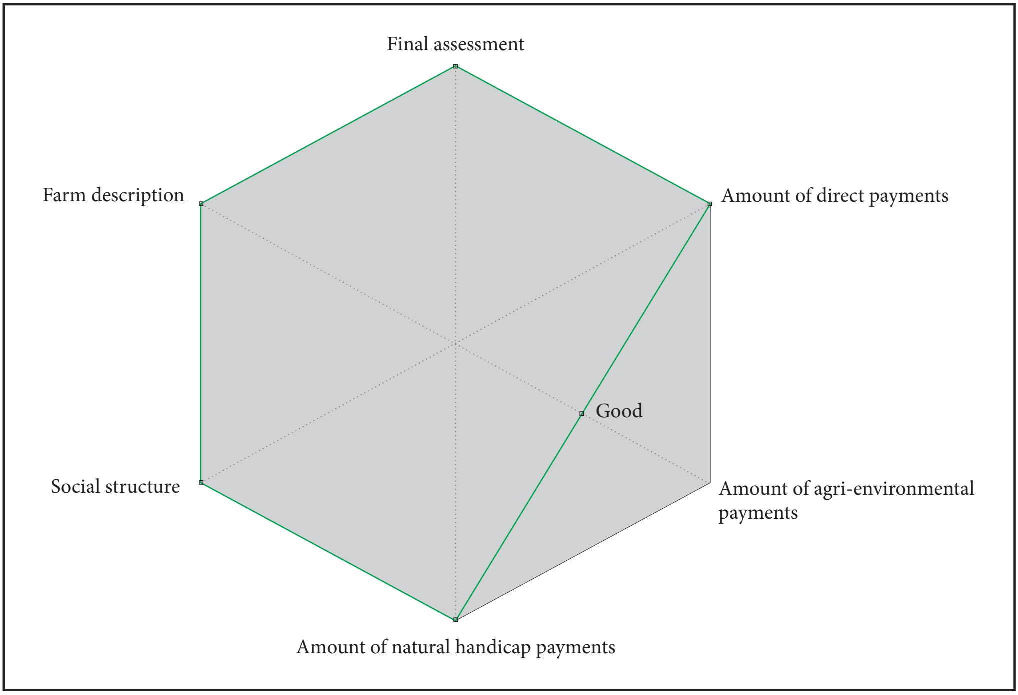

Figure 1: Graphical presentation of the final assessment mountain areas (V)/gafični prikaz končne ocene gorsko-višinskih območij.

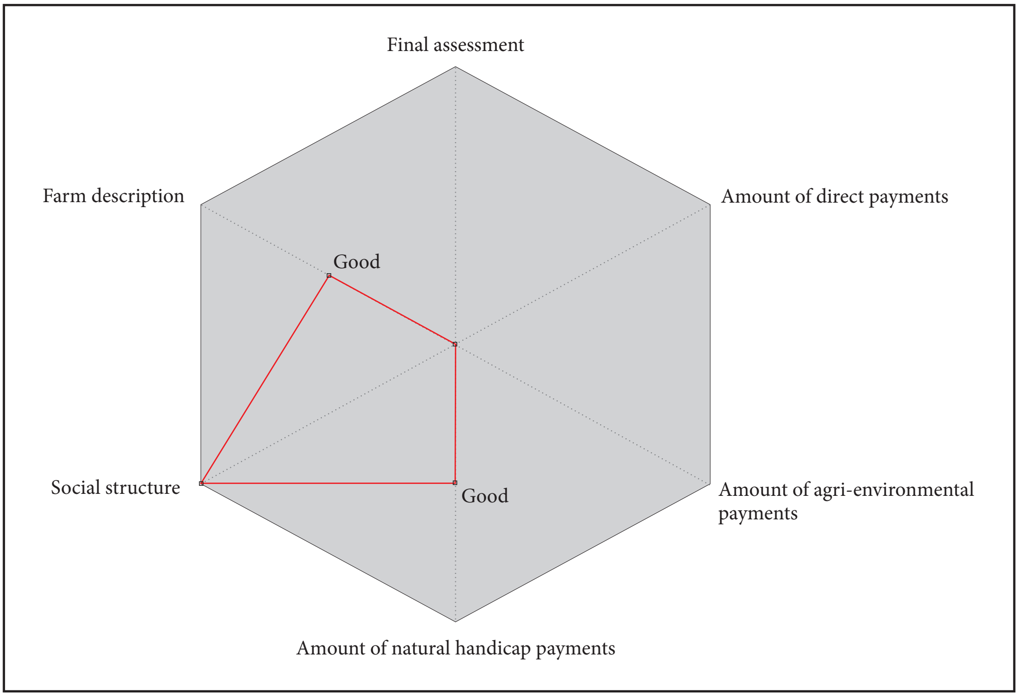

Figure 2: Graphical presentation of the final assessment of the karst (K) areas.

Table 5: The sensitivity analysis (± 1) for the karst areas (K).

Attribute (a)	Plus-minus-1 analysis		
	−1	K	+1
Final assessment		INAPPROPRIATE	
Farm description			
Farm size (ha)		AVERAGE	
Usage type of agricultural land	[	Meadows	
Number of assigned points (points)	[	< 310	
Amount of LFA payments (€)		> 1000	]
Social structure			
Farm holder´s age (years)		40–55	
Successor or not		yes	]
Successor´s age(years)		40–55	
Amount of natural handicap payments			
Number of payment entitlements		6,5–7,5	RATHER INAPPROPRIATE
Value of payment entitlements for arable land (€)		380–400	
Value of payment entitlements for pasture (€)		160–180	
Amount of payment entitlements (€)		1500–2000	
Amount of agri-environment payments			
Organic farming (%)		2–4	
Integrated crop production (%)	[	< 2	RATHER INAPPROPRIATE
Implementation of other agri-environmental measures (%)	[	< 20	
Amount of payments (€)		1200–1600	
Amount of direct payments			
Amount of protein crops payments and nuts payments (€)		150–250	
Amount of additional payments for milk (€)	[	< 500	
Amount of additional payments for beef (€)	[	< 650	

4 Conclusion

According to the results the multi – attribute DEXi model can be regarded and applied practically to smaller number of farms as well as to a broader sphere of scientifically research work. The developed model may also be used in further development of agricultural policy, it also can be upgraded with the latest information and adopted it to specific requirements. The multi – criteria methodology cannot replace or exclude the policy decision maker experts but can serve as an additional instrument that enables faster analysis. The model can be good basis and support tool for further development of more complex models that are designed primarily for planning and decision-making process in agricultural policy especially by definition of different payments types in agriculture.

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THE USE OF NDVI AND CORINE LAND COVER DATABESES FOR FOREST MANAGEMENT IN SERBIA

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An example of illegal logging from the Municipality of Kuršumlija in southern Serbia in 2013.

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The use of NDVI and CORINE Land Cover databases for forest management in Serbia

ABSTRACT: This article evaluates the possible use of normalized difference vegetation index (NDVI) and CORINE Land Cover (CLC) databases for better forest management in the municipalities of Kuršumlija and Topola in Serbia. The forest areas obtained using CLC were up to 11.5% larger than the official forest area estimates, whereas NDVI gave more precise results. Hence, NDVI can efficiently provide local forest managers with essential annual information about the forest inventory.This is of a crucial importance for preventing illegal logging, which is very prevalent in southern Serbian municipalities, which have substantial forested territory. NDVI thus very promising for Serbia and also for countries that rarely carry out national forest inventories. This method can also easily be applied to other Balkan countries with a similar situation regarding local forest management.

KEY WORDS: NDVI, CORINE Land Cover, forest management, illegal logging, Serbia

Raba podatkovnih zbirk NDVI in CORINE pri gospodarjenju z gozdovi v Srbiji

POVZETEK: V članku avtorji preučujejo možnost rabe podatkovnih zbirk NDVI in CORINE za boljše gospodarjenje z gozdovi v srbskih občinah Kuršumlija in Topola. Površina gozda, ugotovljena z uporabo CLC, je bila do 11,5 % večja od uradno ocenjene, medtem ko so bili rezultati NDVI točnejši. NDVI lahko lokalnim upravljavcem gozdov zagotavlja pomembne informacije o gozdu na letni ravni. To je izjemno pomembno za preprečevanje nezakonite sečnje, značilne za občine v južni Srbiji, ki so bogate z gozdom. Uporaba NDVI zato obetavna za Srbijo in tudi druge države, ki redko izvajajo nacionalne popise gozdov. Metoda je primerna tudi za druge balkanske države s podobnimi razmerami na področju lokalnega gospodarjenja z gozdovi.

KLJUČNE BESEDE: NDVI, CORINE, gospodarjenje z gozdovi, nezakonita sečnja, Srbija

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1 Introduction

Permanent clearing of forest cover was typical in the industrialized world until a few decades ago. Vast areas of Europe and North America were cleared for industrial expansion and development of infrastructure. Today deforestation is largely occurring in tropical countries in Africa, Asia, and Latin America (Steininger et al. 2001; Chowdhury 2006), as well as in taiga regions, especially in Russia (Tracy 1994; Deforestation … 2014).

Most reasons for deforestation are due to market imperfections (Jovanović 2012). Market imperfections arise when property cannot be clearly defined, when property cannot be freely transferred, when the use of goods cannot exclude others from such use, and when private rights cannot be protected (McKean 2000; Tietenberg and Lewis 2012). Evidence convincingly shows that illegal and corrupt activities are a major underlying cause of forest decline (Contreras-Hermosilla 2002; Brack 2003). The main reason for this is that governments and private landowners cannot control these illegal operations. In addition, this lack of control may be deliberate, is often corrupt, or may be determined by the limitations of administrative capacity. One way or another, illegal use of forests is rampant (Contreras-Hermosilla 2002; Amacher et al. 2009).

Remote sensing is the detection, recognition, or evaluation of objects by means of distant sensing or recording devices (Oštir 2006). Historically, digital remote sensing developed rapidly from aerial photography and photo interpretation. Information extracted visually from remote sensing is widely used in forestry (Franklin 2001; Hočevar and Kobler 2001; Hočevar and Hladnik 2006; Kobler 2012).

Given the importance and complexity of forest preservation and sustainable forest management (Pagiola et al. 2002; Lee 2008; Ojea et al. 2012), an attempt was made to evaluate the possible use of a normalized difference vegetation index (NDVI; Weier and Herring 2000) and Coordination of Information on the Environment (CORINE) Land Cover (CORINE … 1994) in local forest management. NDVI is one of the most widely used vegetation indices (VIs) and CORINE Land Cover (CLC) is in official use in the EU.

One of the main differences between NDVI and CLC is that, whereas NDVI focuses on the vegetation cover and its status, CLC has a much broader scope and distinguishes agricultural areas, forests and semi-natural areas, artificial surfaces, urban fabric, industrial, commercial, and transport units, bodies of water, wetlands, glaciers and perpetual snow, and other features (Jensen 2007).

NDVI is actually a simple graphic indicator that can be used to analyze remote sensing measurements, whether the target observed contains live green vegetation or not (Chen 2008). NDVI was one of the most successful of many attempts to simply and quickly identify vegetated areas and their »condition,« and it remains the best-known and most-used index for detecting live green plant canopies in multispectral remote sensing data (Fuller 2006; Milanović et al. 2008; Campbell and Wynne 2011; Ne Win et al. 2012). NDVI also has the advantage of allowing comparisons between images acquired at different times (Lillesand et al. 2004). It belongs to the VIs related to vegetation cover and its status, and it provides useful information on biomass productivity and health. VIs have a direct correlation with leaf chlorophyll content and leaf area index (LAI) and vary in relation to vegetation cycle and phenology (Vohland et al. 2007; Montandon and Small 2008). They are also sensitive to other external factors, such as the contribution of the soil and background optical behavior where the vegetation does not completely cover the ground, the geometry of view due to sensor angle of acquisition and to Sun position, atmospheric effects, and other factors (Franklin 2001; De Jong and Van der Meer 2005; Jensen 2007; Campbell and Wynne 2011).

NDVI, like all VIs, relates the spectral absorption of chlorophyll in the red with a reflection phenomenon in the near infrared, influenced by the leaf structure type (Wang and Tenhunen 2004).

In contrast, CLC is a European program launched in 1985 by the European Commission, aimed at obtaining a unique and comparable dataset of land cover for Europe. The aim of CLC is to gather information related to the environment on certain priority topics for the European Union: air, water, soil, land cover, coastal erosion, biotopes, and so on. The main goals of the CLC program are to acquire information about the environment to address the European Community policy, to assess the effectiveness of legislation, to integrate environmental and political aspects, to unify heterogeneous thematic cartographies of Europe at various levels (international, national, regional, local), and to update data at regular intervals, every five to ten years (Bossard et al. 2000; Neumann et al. 2007). CLC is a map of the European environmental landscape based on interpretation of satellite images.

The data have been validated using local cartography and ground surveys (Heymann et al. 1994; Perdigão and Annoni 1997; Genovese et al. 2001). CLC also has an NDVI module for creating vegetation maps, but the deviations in its final results are substantial due to the highly inappropriate scale of Serbian data.

For creating CLC maps for the municipalities of Kuršumlija and Topola, image processing was carried out and a digital elevation model was made based on the municipalities' boundaries and Landsat satellite color composites, and a pseudo-color composite with bands 4, 5, 1 and adequate contrast was applied. Datasets and maps for Serbia, mainly IMAGE2000 and CLC2000 class, were extracted from the European Environmental Agency (EEA) website, with a transfer data scale of 1 : 100,000, which resulted in a very high level of imprecision (Büttner and Kleeschulte 2005).

Of particular interest to this study is that the smallest unit is 25 ha in the original CLC project, although a recent approach yields more precise results because changes < 25 ha and > 5 ha are mapped (CLC2006 … 2007). Nevertheless, even the smallest 5 ha areas, which are highly appropriate at the EU scale, do not properly reflect the land-use situation at the local scale in a country where landscapes and land-use change across very short distances (Hočevar and Kobler 2001; Gabrovec and Petek 2004).

This article shows that remote sensing data collection and analysis methods have great importance for local forest management in Serbia. In Serbia around 30% of land is forested (of which 50% is state-owned forests and 50% privately owned). Forest management (of both privately owned and state-owned forests) is also very poor (Forestry … 2006).

The purpose of this article is to improve the local forest management system in Serbia through more precise methods for assessing land-use changes in forest areas. The study evaluated NDVI and CLC, which are viewed as very efficient tools for classifying and estimating different land cover types of large and remote areas (Meng et al. 2009). Although they both proved to be very effective in the EU, CLC is mostly used as a regional database. Nonetheless, in Serbia they both (recently) became very popular tools for studies at the local level (Report … 2009). This article shows that they are not equally effective at the local level in the Serbian context.

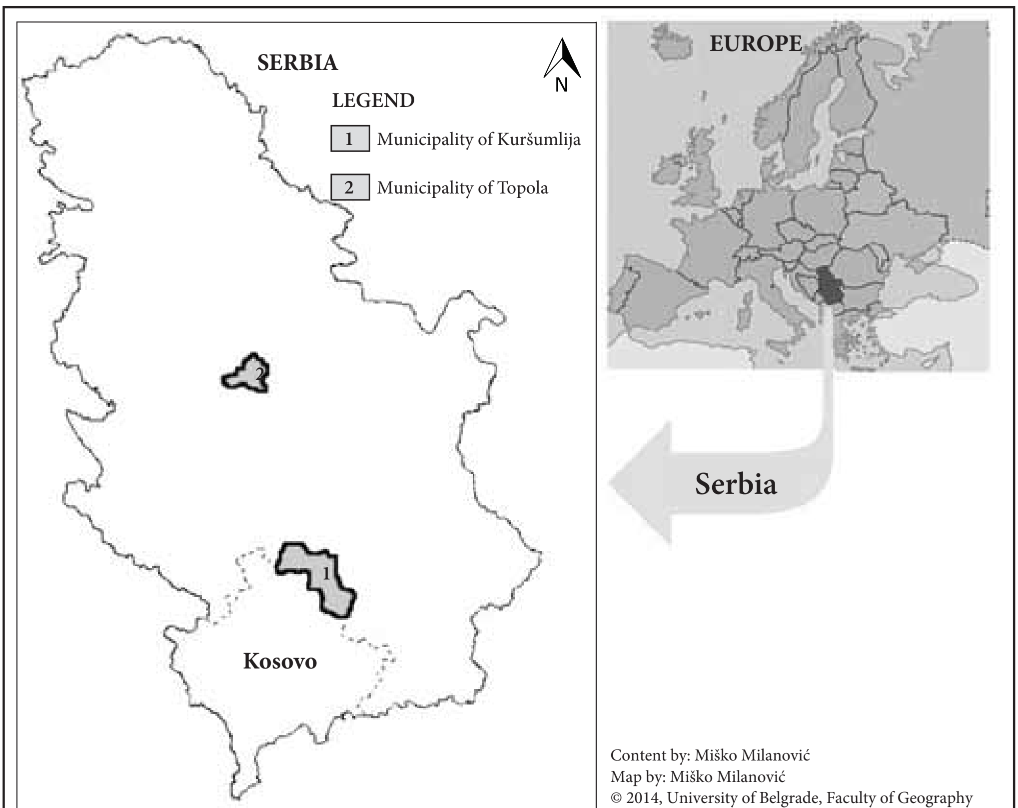


Figure 1: Location of the municipalities of Kuršumlija and Topola (Serbia).

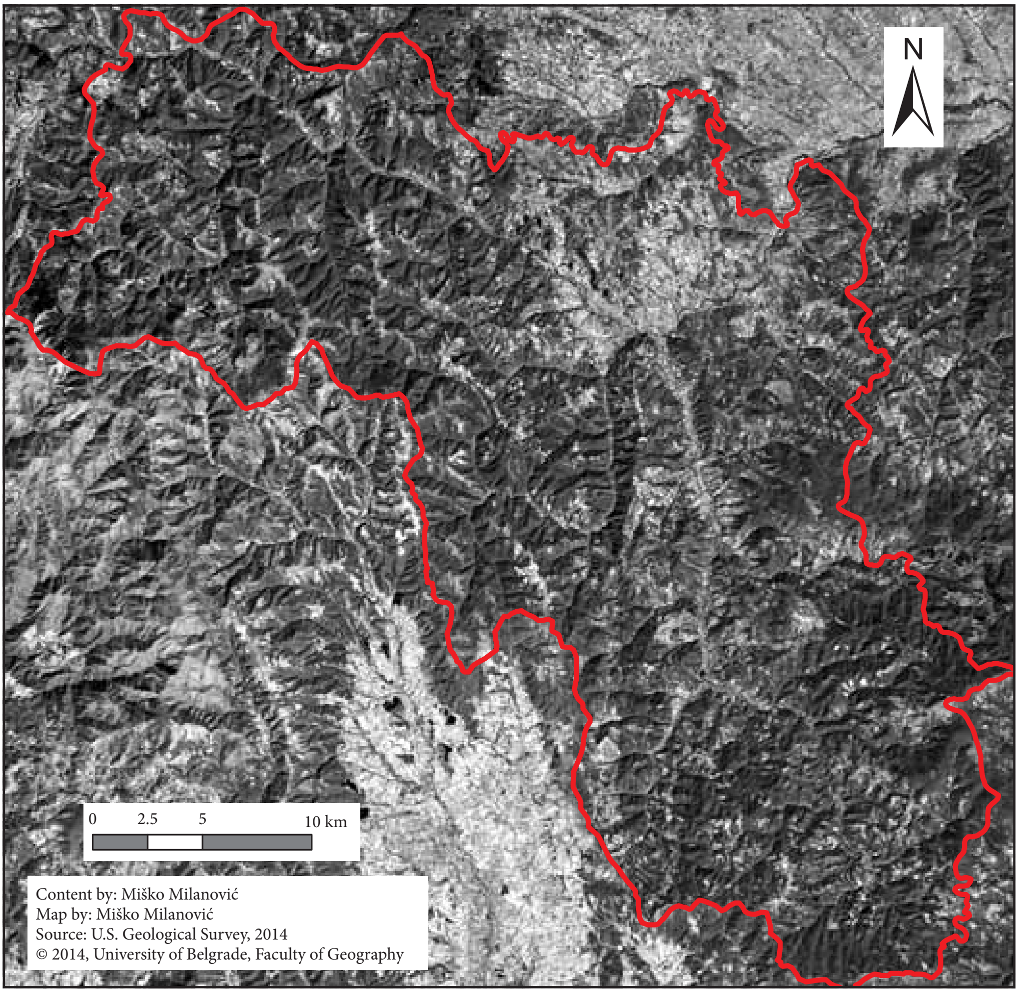
2 Materials and methods

In the study it was not possible to make a reliable long-term comparative analysis between NDVI and CLC data and official forest inventories because national forest inventories have very rarely been carried out in Serbia. Such inventories were carried out at roughly twenty-year intervals: in 1961, 1979, and 2003–2006. Since 2007, official estimates of forest areas have been made annually.

The study was carried out for the municipalities of Topola and Kuršumlija (Figure 1). Data obtained using NDVI and CLC for spring/summer 2006 were analyzed and compared to official forest area estimates for 2006 created at the end of the same year. The Municipality of Topola is located in central Serbia, and the Municipality of Kuršumlija lies in southern Serbia.

NDVI and CLC data for both municipalities are based on Landsat 5 Thematic Mapper (TM) satellite images (Figures 2 and 3) for 2006, which were created during spring/summer (August), with minimum clouds (10 to 20%; Chavez 1996). In order to remove atmospheric effects from the NDVI final results, Idrisi software was used for data preprocessing.

For calculating NDVI, satellite (Landsat) imagery (which has a resolution of approximately 30 m) and pan-sharpening images (with 15 m resolution) were used to obtain more precise results.



LANDSAT IMAGE

Figure 2: The Municipality of Kuršumlija.

NDVI was used and necessary corrections/transformations were applied for visible red in constellation with the infrared spectrum of satellite images using the following procedure: GIS Analysis / Mathematical Operation / Image Calculator, and then the equation NDVI = (NIR – RED) / (NIR + RED), in which NIR is the near-infrared channel and RED is the red channel from the visible part of the spectrum (Hájek 2008; Johnson and Trout 2012).

Basic tasks included analysis and photo interpretation of elements, occurrences, and processes detected on images using specialized GIS software (Idrisi 15-Andes) for processing remotely sensed images through application of NDVI.

Shadows can cause NDVI values to be lower than their actual values. In this sense, »*empirical topographic corrections have proven only marginally successful*« (Franklin 2001). Because shadow areas were less than 5% in the Municipality of Kuršumlija and less than 3% in the Municipality of Topola, no topographic corrections were made.

Characteristic NDVI signatures are as follows: NDVI of dense vegetation canopy tends to have positive values (0.3 to 0.8); clouds and snowfields are characterized by negative values of this index; bodies of water (e.g., oceans, seas, lakes, and rivers) has rather low reflectance in both spectral bands (at least away from shores), thus resulting in very low positive or even slightly negative NDVI values; soils generally exhibit a near-infrared spectral reflectance somewhat larger than the red, and thus also tend to generate rather small positive NDVI values (0.1 to 0.2); very low values of NDVI (0.1 and below) correspond to barren areas of rock, sand, or snow; moderate values represent shrub and grassland (0.2 to 0.3); and high values (0.6 to 0.8) indicate tem-

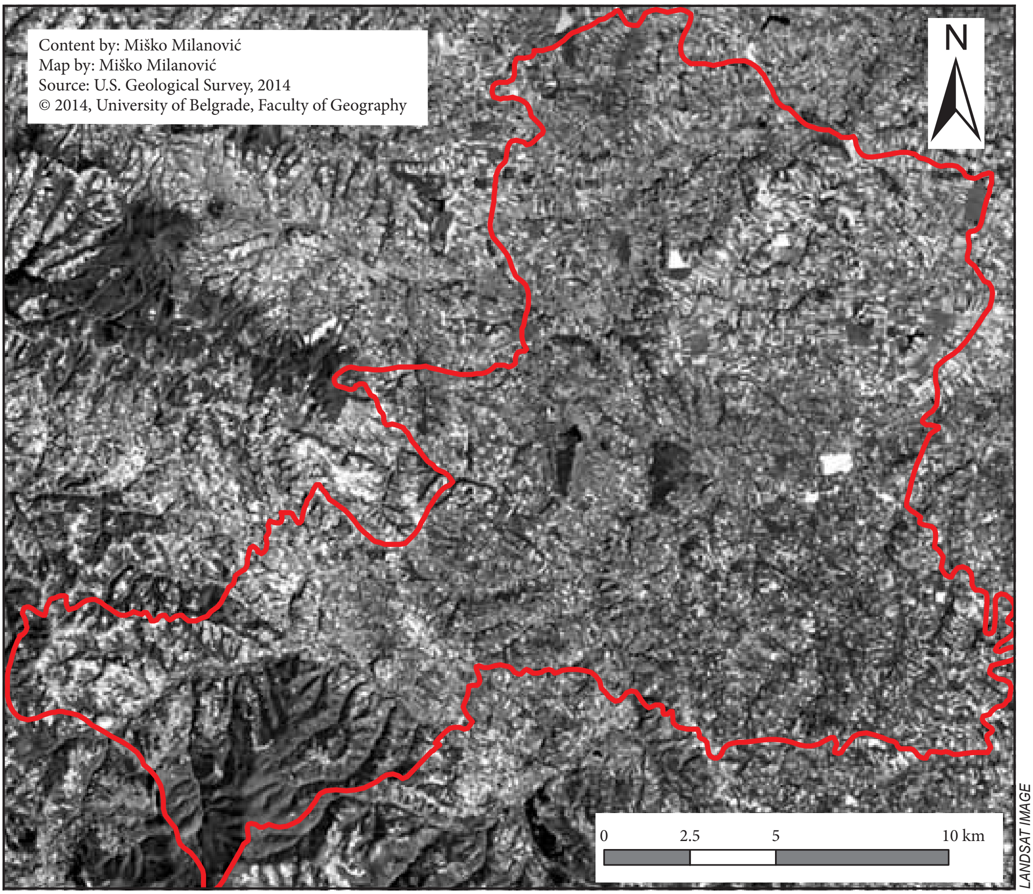


Figure 3: The Municipality of Topola.

perate and tropical rainforests (Finelli et al. 1996; Schmitt and Ruppert 1996). Negative values of NDVI ranging from 0 to –0.3 are displayed in shades from light green to dark purple. These low negative values are detected in arable agricultural land (without vegetation) and are shown in shades of light green. On the other hand, vegetation areas are presented with values between 0 and 1. Grassy areas, meadows, and pastures have values that range from zero (in yellow, due to more intense reflectance of infrared radiation) up to 0.13 (light orange tones). Shrub vegetation has an NDVI value of 0.25 because reflectance of infrared rays decreases (darker red tones). Forest vegetation, with maximal positive NDVI values of 0.85 (due to minimal reflectance of infrared rays), is easily observed. Coniferous forest has an NDVI value above 0.5, mixed forest between 0.35 and 0.5, and broad-leaved forest between 0.3 and 0.4 (Bakx 1995; De Jong and Van der Meer 2005).

3 Results

After image processing it was determined (Table 1) that forest areas encompass 529.83 km^2 or 55.7% of the total area of the Municipality of Kuršumlija, much higher than the average 30% for Serbia; and 50.73 km^2 or 14.2% of the total area of the Municipality of Topola, which is approximately half of the Serbian average.

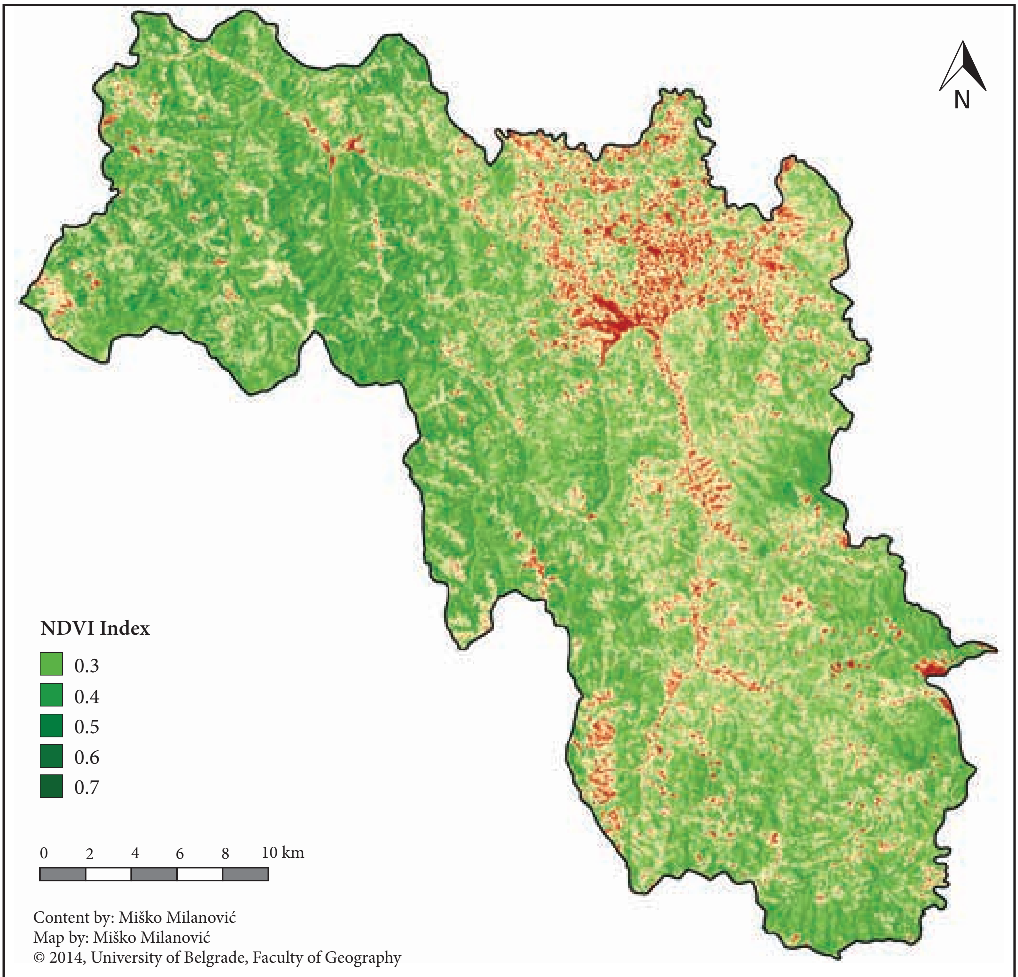


Figure 4: Vegetation cover in the Municipality of Kuršumlija for 2006 obtained from NDVI.

When these NDVI results are compared with official forest area estimates for the same year (2006) (Municipalities … 2007), there is only +0.12 km^2 of difference for Topola's forest area, and −27 km^2 difference for Kuršumlija (Table 3).

Figures 4 and 5 present a raster of NDVI (NIR band and RED band) from *Landsat* 5 TM (bands 4, 5, 1) satellite images. The images were created in August 2006. Figures 6 and 7 present vegetation cover obtained from CLC.

When the (latest available) CLC results for 2006 were compared with official forest area estimates for the same year (Tables 1–3), some inconsistencies became apparent:

- The total areas for the municipalities of Kuršumlija and Topola obtained from CLC were smaller than the official forest statistics: instead of 952 km^2 only 942.9 km^2 for Kuršumlija, and instead of 356 km^2 only 348.9 km^2 for Topola;
- Forest areas obtained from CLC were up to 11.5% larger than the official forest area estimates. Kuršumlija's forest area obtained from CLC (630.45 km^2) is 26 km^2 larger than the official forest area estimates (604.41 km^2) for this municipality (+ 4.3%), and Topola's forest area obtained from CLC (58 km^2) is 6 km^2 larger than the official forest area estimates (52 km^2, + 11.5%).

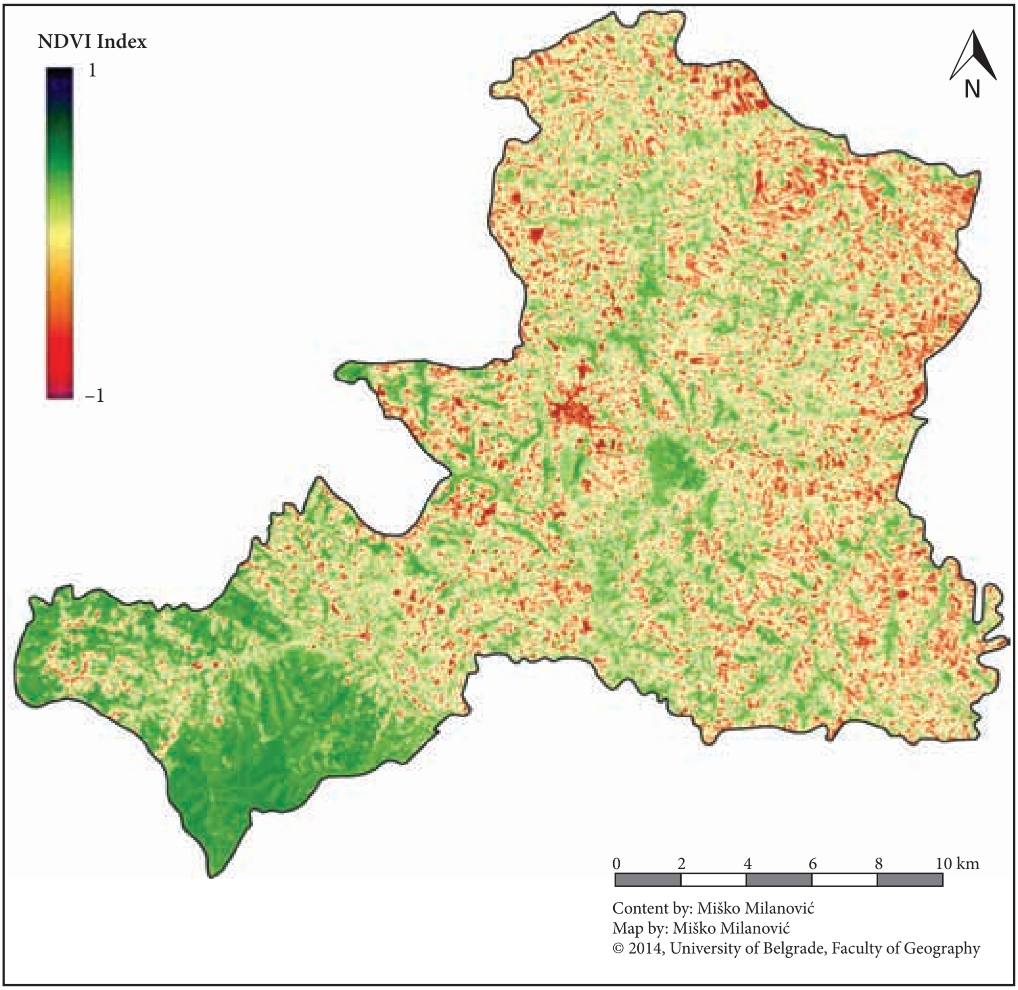


Figure 5: Vegetation cover in the Municipality of Topola for 2006 obtained from NDVI.

Table 1: Vegetation cover in the municipalities of Kuršumlija and Topola for 2006 obtained from NDVI.

Land cover	Kuršumlija		Topola	
	(km^2)	(%)	(km^2)	(%)
Broad-leaved forest	562.71	59.10	49.40	13.84
Coniferous forest	6.46	0.68	0.62	0.17
Mixed forest	8.23	0.86	2.10	0.59
Pastures	32.20	3.40	–	–
Transitional woodland-shrub	51.55	5.41	–	–
Sparsely vegetated areas	9.48	0.99	–	–
Land principally occupied by agriculture, with significant areas of natural vegetation	–	–	63.25	17.72
Other	281.37	29.56	241.63	67.68
Total	952.00	100.00	357.00	100.00

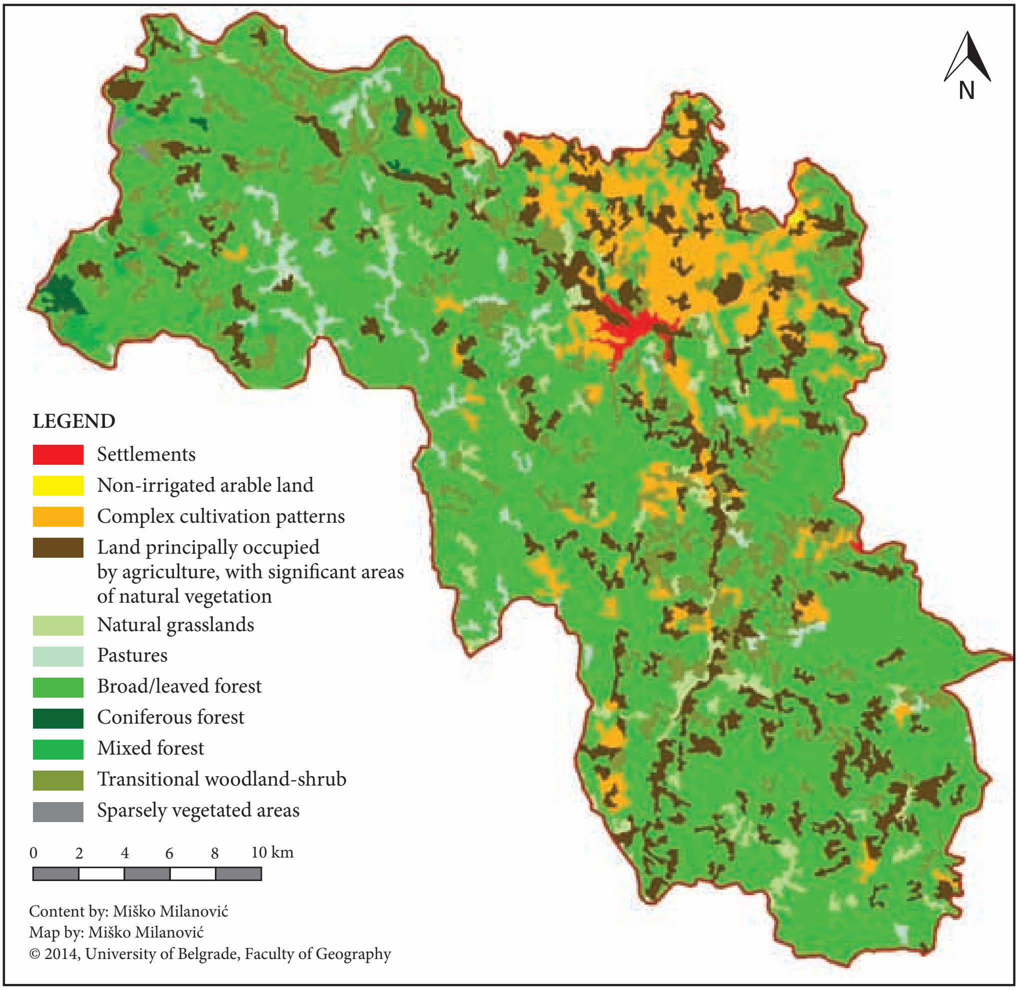


Figure 6: Vegetation cover in the Municipality of Kuršumlija for 2006 obtained from CLC.

Table 2: Land cover in the municipalities of Kuršumlija and Topola for 2006 obtained from CLC.

Land cover	Kuršumlija		Topola	
	(km^2)	(%)	(km^2)	(%)
Settlements	4.60	0.49	9.11	2.61
Green urban areas	–	–	0.82	0.23
Non-irrigated arable land	0.42	0.04	36.51	10.46
Natural grasslands	25.74	2.73	14.44	4.14
Complex cultivation patterns	78.73	8.35	154.94	44.41
Land principally occupied by agriculture, with significant areas of natural vegetation	102.25	10.84	73.17	20.97
Broad-leaved forest	620.68	65.82	55.68	15.96
Coniferous forest	3.63	0.38	0.19	0.05
Mixed forest	6.14	0.65	2.12	0.61
Pastures	24.18	2.56	1.11	0.32
Transitional woodland-shrub	75.78	8.04	0.81	0.23
Sparsely vegetated areas	0.78	0.08	–	–
Total	942.93	100.00	348.90	100.00

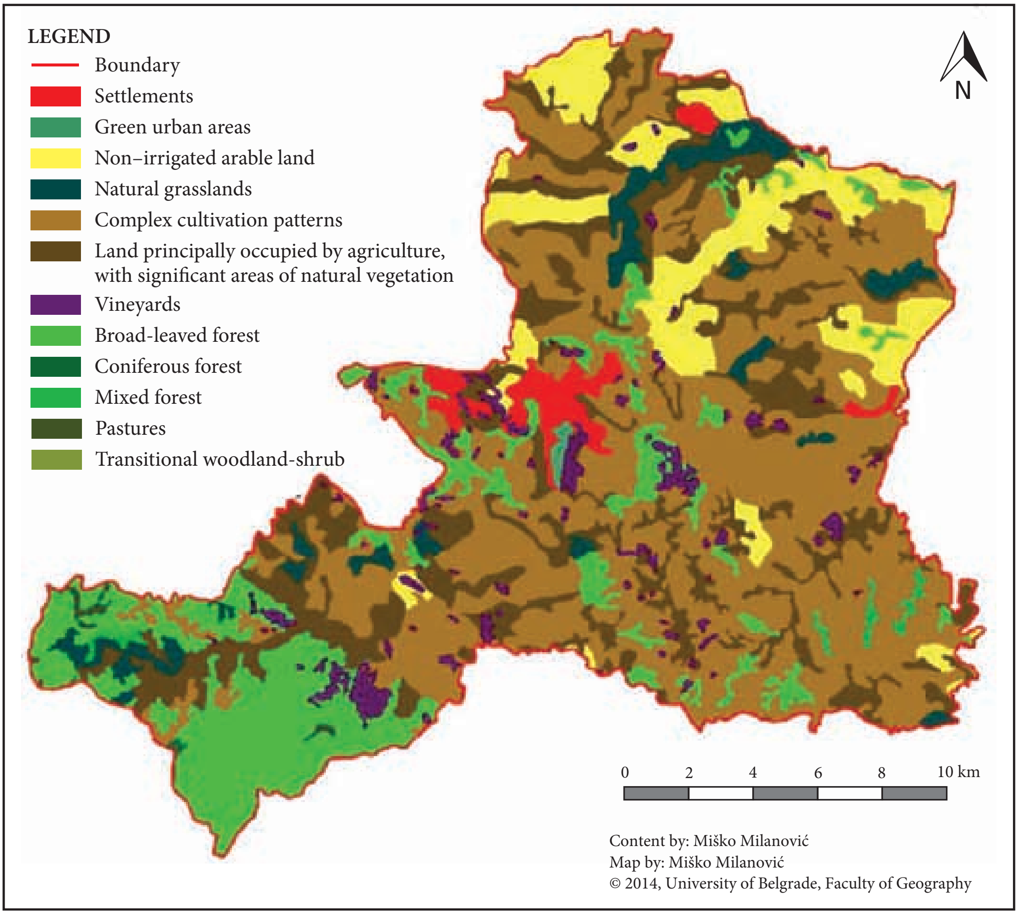


Figure 7: Vegetation cover in the Municipality of Topola for 2006 obtained from CLC.

Table 3: Forest areas according to official statistics and calculated on the basis of NDVI and CLC for 2006.

Municipality	Municipality: total area (km^2)	Forest area			NDVI – official statistics difference (km^2)	CLC – official statistics difference (km^2)
		Official statistics (km^2)*	Calculated on the basis of NDVI (km^2)	Calculated on the basis of CLC (km^2)		
Topola	356	52.00	52.12	57.99	+0.12	+ 5.99
Kuršumlija	952	604.41	577.40	630.45	–27.01	+ 26.04

* Source: Municipalities . . . 2008.

Table 4: Forest areas according to official statistics and calculated on the basis of NDVI for 2011 and CLC for 2006.

Municipality	Municipality: total area (km^2)	Forest area			NDVI – official statistics difference (km^2)	CLC – official statistics difference (km^2)
		Official statistics (km^2)*	Calculated on the basis of NDVI (km^2)	Calculated on the basis of CLC (km^2)		
Topola	357	52.0494	50.73	57.99	–1.3194	+ 5.9407
Kuršumlija	952	544.2856	529.83	630.45	–14.4556	+ 86.1644

* Source: Municipalities . . . 2013.

4 Discussion

Although both CLC and NDVI have recently been used in Serbia for studies at the local level, the main problem with CLC data is that: a) although CLC data are produced at various levels (international, national, regional, and local; Bossard et al. 2000; Neumann et al. 2007), CLC is actually a predominantly regional database, updated rarely (every five to ten years), whereas NDVI is available for every year; and b) NDVI is much more precise than CLC.

When official statistics and NDVI and CLC forest areas were compared for the same year (2006), NDVI was more precise than CLC. Because both NDVI and CLC used the same Landsat satellite images and the same (NDVI) methodology, these major differences in the data obtained were due to the different spatial resolution of NDVI and CLC.

Whereas CLC does not go below the range of 4 to 5 ha, NDVI easily deals with minimum space units of 25 m^2. This proved to be decisive for Serbia, where privately owned forest parcels, which account for half of the total forest area of the country, usually cover much smaller areas (the average private holding is 0.5 ha; Glavonjić et al. 2005). In short, CLC proved not to be very suitable for local forest management in Serbia (questionable results regarding forests were also determined in Slovenia; e.g., Gabrovec and Petek 2004). In addition, apart from the obvious CLC imprecision for studies at the local level, CLC data are not available for every year.

When compared with official forest area estimates, the NDVI results show a mere +0.12 km^2 (+0.2%) difference for the Municipality of Topola's forest area, and a –27.01 km^2 (–4.7%) difference for the Municipality of Kuršumlija (Table 3). Not only do these results completely fit within the ± 5% margin of error allowed for this method (Eastman 2001; Lunetta et al. 2007), but they also allow room for further analysis and investigation.

Because the NDVI aerial photos were taken during spring/summer, whereas official forest area estimates are made at the end of the year, NDVI values would be expected to be higher, not lower–at least for the Municipality of Kuršumlija (known for its illegal logging). Moreover, because additional NDVI forest area estimates were made for 2011 (Table 4), it seems that even for 2006 this study's NDVI results better fit the forest area trajectory of Kuršumlija for the 2006–2011 period than do the official statistics (the official forest inventory for 2006 is 604.41 km^2 and NDVI results 577.4 km^2; and the official forest inventory for 2011 is 544.3 km^2 and NDVI results 529.8 km^2).

The main reason that the (slightly smaller) NDVI results possibly better fit the forest area trajectory of Kuršumlija than the official inventory is that this municipality is known for illegal logging. According to the state-owned forest-management company *Srbijašume*, in Kuršumlija more than 40,000 m^3 of timber was illegally cut during the last thirteen years alone, and that municipality also experienced a 10% loss in forest area in the last few years alone (Forestry … 2006; Anfodillo et al. 2008; Illegal … 2009, Municipalities … 2013).

Obviously, governments often cannot efficiently control these illegal operations. As Contreras-Hermosilla (2000) points out: »*This lack of control can be either deliberate, often corrupt, or determined by the limitations of administrative capacity. One way or the other, illegal use of forests is rampant in most forested countries. By their very nature, the true extent of illegal operations in the forestry sector cannot be known with precision, but evidence suggests that such activities are important and that they constitute an important underlying cause of forest decline.*«

Because this research strongly implies that illegal logging in Kuršumlija is not properly covered by current official forest area estimates, further NDVI research on the extent of illegal logging in southern Serbian municipalities is of the utmost importance.

In short, because the Municipality of Kuršumlija has a large territory (952 km^2), with more than 544 km^2 (or 55.7%) of its total area covered by forests, and because NDVI can be performed very quickly, it is obvious that NDVI can provide local forest managers in Kuršumlija with much essential annual information about the forest inventory (Chen et al. 2004; Bellone 2009; Fensholt et al. 2009; Martinez and Gilabert 2009; Alessandrini et al. 2010; Corral-Rivas 2010). This is of crucial importance for preventing illegal logging, which is very prevalent in this southern Serbian municipality (Forestry … 2006; Anfodillo et al. 2008; Illegal … 2009).

5 Conclusion

Despite certain shortcomings (Franklin 2001; Campbell and Wynne 2011), classification and area estimation of various land-cover types based on remote sensing has obviously advanced to a point where it surpasses old wood inventory techniques, especially in the case of Serbia. Specifically:

- It is relatively cheap and quick, and it can provide forest managers with essential information;
- It is easy to implement, which is of crucial importance for Serbia, where national forest inventories have been carried out very rarely. The last three national forest inventories were carried out at roughly twenty-year intervals; however, since the last national forest inventory (2003–2006), necessary updates have been made every year, but only at the municipality level;
- The objectivity of these methods can significantly help in avoiding corruption in forest management because corruption is one of the main weaknesses of Serbia's economy.

Through this analysis of NDVI and CLC results for the municipalities of Kuršumlija and Topola, CLC was shown not to be a very suitable tool for local forest management in Serbia. On the other hand, it is evident that NDVI, especially in southern Serbian municipalities with prevalent illegal logging (like Kuršumlija), can provide local forest managers with much annual information about forest areas. This is of crucial importance for monitoring (and consequently preventing) illegal logging.

NDVI is also very promising for countries like Serbia, which very rarely carry out national forest inventories. It is easy implemented and it has objectivity that can greatly help avoid corruption and illegal logging in forest management.

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NITROGEN AND PHOSPHORUS POLLUTION IN GORIČKO NATURE PARK

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Ledava River at Domajinci.

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Nitrogen and Phosphorus Pollution in Goričko Nature Park

ABSTRACT: This article deals with the impact of diffuse and point sources of nitrogen and phosphorus pollution on the environment in Goričko Nature Park. The park was divided into three parts: the Ledava, Big Krka (*Velika Krka*), and Kobilje Creek (*Kobiljski potok*) basins, which were then compared. The surface waters were monitored and their chemical composition was examined. All three areas are characterized by elevated levels of nitrogen and phosphorus compounds in the water. Nitrogen and phosphorus pollution results from unregulated manure pits on livestock farms, unregulated sewage systems, and runoff of nitrogen and phosphorus compounds from farmland.

KEY WORDS: geography, nature protection, pollution, nitrogen, phosphorus, Goričko Nature Park, Slovenia

Onesnaženje z dušikom in fosforjem v Krajinskem parku Goričko

POVZETEK: Članek obravnava vpliv razpršenih in točkovnih virov na obremenjevanje okolja z dušikom in fosforjem na območju Krajinskega parka Goričko. Krajinski park Goričko smo razdelili na tri dele: porečja Ledave, Velike Krke in Kobiljskega potoka ter med območji izvedli primerjalno analizo. Z monitoringom površinskih tekočih voda smo preučili njihovo kemijsko stanje. Za vsa tri območja so značilne povišane koncentracije dušikovih in fosforjevih spojin v vodi. Onesnaženje z dušikovimi in fosforjevimi spojinami, je posledica neurejenih gnojnih jam na živinorejskih obratih, neurejena kanalizacijska infrastruktura in izgube dušikovih in fosforjevih spojin s kmetijskih zemljišč.

KLJUČNE BESEDE: geografija, varstvo okolja, onesnaženje, dušik, fosfor, Krajinski park Goričko, Slovenija

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1 Introduction

Factors that alter the chemical, biological, physical, and hydromorphological properties of water are those that pollute water and thus have an impact on its condition. Nutrient sources of water contamination (primarily nitrogen and phosphorus) can be divided into point and diffuse sources (Novotny 1988). The point sources of one or more pollutants can be defined and illustrated as points on the map from which pollution spreads into the surrounding areas; the impact decreases with distance. Point sources include industrial and domestic wastewater, direct discharges from livestock farms, and so on. Diffuse pollution sources, which cannot be defined as a single point but rather originate from a specific area, include settlements, agriculture, and traffic infrastructure. Diffuse pollution is the leading form of pollution that is difficult to control (Novotny 2003; De Wit and Behrendt 1999). Intensive agriculture is especially problematic in this regard, because increased fertilizer use and intensive livestock farming increase nutrient inputs.

Healthy drinking water (ground or surface) is recognized as one of the fundamental environmental problems. Water is a partially renewable resource, but excessive contamination, especially by inorganic matter, can turn it into a health risk. In order to prevent this type of contamination as much as possible, water pollution sources must be determined to the greatest possible extent. This is an especially big challenge in the case of diffuse water pollution because the sources must be defined locally. An expressly local approach is required because each area has its own special features.

Nitrogen is an important element of the global ecosystem and a component of many organic and inorganic substances (Williams 2001). Water contains low levels of nitrogen in the form of organic or inorganic compounds (Ibanez et al. 2007). The most important inorganic forms of nitrogen include ammonium (as the ammonium ion NH_4^+ and ammonia or NH_3, which are in balance in a water solution; they have an oxidation number of –3), nitrate (NO_3^- with an oxidation number of +5), and nitrite (NO_2^- with an oxidation number of +3). These ionic forms play an important role in the nitrogen cycle.

After nitrogen, phosphorus is the second most important element in primary production (Green et al. 2007) and it is the most important nutrient to cause the eutrophication of fresh water (Lemmunyon and Daniel 1998), which stimulates algal growth, decreases dissolved oxygen levels, and reduces water transparency (Wood 1998). Excess phosphorus in water from both point and diffuse sources can result in increased primary production and eutrophication, with the potential for seasonal toxic algal blooms, which can have a major negative impact on global water quality (Worsfold 2005). The majority of phosphorus is washed from farmland into surface waters, whereas only small amounts are washed into the groundwater (Bryant 2004). Phosphorus losses from farmland amount to 0.97–1.85 kg/ha a year (Baker 1984). Phosphorus losses from farmland in Goričko Nature Park can be up to 8.2 kg/ha (Karta presežkov fosforja 2006) as a result of surface runoff (Karta površinskega odtoka 2003).

2 Methods

Water quality in Goričko Nature Park was monitored through field measurements and laboratory analyses. Field research included measurements of water and air, pH, electrical conductivity, redox potential, turbidity, and oxygen. Sampling was carried out in line with the Slovenian Standard (Kakovost vode … 2007). Eleven sites were used for sampling, which was carried out once a month from May 28th, 2008 to May 20th, 2009. Discharge was measured using the float method (Brilly 1992), and chemical parameters (i. e., ammonium, nitrate, nitrite, total nitrogen, orthophosphate, total phosphorus, potassium, chemical oxygen demand (COD), five-day biochemical oxygen demand (BOD_5), and undissolved matter) were determined using standard methods (Eaton et al. 1995).

2.1 Description of the study area

Goričko Nature Park is located in the extreme north-east of Slovenia. Most of the area (96%) is a Natura 2000 site (Uredba … 2004). This is a hilly area with an average elevation between 300 and 350 m above sea level and intermittent valleys at an elevation of 220–260 m (Digitalni … 2001).

Acid to neutral soil developed on noncarbonate bedrock (Internet 3). Average annual air temperature is 9.7 °C and the average annual precipitation is 761.8 mm (Meteorološki podatki … 2009). According to

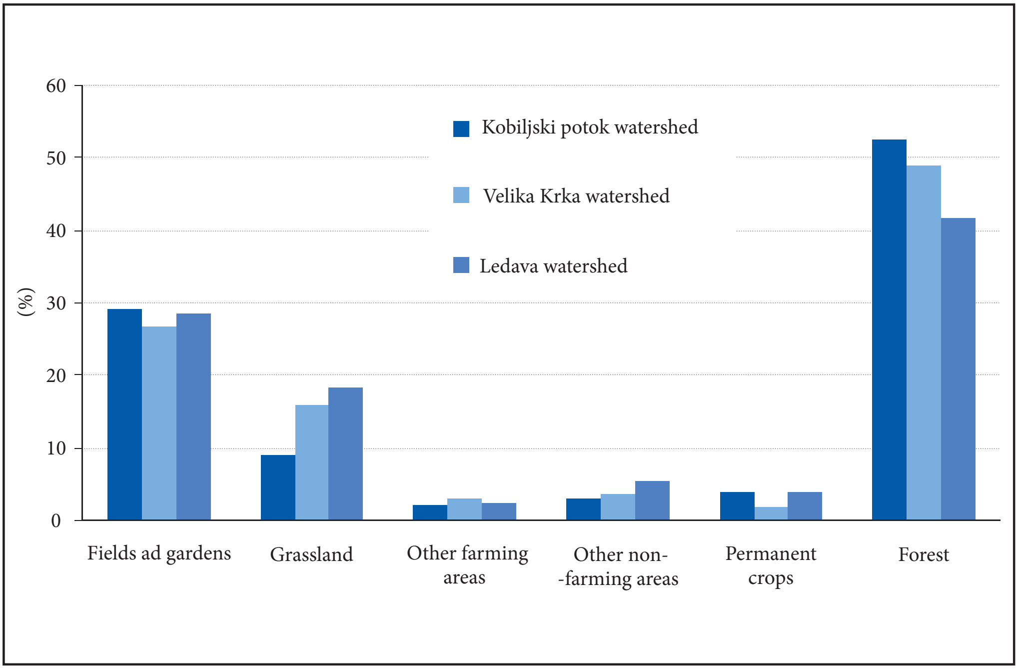

Figure 1: Land use by basin in Goričko Nature Park.

Gabrovec and Kastelec (1998), the annual quasi-global radiation energy (the sum of direct and diffuse solar radiation) on inclined surfaces ranges from 3,300 MJ/m^2 at lower elevations of the central and eastern parts of Goričko Nature Park to around 4,000–4,800 MJ/m^2 in the remaining parts.

Goričko Nature Park was divided into three parts: the Ledava, Big Krka (*Velika Krka*), and Kobilje Creek (*Kobiljski potok*) basins.

The Ledava Basin (Internet 1) covers 21.4 km^2 (46.3%) of Goričko Nature Park, the Big Krka Basin covers 14.6 km^2 (31.6%), and the Kobilje Creek Basin covers 7.9 km^2 (17%). The total length of all watercourses in the nature park is 664 km: 309 km in the Ledava Basin, 95 km in the Big Krka Basin, and the rest in the Kobilje Creek Basin. These three basins cover a total of nearly 95% of the area of Goričko Nature Park.

There are differences (Internet 4) in the land use structure (Figure 1) between individual basins. The share of forest increases from the west; it accounts for 42% of land use in the Ledava Basin, 49% in the Big Krka Basin, and 52% in the Kobilje Creek Basin in the east. The Kobilje Creek Basin has a significantly smaller share of grassland (9%) compared to the Big Krka and Ledava basins, where the percentages are 16% and 18%, respectively. There are no significant differences between the basins in other land use categories.

3 Results

Pollution sources are studied in relation to discharge. In watercourses with predominantly diffuse pollution sources, pollution increases with discharge (Novotny 1988). The opposite is typical of point pollution sources, where pollutant concentration decreases with increased discharge.

3.1 Nitrogen compounds

The presence of ammonium nitrogen (NH^{4+}) in river water is the result of faecal pollution (with people and livestock farming being its main sources; Ibanez et al. 2007). The recommended ammonium levels of 0.04 mg/l

Table 1: Correlation coefficients at sampling sites

r^2	Ledava Nuskova	Ledava Domajinci	Bodonci Creek	Bokrači Creek	Adrijanci Creek	Dolenci Creek	Big Krka	Small Krka	Kobilje Creek	Bukovnica Creek	Bogojina Creek
[WaterT]/[AirT]	0.92	0.88	0.92	0.93	0.93	0.85	0.87	0.94	0.94	0.92	0.91
[WaterT]/[Oxygen concentration]	–0.50	–0.84	–0.89	–0.87	–0.80	–0.76	–0.42	–0.88	–0.07	–0.82	–0.84
[Nitrite]/[Ammonium]	0.27	–0.27	–0.17	0.03	–0.11	0.00	0.33	0.31	0.76	0.02	0.46
[Turbidity]/[Discharge]	0.02	–0.05	0.55	0.89	0.77	0.61	0.47	0.75	0.37	0.48	0.86
[Turbidity]/[Undissolved matter]	0.94	0.93	0.95	0.88	0.99	1.00	0.35	0.10	0.87	0.90	1.00
[Undissolved matter]/[Discharge]	–0.01	–0.15	0.75	0.93	0.77	0.62	0.14	0.36	0.33	0.75	0.87
[Orthophosphate]/[Undissolved matter]	0.79	–0.06	0.70	0.91	0.87	0.47	0.15	0.25	0.22	0.16	0.90
[Total phosphorus]/[Undissolved matter]	0.95	0.73	0.91	0.87	0.99	0.58	0.53	0.39	0.81	0.58	0.98
[Nitrate]/[Discharge]	0.95	0.47	0.67	0.81	0.59	0.57	0.31	0.91	0.45	0.27	0.76

specified in the Decree on the Quality of Surface Waters for the Life of Freshwater Fish Species for Salmonid Waters (Uredba … 2002) are regularly exceeded at all the sampling sites. It can be established that the average ammonium levels at the Ledava Nuskova sampling site before its inflow into Lake Ledava are lower than at the Ledava Domajinci sampling site after its outflow from Lake Ledava. On the other hand, the mean nitrate levels (NO^{3-}) before Lake Ledava are higher than after Lake Ledava. Hence it can be concluded that denitrification is taking place in the predominantly anaerobic conditions in the reservoir Lake Ledava. Because the standard deviation for nitrate at the Ledava Domajinci sampling site is typically smaller than at the Ledava Nuskova sampling site, this seems to be an ongoing process.

Nitrate is a soluble form of nitrogen that usually seeps into groundwater quickly and is then released into the river water as base runoff. Table 1 shows the correlation coefficients for [NITRATE]/[DISCHARGE], $r^2 > 0.4$. It can be concluded that this results from the nitrate being washed from farmland due to poor soil permeability. The nitrate levels do not exceed the limits specified in the Rules on Drinking Water, but the levels measured in the surface watercourses are nonetheless high. A seasonal impact of nitrate being washed from farmland can also be observed, with excesses after spring or fall fertilization, depending on precipitation.

Based on what is known about the nitrogen cycle, nitrites result from nitrification processes. Compared to the levels recommended in the Decree on the Quality of Surface Waters for the Life of Freshwater Fish Species for Salmonid Waters (Uredba … 2002), these levels are elevated, and they are constant. Some sampling sites (Kobilje Creek, Bogojina Creek, Small Krka, and Big Krka) have a high correlation for [NITRITE]/[AMMONIUM], $r^2 > 70$, which may be due to nearby settlements, unregulated sewage systems, and livestock farming. Such correlations were not established at sampling sites for which the impact of settlements is smaller.

Pollution by total nitrogen compounds is presented in Figures 2 to 4. The pollution curves indicate a significant impact of diffuse sources on the watercourses in Goričko Nature Park. The impact is less pronounced at the Ledava Domajinci sampling site, which is most likely due to the influence of Lake Ledava, in which chemical processes and accumulation take place. This impact is also less pronounced at the Bukovnica Creek sampling site, which is probably due to the creek's lower flow rate, which is regulated by the artificial reservoir Lake Bukovnica. This is a tourist area, where a large number of visitors can influence the current conditions in the watercourse.

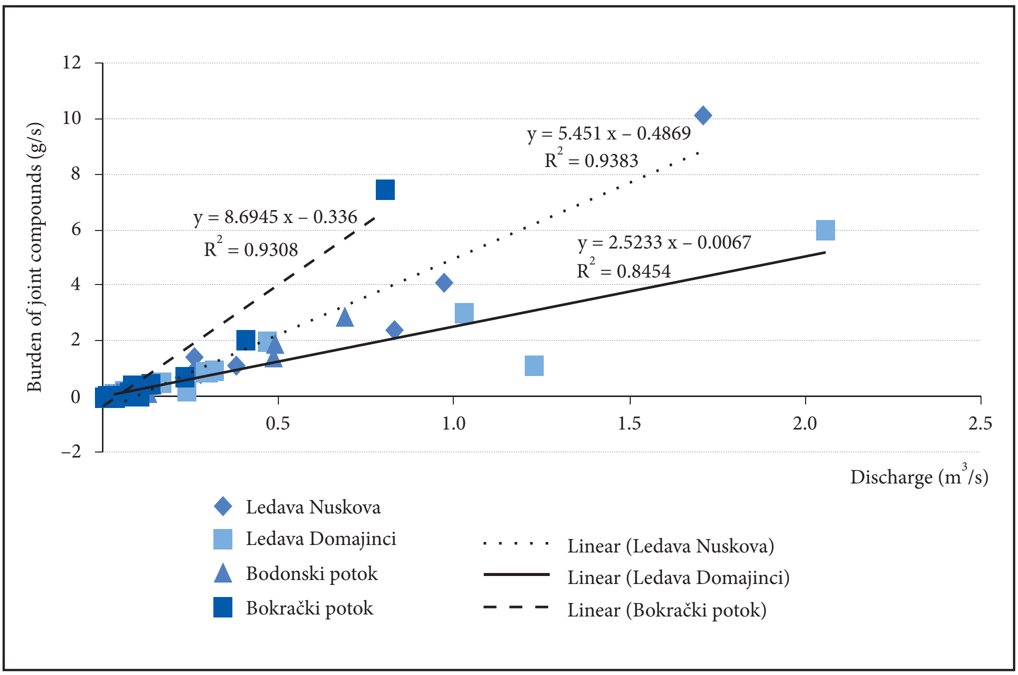

Figure 2: Total nitrogen pollution in the Ledava Basin.

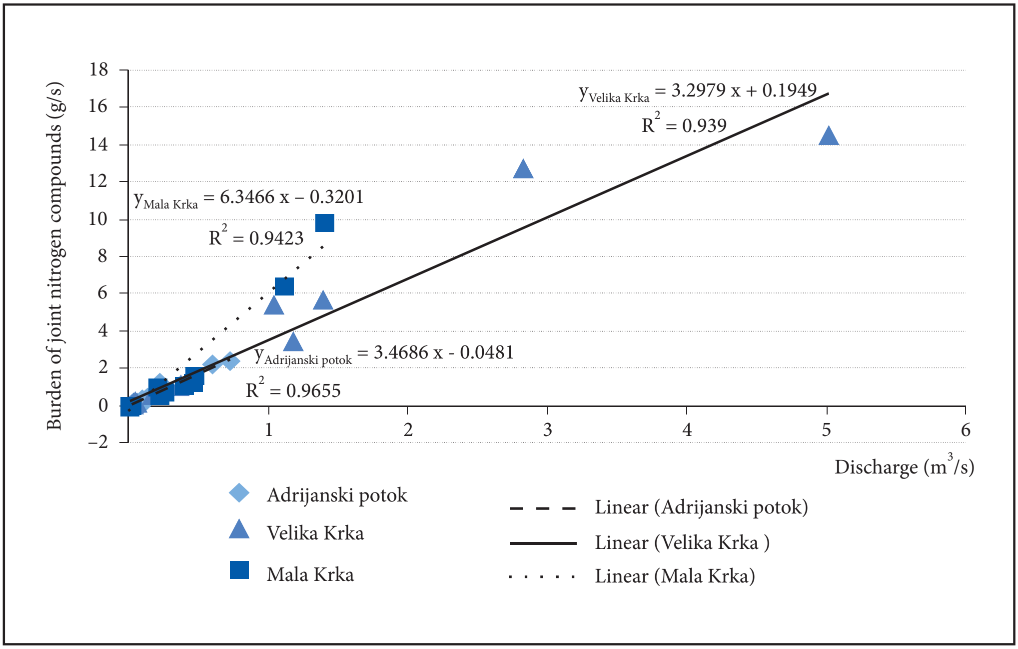

Figure 3: Total nitrogen pollution in the Big Krka Basin.

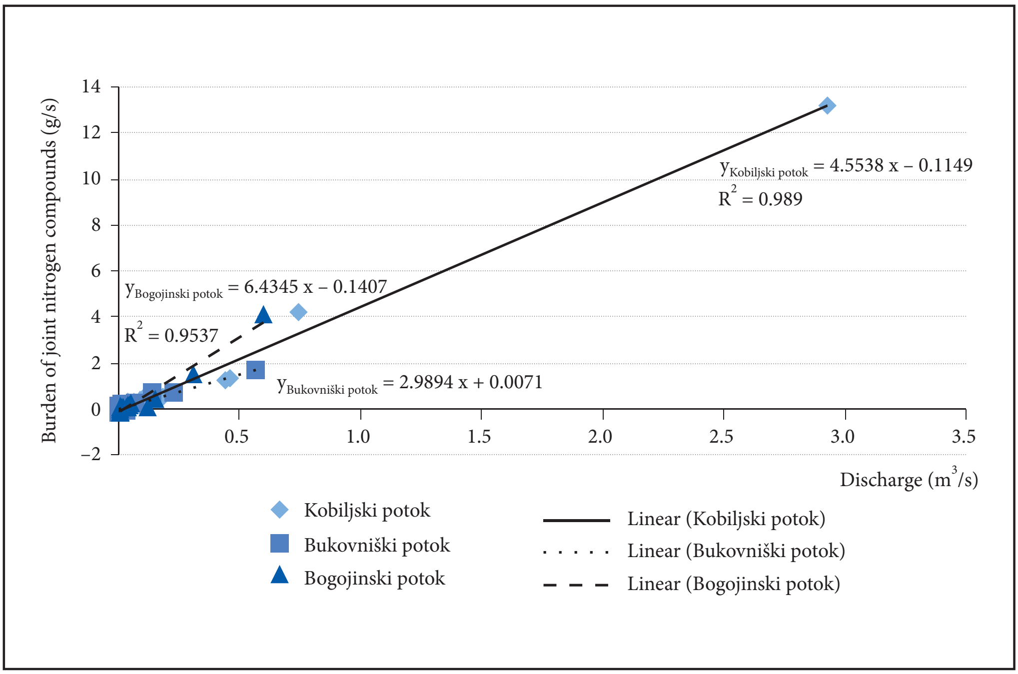

Figure 4: Total nitrogen pollution in the Kobilje Creek Basin.

3.2 Phosphorus compounds

The moderate correlation of [TOTAL PHOSPORUS]/[UNDISSOLVED MATTER], $r^2 > 0.5$ stands out. When water erodes the soil, the phosphorus bound in the soil particles is washed into watercourses (the impact of diffuse source pollution; Pierzynsky et al. 1994). During periods of low discharge, total phosphorus concentrations are typically smaller, but constant, and are the result of unregulated sewage systems and manure pits on farms (the impact of point source pollution by total phosphorus). Just like with total phosphorus, the correlation for [ORTHOPHOSPHATE]/[UNDISSOLVED MATTER] is also high: $r^2 > 0.7$ is typical of the Ledava Basin, except at the Ledava Domajinci sampling site, where there is hardly any correlation. It can be concluded that this is due to the accumulation of orthophosphate in Lake Ledava, which is a hypertrophic lake according to the OECD criteria (Poročilo … 2007).

Pollution by total phosphorus compounds is shown in Figures 5 to 7. The impact of point sources on pollution in the Ledava Basin is small, but constant. Based on these results it can be concluded that unregulated sewage systems and farming (livestock breeding) contribute to both point and diffuse source pollution.

4 Discussion

Extensive surface water quality monitoring was performed in Goričko Nature Park in order to determine the level of nitrogen and phosphorus pollution and other accompanying parameters. The study area was divided into three subareas or third-order basins: the Ledava, Big Krka, and Kobilje Creek basins. Measurements were taken once a month over the course of 1.5 years. Pollution in relation to discharge was calculated for each sampling site. The results show that the nutrient release dynamics in Goričko Nature Park are in high correlation with precipitation events. Similar dynamics have also been established for the Krka River Basin (Drolc 1998) and the Padež Basin (Rusjan 2008). The chemical composition of the waters included in the study is poor at all sampling sites. During the study the total nitrogen concentrations were high and fairly stable. Ammonium and nitrite (as an intermediate product of nitrification) stand out more than nitrogen.

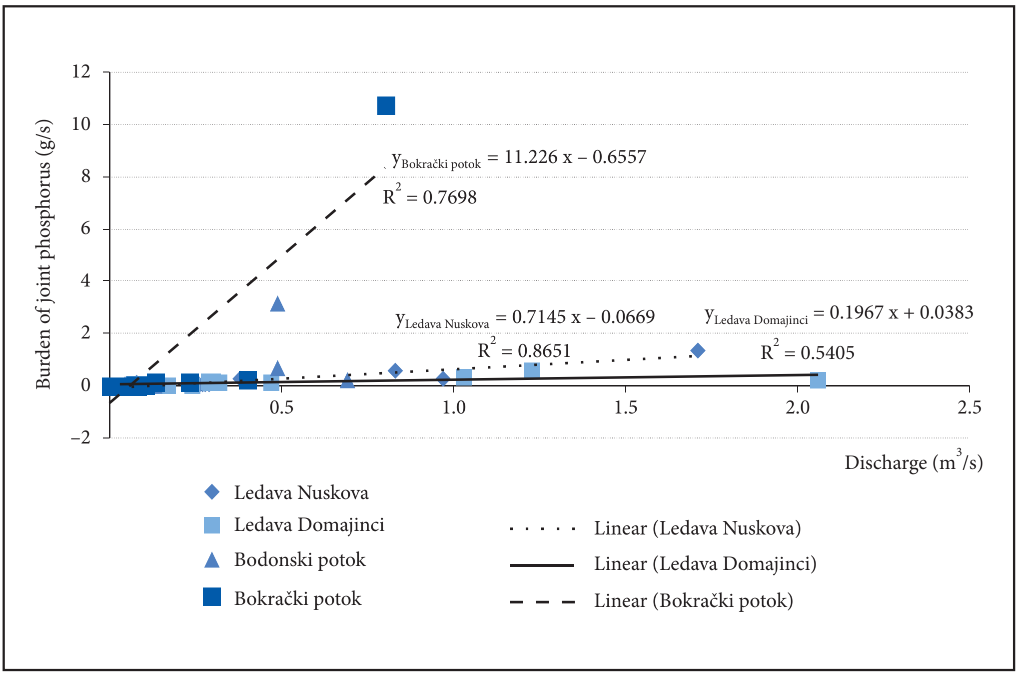

Figure 5: Pollution by total phosphorus compounds in the Ledava Basin.

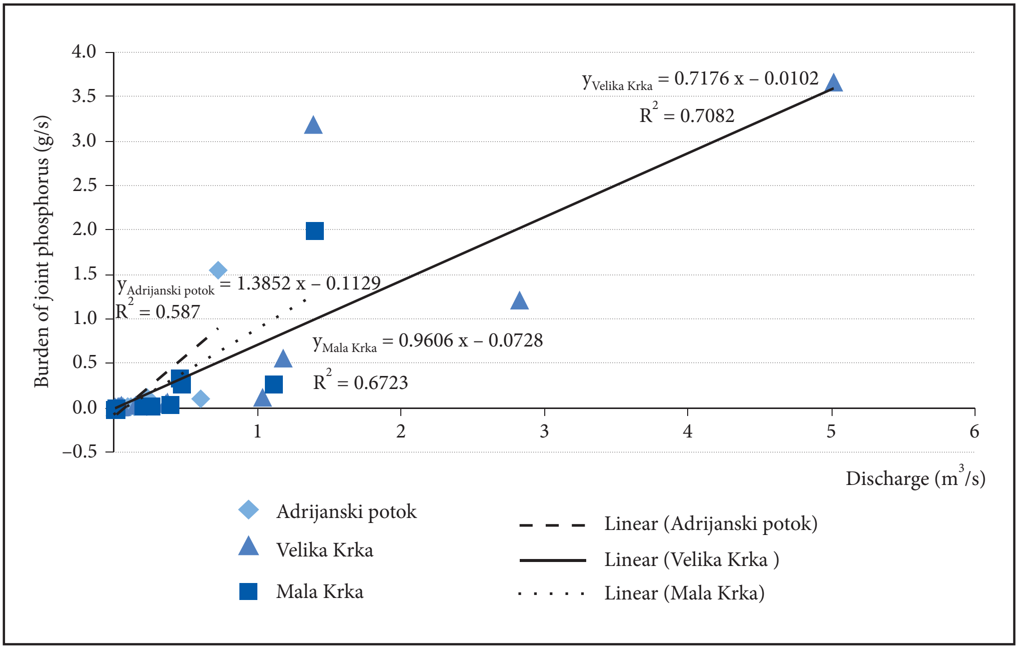

Figure 6: Pollution by total phosphorus compounds in the Big Krka Basin.

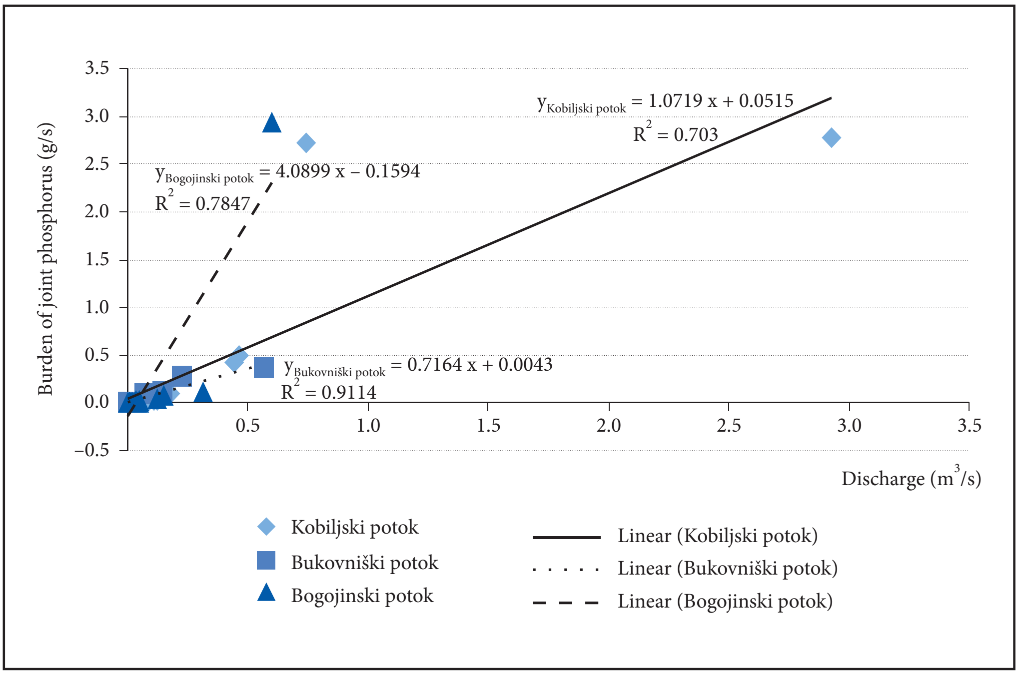

Figure 7: Pollution by total phosphorus compounds in the Kobilje Creek Basin.

It can be concluded that unregulated manure pits on livestock farms are the main reason for the high levels of ammonium release. In a study conducted by Lapajne (2006), no final conclusions were reached on the high ammonium levels in the Ledava Valley, but the researchers did conclude that they were due to emissions from the livestock farms or wastewater from unregulated sewage systems. The main reasons for the high levels of nitrogen compounds lie in the chemical composition of nitrogen and the nitrogen releases from intensively farmed land (Eickhout et al. 2006), as well as the low effectiveness of nitrogen fertilizers (Strebel et al. 1989). Beaudoin et al. (2005) established that the levels of nitrates washed from farmland depend primarily on the type of soil: low levels were determined in deep, poorly permeable clay soil and the highest levels were found in shallow, permeable sandy soil. Ju et al. (2006) established a high correlation between the intensity of farming and nitrate levels in groundwater. Another important factor in nutrient release is the natural conditions that affect land use and the use structure of farmland.

The total phosphorus concentration is highly correlated with precipitation events, because it binds to suspended particles and erodes into the drains. Likewise, the excessive levels of phosphorus compounds in the Ledava River also result from farm runoff via precipitation (Lapajne 2006). Sharpley et al. (1999) also determined that the concentration of phosphorus compounds increases with precipitation, and Hanrahan et al. (2003) concluded that the majority of phosphorus transfer takes place periods of intense precipitation.

Measures for reducing nutrient pollution in rivers should focus on decreasing the nutrient concentrations at the outflows through tertiary treatment at treatment plants and significant reduction of inputs from agriculture. Drolc and Končan (2002) believe that by implementing all of these water management measures, the total phosphorus emissions in river basins could decrease by 40%. In order to reduce the nutrient release caused by diffuse pollution, certain measures have been proposed (Internet 2) to increase fertilizer effectiveness and hence decrease erosion from farmland (Komac and Zorn 2005; Zorn 2009), and to promote unconventional farming in environmentally more sensitive regions. Some measures for decreasing diffuse sources of pollution do not comply with agricultural practice and economics. Tertiary treatment of phosphorus and nitrogen at large treatment plants can also help reduce water pollution. Despite the work carried out by large treatment plants, minor point sources of pollution still remain a problem. In order to solve it effectively, tertiary treatment at small treatment plants should be introduced. These treatment plants release water into small, environmentally more sensitive creeks in the countryside (Wheater and Daldorf 2003), where tertiary treatment could help reduce the pollution of river basins.

5 Conclusion

The acquired data show that rivers have only moderate thermal potential and that weather has the most significant impact on watercourse conditions. This is primarily reflected in the high correlations between water and air temperature. Subsequently, the thermal potential of watercourses has a strong impact on the concentration of dissolved oxygen in water. A comparative analysis was conducted using the data collected from eleven sampling sites used to monitor the surface waters in Goričko Nature Park. Because the study area was divided into three parts, the data obtained were also compared by river basin. All three basins are characterized by increased concentrations of nitrogen and phosphorus compounds, which resulted in poor chemical composition of surface waters at all sampling sites.

The results of this study show that the watercourses in the entire study area are polluted by nitrogen and phosphorus compounds. A trend of significant nitrate increase can be observed in the Mura Basin and the watersheds of Adriatic rivers, and orthophosphate pollution is increasing as well (Internet 5).

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Guidelines for contributing authors in Acta geographica Slovenica

EDITORIAL POLICIES

1 Focus and scope

The Slovenian geographical journal *Acta geographica Slovenica* (print version: ISSN: 1581-6613, digital version: ISSN: 1581-8314) is published by the Anton Melik Geographical Institute of the Slovenian Academy of Sciences and Arts Research Center.

Acta geographica Slovenica publishes original research papers from all fields of geography and related disciplines, and provides a forum for discussing new aspects of theory, methods, issues, and research findings, especially in central and southeast Europe.

We accept original research papers and review papers.

Papers presenting new developments and innovative methods in geography are welcome. Submissions should address current research gaps and explore state-of-the-art issues. Research based on case studies should have the added value of transnational comparison and should be integrated into established or new theoretical and conceptual frameworks.

The target readership is researchers, policymakers, and university students studying or applying geography at various levels.

Submissions are accepted in English or Slovenian.

The journal is indexed in the following bibliographic databases: SCIE (Science Citation Index Expanded), Scopus, JCR (Journal Citation Report, Science Edition), ERIH PLUS, GEOBASE Journals, Current Geographical Publications, EBSCOhost, Geoscience e-Journals, Georef, FRANCIS, SJR (SCImago Journal & Country Rank), OCLC WorldCat, and Google Scholar. The journal's publisher is a member of CrossRef.

2 Types of papers

Unsolicited or invited original research papers and review papers are accepted. Papers and materials or sections of them should not have been previously published elsewhere. The papers should cover subjects of current interest within the journal's scope.

3 Special issues

The journal also publishes special issues (thematic supplements). Special issues usually consist of invited papers and present a special topic, with an introduction by the (guest) editors. The introduction briefly presents the topic, summarizes the papers, and provides important implications.

4 Peer-review process

All papers are examined by the editor-in-chief. This includes fact-checking the content, spelling and grammar, writing style, and figures. Papers that appear to be plagiarized, are ghost-written, have been published elsewhere, are outside the scope of journal, or are of little interest to readers of *Acta geographica Slovenica* may be rejected. If the article exceeds the maximum length, the author(s) must correct this before the article is reviewed. The paper is then sent to responsible editors, who check the relevance, significance, originality, clarity, and quality of the paper. If accepted for consideration, the papers are then sent to peer reviewer(s) for double-blind review. Paper are rejected or accepted based on the peer reviews and editorial board's decision.

5 Publication frequency

Acta geographica Slovenica is published twice a year.

6 Open-access policy

This journal provides immediate free open access to its content and supports greater global exchange of knowledge by making research freely available. The papers in *Acta geographica Slovenica* and its predecessors *Acta geographica / Geografski zbornik* and *Geographica Slovenica* are available online free of charge. The author(s) receive a free print copy.

The journal's publication ethics and publication malpractice statement is available online, as well as information on subscriptions and prices for print copies.

AUTHOR GUIDELINES

Before submitting a paper, please read the details on the journal's focus and scope, peer-review process, publication frequency, history, and open-access policy. This information is available in the editorial policies.

1 The papers

Research papers must be prepared using the journal's template and contain the following elements:
- **Title:** this should be clear, short, and simple.
- **Information about author(s):** submit names (without academic titles), institutions, and e-mail addresses through the online submission system.
- **Abstract:** introduce the topic clearly so that readers can relate it to other work by presenting the background, why the topic was selected, how it was studied, and what was discovered. It should contain one or two sentences about each section (introduction, methods, results, discussion, and conclusions). The maximum length is 800 characters including spaces.
- **Key words:** include up to seven informative key words. Start with the research field and end with the place and country.
- **Main text:** limit the text of the paper to 20,000 characters including spaces and without the reference list, and tables. Do not use footnotes or endnotes. Divide the paper into sections with short, clear titles marked with numbers without final dots: **1 Section title**. Use only one level of subsections: **1.1 Subsection title**.

Research papers should have the following structure:
- **Introduction:** present the background of the research problem (trends and new perspectives), state of the art (current international discussion in the field), research gap, motivation, aim, and research questions.
- **Methods:** describe the study area, equipment, tools, models, programs, data collection, and analysis, define the variables, and justify the methods.
- **Results:** follow the research questions as presented in the introduction and briefly present the results.
- **Discussion:** interpret the results, generalize from them, and present related broader principles and relationships between the study and previous research. Critically assess the methods and their limitations, and discuss important implications of the results. Clarify unexpected results or lacking correlations.
- **Conclusion:** present the main implications of the findings, your interpretations, and unresolved questions, offering a short take-home message.

Review papers (narratives, best-practice examples, systematic approaches, etc.) should have the following structure:
- **Introduction:** include 1) the background; 2) the problem: trends, new perspectives, gaps, and conflicts; and 3) the motivation/justification.
- **Material and methods:** provide information such as data sources (e.g., bibliographic databases), search terms and search strategies, selection criteria (inclusion/exclusion of studies), the number of studies screened and included, and statistical methods of meta-analysis.

  - **Literature review:** use subheadings to indicate the content of the various subsections. Possible structure: methodological approaches, models or theories, extent of support for a given thesis, studies that agree with one another versus studies that disagree, chronological order, and geographical location.
  - **Conclusions:** provide implications of the findings and your interpretations (separate from facts), identify unresolved questions, summarize, and draw conclusions.
- **Acknowledgement:** use when relevant.
- **Reference list:** see the guidelines below.

2 Paper submission

2.1 Open journal system

Author(s) must submit their contributions through the *Acta geographica Slovenica* Open Journal System (OJS) using the Word document template.

Enter all necessary information into the OJS. Any addition, deletion, or rearrangement of names of the author(s) in the authorship list should be made and confirmed by all coauthors before the manuscript has been accepted, and is only possible if approved by the journal editor.

To make anonymous peer review possible, the paper text and figures should not include names of author(s).

Do not use contractions or excessive abbreviations. Use plain text, with sparing use of **bold** and *italics*. Do not use auto-formatting, such as section or list numbering and bullets.

If a text is unsatisfactory, the editorial board may return it to the author(s) for professional copyediting or reject the paper. See the section on the peer-review process for details. Author(s) may suggest reviewers when submitting a paper.

2.2 Language

Papers are published in English.

Papers are submitted in English or Slovenian and copyedited/translated after acceptance by a professional chosen by the editorial board.

The translation or copyediting costs are borne by the author(s) (translation €500, copyediting €200) and must be paid before layout editing.

All papers should have English and Slovenian abstracts.

2.3 Supplementary file submission

Supplementary files (figures) can be submitted to the OJS packed in one zip file not exceeding 50 MB.

2.4 Submission date

The journal publishes the submission date of papers. Please contact the editor, Blaž Komac, with any questions.

3 Citations

Examples for citing publications are given below. Using "gray literature" is highly discouraged.

3.1 Citing papers

- Fridl, J., Urbanc, M., Pipan, P. 2009: The importance of teachers' perception of space in education. Acta geographica Slovenica 49-2. DOI: https://doi.org/10.3986/AGS49205
- Perko, D. 1998: The regionalization of Slovenia. Geografski zbornik 38.
- Gams, I. 1994a: Types of contact karst. Geografia fisica e dinamica quaternaria 17.

- Gams, I. 1994b: Changes of the Triglav glacier in the 1955-94 period in the light of climatic indicators. Geografski zbornik 34.
- de Kerk, G. V., Manuel, A. R. 2008: A comprehensive index for a sustainable society: The SSI – the Sustainable Society Index. Ecological Economics 66-2,3. DOI: https://doi.org/10.1016/j.ecolecon.2008.01.029
- van Hall, R. L., Cammeraat, L. H., Keesstra, S. D., Zorn, M. 2016: Impact of secondary vegetation succession on soil quality in a humid Mediterranean landscape. Catena, In press. DOI: https://doi.org/10.1016/j.catena.2016.05.021 (25. 11. 2016).

3.2 Citing books

- Cohen, J. 1988: Statistical power analysis for the behavioral sciences. New York.
- Nared, J., Razpotnik Visković, N. (eds.) 2014: Managing cultural heritage sites in Southeastern Europe. Ljubljana.
- Fridl, J., Kladnik, D., Perko, D., Orožen Adamič, M. (eds.) 1998: Geografski atlas Slovenije. Ljubljana.
- Luc, M., Somorowska, U., Szmańda, J. B. (eds.) 2015: Landscape analysis and planning. Heidelberg. DOI: https://doi.org/10.1007/978-3-319-13527-4

3.3 Citing parts of books or proceedings

- Zorn, M., Komac, B. 2013: Land degradation. Encyclopedia of Natural Hazards. Dordrecht. DOI: https://doi.org/10.1007/978-1-4020-4399-4_207
- Hrvatin, M., Perko, D., Komac, B., Zorn, M. 2006: Slovenia. Soil Erosion in Europe. Chichester. DOI: https://doi.org/10.1002/0470859202.ch25
- Gams, I. 1987: A contribution to the knowledge of the pattern of walls in the Mediterranean karst: a case study on the N. island Hvar, Yugoslavia. Karst and man, Proceedings of the International Symposium on Human Influence in Karst. Ljubljana.
- Komac, B., Zorn, M. 2010: Statistično modeliranje plazovitosti v državnem merilu. Od razumevanja do upravljanja, Naravne nesreče 1. Ljubljana.

3.4 Citing expert reports, theses, and dissertations

- Breg Valjavec, M. 2012: Geoinformatic methods for the detection of former waste disposal sites in karstic and nonkarstic regions (case study of dolines and gravel pits). Ph.D. thesis, University of Nova Gorica. Nova Gorica.
- Hrvatin, M. 2016: Morfometrične značilnosti površja na različnih kamninah v Sloveniji. Ph.D. thesis, Univerza na Primorskem. Koper.
- Holmes, R. L., Adams, R. K., Fritts, H. C. 1986: Tree-ring chronologies of North America: California, Eastern Oregon and Northern Great Basin with procedures used in the chronology development work including user manual for computer program COFECHA and ARSTAN. Chronology Series 6. University of Arizona, Laboratory of tree-ring research. Tucson.
- Šifrer, M. 1997: Površje v Sloveniji. Elaborat, Geografski inštitut Antona Melika ZRC SAZU. Ljubljana.

3.5 Citing online material with authors and titles

- Bender, O., Borsdorf, A., Heinrich, K. 2010: The interactive alpine information system GALPIS. Challenges for mountain regions, Tackling complexity. Internet: http://www.mountainresearch.at/images/Publikationen/Sonderband/bender-borsdorf-heinrich.pdf (4. 8. 2014).

3.6 Citing online material without authors

- Internet: http://giam.zrc-sazu.si (18. 11. 2016).
- Internet 1: http://giam.zrc-sazu.si/ (22. 7. 2012).
- Internet 2: http://ags.zrc-sazu.si (23. 7. 2012).

3.7 Citing sources without authors

- WCED – World commission on environmental and development: Our common future – Brundtland report. Oxford, 1987.
- Popis prebivalstva, gospodinjstev, stanovanj in kmečkih gospodarstev v Republiki Sloveniji, 1991 – končni podatki. Zavod Republike Slovenije za statistiko. Ljubljana, 1993.

3.8 Citing cartographic sources

- Državna topografska karta Republike Slovenije 1 : 25.000, list Brežice. Geodetska uprava Republike Slovenije. Ljubljana, 1998.
- Franciscejski kataster za Kranjsko, k. o. Sv. Agata, list A02. Arhiv Republike Slovenije. Ljubljana, 1823–1869.
- Buser, S. 1986: Osnovna geološka karta SFRJ 1 : 100.000, list Tolmin in Videm (Udine). Savezni geološki zavod. Beograd.
- The vegetation map of forest communities of Slovenia 1 : 400,000. Biološki inštitut Jovana Hadžija ZRC SAZU. Ljubljana, 2002.
- Digitalni model višin 12,5. Geodetska uprava Republike Slovenije. Ljubljana, 2005.

3.9 Citing official gazettes

- Zakon o kmetijskih zemljiščih. Uradni list Republike Slovenije 59/1996. Ljubljana.
- Zakon o varstvu pred naravnimi in drugimi nesrečami. Uradni list Republike Slovenije 64/1994, 33/2000, 87/2001, 41/2004, 28/2006 in 51/2006. Ljubljana.
- 1999/847/EC: Council Decision of 9 December 1999 establishing a Community action programme in the field of civil protection. Official Journal 327, 21. 12. 1999.

3.10 In-text citations

Please ensure that every reference cited in the text is also in the reference list (and vice versa). In-text citations should state the last name of the author(s) and the year, separate individual citations with semicolons, order the quotes according to year, and separate the page information from the name of the author(s) and year information with a comma; for example: (Melik 1955), (Melik, Ilešič and Vrišer 1963; Kokole 1974, 7–8; Gams 1982a; Gams 1982b).

For sources with more than three authors, list only the first followed by *et al.*: (Melik et al. 1956). Cite page numbers only for direct citations: Perko (2016, 25) states: »Hotspots are …« To cite online material with authors, cite the name: (Zorn 2010). To cite online material without authors, cite only Internet followed by a number: (Internet 2).

3.11 Works cited list

Arrange references alphabetically and then chronologically if necessary. Identify more than one reference by the same author(s) in the same year with the letters *a*, *b*, *c*, etc., after the year of publication: (1999a, 1999b). Use this format for indirect citations: (Gunn 2002, cited in Matei et al. 2014).

Include the Digital Object Identifier (DOI) in the reference if available. Format the DOI as follows: https://doi.org/… (for example: https://doi.org/10.3986/AGS.1812).

4 Tables and figures

Number all tables in the paper uniformly with their own titles. The number and the text are separated by a colon, and the caption ends with a period. Example:

Table 1: Number of inhabitants of Ljubljana.
Table 2: Changes in average air temperature in Ljubljana (Velkavrh 2009).

Tables should contain no formatting and should not be too large; it is recommended that tables not exceed one page.

Upload figures to the OJS as separate supplementary files in digital form. If the graphic supplements prepared cannot be uploaded using these programs, consult the editorial board in advance.

Number all figures (maps, graphs, photographs) in the paper uniformly with their own titles. Example:

Figure 1: Location of measurement points along the glacier.

All graphic materials must be adapted to the journal's format. Illustrations should be exactly 134 mm wide (one page) or 64 mm wide (half page, one column), and the height limit is 200 mm.

To make anonymous peer review possible, include the name of the author(s) with the title of the illustration in the supplementary file metadata, but not in the paper text.

Maps should be made in digital vector form with *Corel Draw, Adobe Illustrator*, or a similar program, especially if they contain text. They can exceptionally be produced in digital raster form with at least 300 dpi resolution, preferably in TIFF or JPG format. For maps made with *CorelDraw* or *Adobe Illustrator*, two separate files should be prepared; the original file (.cdr or .ai format) and an image file (.jpg format).

For maps made with *ArcGIS* with raster layers used next to vector layers (e.g., .tif of relief, airborne or satellite image), three files should be submitted: the first with a vector image without transparency together with a legend and colophon (export in .ai format), the second with a raster background (export in .tif format), and the third with all of the content (vector and raster elements) together showing the final version of the map (export in .jpg format).

Do not print titles on maps; they should appear in a caption.

Save colors in CMYK, not in RGB or other formats.

Use Times New Roman for the legend (size 8) and colophon (size 6). List the author(s), scale, source, and copyright in the colophon. Write the colophon in English (and Slovenian, if applicable). Example:

Scale: 1 : 1,000,000
Content by: Drago Perko
Map by: Jerneja Fridl
Source: Statistical Office of the Republic of Slovenia, 2002
© 2005, ZRC SAZU Anton Melik Geographical Institute

Graphs should be made in digital form using *Excel* on separate sheets and accompanied by data.

Photos must be in raster format with a resolution of 240 dots per cm or 600 dpi, preferably in .tif or .jpg formats; that is, about 3,200 dots per page width of the journal.

Figures containing a screenshot should be prepared at the highest possible screen resolution (Control Panel\All Control Panel Items\Display\Screen Resolution). The figure is made using Print Screen, and the captured screen is pasted to the selected graphic program (e.g., *Paint*) and saved as .tif. The size of the image or its resolution must not be changed.

Examples of appropriate graphic data forms: see the templates of maps in cdr and mxd files for a whole-page map in landscape view and an example of correct file structure for submitting a map made with *ESRI ArcGIS*.

SUBMISSION PREPARATION CHECKLIST

As part of the submission process, check your submission's compliance with the following items. Submissions may be returned to author(s) that do not follow these guidelines.

1. The journal policies have been reviewed.
2. The submission has not been previously published and is not being considered for publication elsewhere (or an explanation has been provided in comments to the editor).
3. The metadata (title, abstract, key words, full address, etc.) are provided in English and Slovenian, when applicable.
4. The submission is in Microsoft Word format and the document template was used (single-spaced text, 12-point font, no formatting except italics and bold).

5. The manuscript has been checked for spelling and grammar.
6. All figure locations in the text are marked. Figures are not in the text and are provided as supplementary files: cdr, .ai for maps and illustrations; .tif for photographs; xlsx for graphs.
7. Tables are placed in the text at the appropriate place.
8. The reference list was prepared following the guidelines.
9. All references in the reference list are cited in the text, and vice versa.
10. Where available, URLs and DOI numbers for references are provided.
11. Supplementary files are in one .zip file not exceeding 50 MB.
12. I agree for this article to be translated or copyedited at my expense AFTER the article is accepted for publication (see guidelines for details).
13. Permission has been obtained for the use of copyrighted material from other sources, including online sources; see the copyright notice below.
14. The instructions for ensuring a double-blind review have been followed.

ACTA GEOGRAPHICA SLOVENICA EDITORIAL REVIEW FORM

Acta geographica Slovenica editorial review form

1 The paper is an original scientific one – the paper follows the standard IMRAD scheme and is original and the first presentation of research results with the focus on methods, theoretical aspects or case study.)

Yes No

2 The paper's content is suitable for publishing in the AGS journal – the paper is from the field of geography or related fields of interest, the presented topic is interesting and well presented. In case of negative answer add comments below.)

Yes No

3 Editorial notes regarding the paper's content.

4 Length of the paper is acceptable for further processing (20.000 characters including space). If longer, the paper has to be shortened by the author and resubmitted.

- The paper has less than 20.000 characters.
- The paper has more than 20.000 characters, but less than 25.000.
- The paper has more than 25.000 characters.

5 The style and formatting of the paper is according to the AGS guidelines – the paper is prepared in plain text, no other text formatting is used than bold and italic. See the Guidelines of AGS journal for details.)

Yes No

6 Notes regarding style and formatting.

7 Citing in the paper is according to the AGS guidelines and style, including DOI identificators.

Yes No

8 The reference list is suitable (the author cites previously published papers with similar topic from other relevant scientific journal).

Yes, the author cited previously published papers on similar topic.

No, the author did not cite previously published papers on similar topic.

9 Scientific language of the paper is appropriate and understandable.

Yes No

10 Supplementary files (ai, cdr, pdf, tif, jpg, xlsx etc.) that were added to the paper are in proper format and resolution (including the introductory photo), maps are prepared according to the AGS Guidelines. (In this step contact the technical editor [rok.ciglic@zrc-sazu.si] for assistance if needed).
- Supplementary files are correct.
- Supplementary files are not appropriate and need a major correction.
- Some supplementary files need corrections.

11 Describe the possible deficiencies of the supplementary files:

12 DECISION OF THE RESPONSIBLE EDITOR
The paper is accepted for further processing and may be sent to the reviewer.
The paper is accepted for further processing but needs technical improvements (see notes).
The paper is accepted for further processing but its content needs additional improvements (see notes).
The paper is not accepted for publication because:
- It is more suitable for a specialized journal.
- Does not fit the aims and scopes of the AGS journal.
- Is not an original scientific paper.
- The presentation of the results is poor.
- The paper is of very low quality.
- The paper has already been published elsewhere.
- Other (see comments below).
- Other reasons for rejection of the paper.

ACTA GEOGRAPHICA SLOVENICA REVIEW FORM

1 RELEVANCE

1a) Are the findings original and the paper is therefore a significant one?

Yes No Partly

1b) Is the paper suitable for the subject focus of the AGS journal?

Yes No

2 SIGNIFICANCE

2a Does the paper discuss an important problem in geography or related fields?

Yes No Partly

2b Does it bring relevant results for contemporary geography?

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2c What is the level of the novelty of research presented in the paper?

High Middle Low

3 ORIGINALITY

3a Has the paper been already published or is too similar to work already published?

Yes No

3b Does the paper discuss a new issue?

Yes No

3c Are the methods presented sound and adequate?

Yes No Partly

3d Do the presented data support the conclusions?

Yes No Partly

4 CLARITY

4a Is the paper clear, logical and understandable?

Yes No

4b If necessary, add comments and recommendations to improve the clarity of the title, abstract, keywords, introduction, methods or conclusion:

5 QUALITY

5a Is the paper technically sound? (If no, the author should discuss technical editor [rok.ciglic@zrc-sazu.si] for assistance.)

Yes No

5b Does the paper take into account relevant current and past research on the topic?

Yes No

Propose amendments, if no is selected:

5d Is the references list the end of the paper adequate?

Yes No

Propose amendments, if no is selected:

5e Is the quoting in the text appropriate?

Yes No Partly

Propose amendments, if no is selected:

5f Which tables are not necessary?

5g Which figures are not necessary?

6 COMMENTS OF THE REVIEWER

Comments of the reviewer on the contents of the paper:
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7 RECOMMENDATION OF THE REVIEWER TO THE EDITOR-IN-CHIEF

My recommendation is:
Please rate the paper from 1 [low] to 100 [high]:
Personal notes of the reviewer to editor-in-chief.

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FAQ

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Acta geographica Slovenica (print version: ISSN: 1581-6613, digital version: ISSN: 1581-8314) was founded in 1952. It was originally named *Geografski zbornik / Acta geographica* (ISSN 0373-4498). Altogether 42 volumes were published. In 2002 *Geographica Slovenica* (ISSN 0351-1731, founded in 1971, 35 volumes) was merged with the journal.

Since 2003 (from volume 43 onward) the name of the joint journal has been *Acta geographica Slovenica*. The journal continues the numbering system of the journal *Geografski zbornik / Acta geographica*.

Those interested in the history of the journal are invited to read the paper »The History of *Acta geographica Slovenica*.«

All published issues of *Acta geographica Slovenica* are available free of charge at http://ags.zrc-sazu.si or http://ojs.zrc-sazu.si/ags.

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