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GEOGRAFSKI ZBORNIK

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Front cover photography: Sveta Gora, a settlement with a franciscan monastery overlooking the Soča valley, renowned as a Marian pilgrimage site, is located near the Slovenia-Italy border, at the intersection of Alpine, Medditerranean and Dinaric landscapes (photograph: Jure Tičar).
Fotografija na naslovnici: Sveta Gora, naselje s frančiškanskim samostanom nad dolino Soče, ki je znano po marijanskem romarskem središču, leži na meji Slovenije in Italije ter na stiku alpskih, sredozemskih in dinarskih pokrajin (fotografija: Jure Tičar).

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DISCHARGE REGIMES OF SLOVENIAN RIVERS: 1991–2020

Borut Stojilković, Valentina Brečko Grubar

BORUT STOJILKOVIĆ

The Rinka Waterfall as a spring of the Savinja River is a natural monument of national importance.

DOI: https://doi.org/10.3986/AGS.13654
UDC: 911.2:556.535(497.4)"1991/2020"

Borut Stojilković[1], Valentina Brečko Grubar[2]

Discharge regimes of Slovenian rivers: 1991–2020

ABSTRACT: Various researchers have examined discharge regimes of rivers in Slovenia in the past 75 years: four major studies made by Ilešič, Kolbezen, Hrvatin, and lastly Hrvatin and Frantar have analysed and classified the regimes, and clustered them into regime types. They have varied due to changes in discharge characteristics, mainly as a consequence of climate change. In the present paper, we used average monthly discharges between 1991–2020 to calculate the discharge coefficients and determine the modern typology of the regime types on 36 streams at 45 gauging stations. The final result was five types of contemporary discharge regimes which are a consequence of the landscapes' heterogenous climate- and geodiversity characteristics as well as human interventions.

KEYWORDS: discharge regime, typology, hydrograph, hydrogeography, cluster analysis, climate changes, Slovenia

Pretočni režimi slovenskih rek: 1991–2020

IZVLEČEK: Pretočne režime slovenskih rek so v zadnjih 75 letih preučevali različni avtorji: štiri ključne študije Ilešiča, Kolbezna, Hrvatina ter nazadnje Hrvatina in Frantarja so predstavile analizo in klasifikacijo režimov v različnih kategorijah. Slednje so se medsebojno razlikovale zaradi odtočnih sprememb, večinoma posledice podnebnih sprememb. V tem članku smo uporabili povprečne mesečne pretoke 36 vodotokov na 45 vodomernih postajah med letoma 1991 in 2020, da smo izračunali pretočne količnike in določili tipologijo pretočnih režimov tega obdobja. Končni rezultat je pet tipov današnjih pretočnih režimov, ki so posledica heterogenih značilnosti podnebja in geodiverzitete pokrajin ter človekovega delovanja.

KLJUČNE BESEDE: pretočni režim, tipologija, hidrogram, hidrogeografija, razvrščanje v skupine, podnebne spremembe, Slovenija

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1 Introduction

Studying discharge regimes has been a traditional topic of hydrogeographic and hydrologic research for nearly a century since it reflects the climatic characteristics and other factors in a drainage basin. Monthly discharge coefficient (fr. *coefficient mensuel de débit*, si. *mesečni pretočni količnik*), defined by Pardé (1933) as the ratio between the average monthly and average yearly discharge, shows us the dynamics of water runoff throughout the year while making it possible to link average monthly discharges with the distribution and type of precipitation, as well as the temperatures, and consequently the evaporation that decreases the runoff in an area. Hydro-meteorological trends and anthropogenic functions affect river discharges, which can lead to evapotranspiration rate changes (Krebs et al. 2021), as well as changes in river biodiversity and ecosystem functions (Palmer and Ruhi 2019).

The importance of discharges, which are the flown-away surplus precipitation not being used for transpiration nor being evaporated, is that they provide elementary data for the majority of further hydrological analyses (Bat et al. 2008). When they are measured at a certain gauging station, they reflect the characteristics of their catchment areas and significantly contribute to the water cycle (World Meteorological Organisation 2020). They are a water balance parameter and, for example, a basis for determining discharge regimens, which show rivers' average fluctuation across the year, discharge trends, which can show temporal variability, specific runoffs, which is a value of runoff water quantity per time interval per area, runoff coefficients, which shows the percentage of precipitation that ran off, etc. (Bat et al. 2008). In this article, we focus on discharge regimes, which are in Slovenia influenced primarily by climate (including precipitation and temperature both temporal and regional distributions as well as the rate of snowmelt), secondly by geodiversity and vegetation, and thirdly, but increasingly by human activities (Hrvatin 1998; Frantar and Hrvatin 2008).

Studying discharge regimes is not only of scientific and regional planning importance; it has a vital educational role as well. It is essential to keep regime-type analyses (scientifically and commercially-editorially) up to date since learning about them is prescribed in national secondary education curriculums for geography (Polšak et al. 2008) and hence also integrated into textbooks (e.g. Ogrin et al. 2022; Senegačnik 2022) and tested at national geography matricular examinations (Gaál et al. 2019). When studying geography, this content is one of the introductory topics in hydrogeography courses at all three Slovenian universities (Stojilković 2023).

The aims of this paper are: (i) to overview the existing literature on discharge analyses and their clustering for Slovenian rivers, (ii) to analyse the mean discharge data for them and to determine present-day clusters, and (iii) to describe them and briefly address the changes that they have faced since last national-level analyses.

1.1 From discharge variability in centennial perspective to current state

Temporal variability of river discharges shows various trends that correspond or relate to other events or changes in purely natural conditions of the catchment area (primarily climate change, but also changes after floods and earthquakes…) or anthropogenic changes triggered by human activity (land use changes, urbanization, etc.). In Slovenian rivers' case, most stations have been running for 50–70 years. However, there are certain that collect data from the beginning of the 20th century. On a global scale, Slovenian rivers belong to the temperate hydroclimate type, characterised by relatively low seasonal precipitation variability, but they are more prone to hazardous events since individual storms have a great impact on their hydrology (Hansford et al. 2020). Even if the Slovenian territory is characterized as low in its variability on a global scale, a more detailed overview points to substantial differences in mean monthly and mean annual discharges. The latter are predominantly decreasing, while maximum and extreme discharges are increasing (Frantar et al. 2008; Oblak et al. 2021).

The gauging stations that have one of the longest records in Slovenia are Litija and Laško. Centennial illustration (Figures 1 and 2) of discharge changes per 30-year spans was done for the rivers Sava (stations Litija & Litija I) and Savinja (stations Laško & Laško I) since they have obtained data recordings for their stations from the very beginning of the 20th century, which is the period we wanted to illustrate with the two examples, or even from earlier years. As seen from Figures 1 and 2, monthly variations among the periods are visible in each month, the most drastic being in April and November.

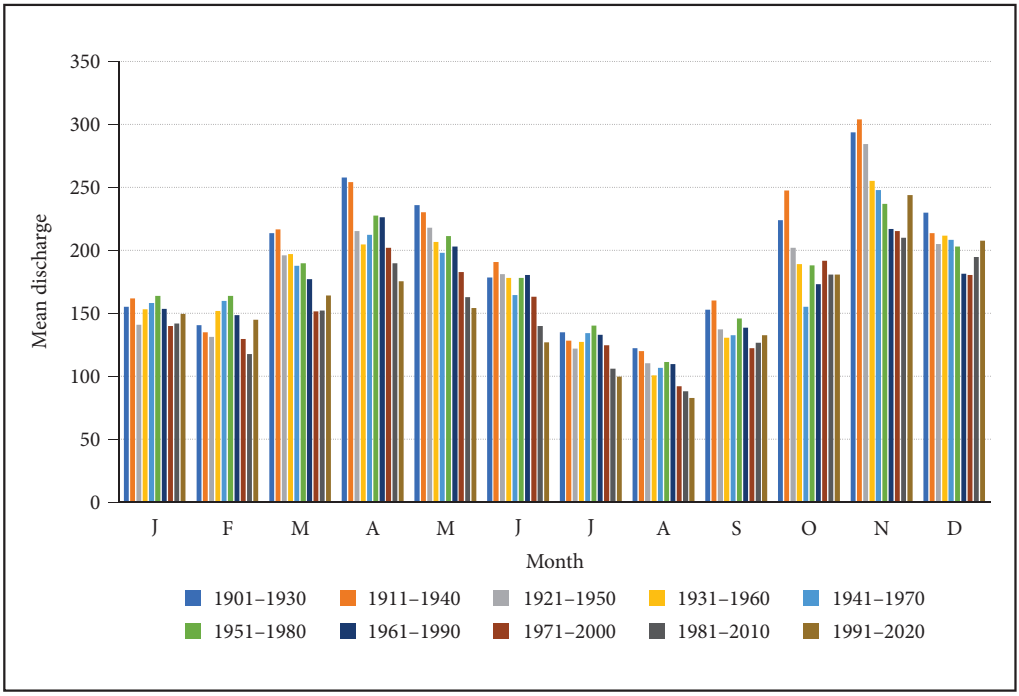


Figure 1: Mean monthly discharges for the Sava River in Litija in different periods.

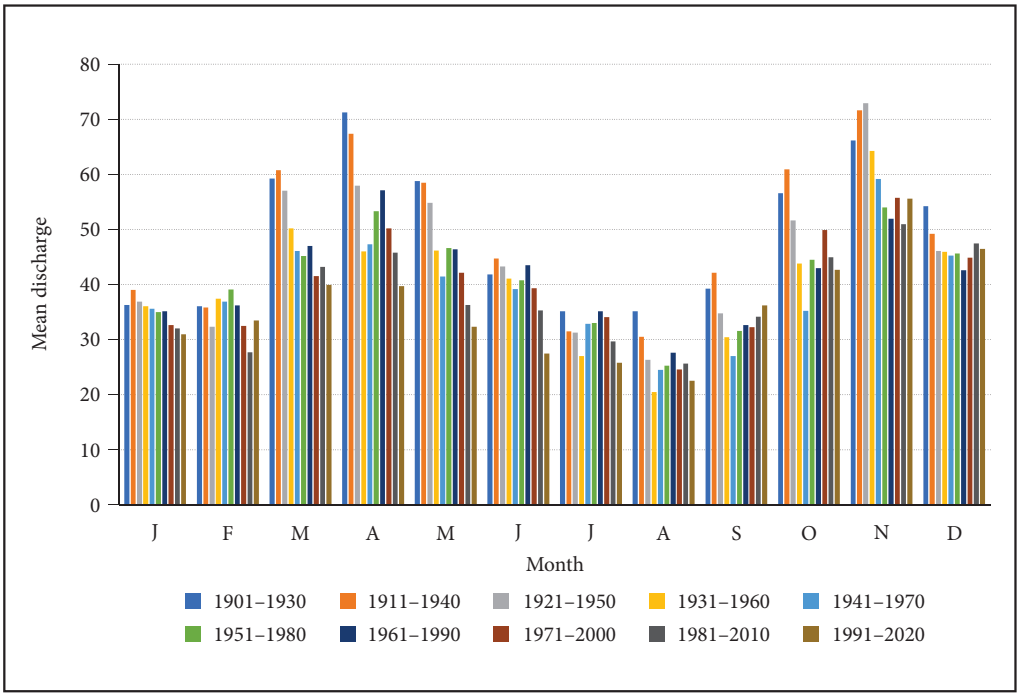


Figure 2: Mean monthly discharges for the Savinja River in Laško in different periods.

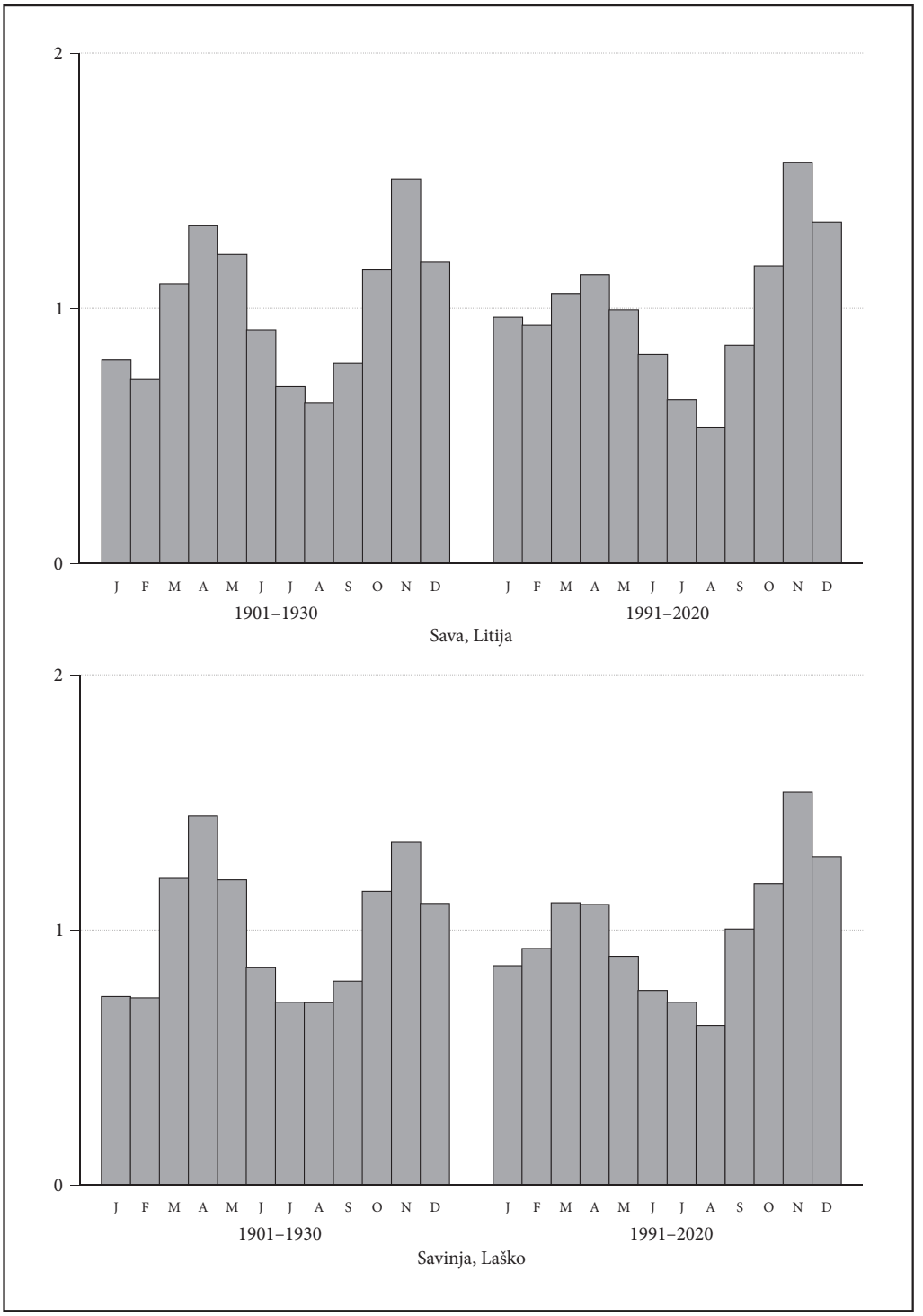


Figure 3: Comparison of discharge coefficients for the Sava (in Litija, above) and the Savinja (in Laško, bellow) Rivers between 1901–1930 and 1991–2020.

Looking at discharge coefficients, as calculated in the next chapter, for both rivers for the periods 1901–1930 and 1991–2020 (Figure 3), monthly coefficients have changed for both of them. In the case of the Sava River (Figure 3, above), the main discharge peak is the autumn one in both cases, with the values decreasing the most in spring, and being the highest and intensifying in November. The primary low in August has even decreased, whereas even more importantly, the winter one increased significantly. Both of them can be classified as pluvial-nival regimes. However, the regime changed for the Savinja River over time (Figure 3, below): in the 1901–1930 period it had its main peak in spring due to snow-melt in the river basin, whereas both lows were characterised by the same value; hence the regime being nival-pluvial. In the second period, the winter low considerably rose, and the spring values lowered, which is a consequence of the rising temperatures, less snow precipitation and snow retinence. Notably higher is the month discharge in November and December. The second hydrograph reflects the characteristics of the pluvial-nival one.

1.2 Previous research

There have been discharge regime scientific classifications published in the last 75 years in Slovenia (Table 1), beginning with Ilešič's (1947) discharge regimes in former Yugoslavia, which puts the rivers of present Slovenia

Table 1: Discharge regime types in Slovenia according to different authors.

Period	Regime types (and river examples)	Source
1898–1913 (littoral) & 1923–1938 (inland)	• Pure nival (Drava) • Transitional nival (Mura, upper Soča) • Alpine nival-pluvial (upper Sava, Savinja) • Moderate Mediterranean nival-pluvial (Tržiška Bistrica, Kamniška Bistrica) • Central-European pluvial-nival (Sotla) • Moderate Mediteranean pluvial-nival (Sora, Ljubljanica) • Mediterranean pluvial-nival (Vipava, Idrijca)	Ilešič 1947
Not specified	• Pure nival (Drava) • Transitional nival (Mura) • Mediterranean transitional nival (upstream Soča, Sava Dolinka) • Nival-pluvial (Sava Bohinjka, Kamniška Bistrica) • Moderate Mediterranean pluvial-nival (Savinja, lower Sava) • Moderate Mediteranean karst pluvial-nival (Krka, Kolpa) • Moderate continental pluvial nival (Sotla, Ledava) • Mediterranean pluvial (Rižana)	Stele 1987
1961–1990	• Nival (Mura, Drava) • Nival-pluvial (upstream Soča, upstream Savinja, upstream Sava, Meža, Mislinja) • Pluvial-nival (downstream Savinja, Dravinja, downstream Sava, Krka) • Continental pluvial-nival (Pesnica, Sotla, Mirna) • Mediterranean pluvial-nival (Vipava, Bača, Ljubljanica, Kolpa, Idrijca, central Soča) • Pluvial (Reka, Rižana, Pivka)	Kolbezen 1998
1961–1990	• Alpine nival (Drava, Mura) • Alpine high mountain nival-pluvial (upstream Savinja, Kamniška Bistrica, upstream Soča, Sava Dolinka and Bohinjka) • Alpine medium mountain nival-pluvial (Tržiška Bistrica, Kokra, central stream Savinja and Sava) • Alpine pluvial-nival (downstream Sava, Dreta) • Dinaric-Alpine pluvial-nival (Ljubljanica, Krka, Voglajna) • Dinaric pluvial-nival (Idrijca, Vipava, Sora, Unica, Kolpa) • Pannonian pluvial-nival (Ledava, Ščavnica, Pesnica, Sotla) • Mediterranean pluvial (Pivka, Reka, Rižana)	Hrvatin 1998
1971–2000	• Alpine nival-pluvial (Sava Dolinka and Bohinjka, Savinja at Solčava, upstream Soča, Kamniška Bistrica, Mura, Drava) • Alpine pluvial-nival (Soča at Solkan, Sava, Savinja from Nazarje onward, Meža, Paka) • Dinaric pluvial-nival (Idrijca, Sora, Unica, Vipava, Ljubljanica, Krka, Kolpa) • Pannonian pluvial-nival (Temenica, Mirna, Sotla, Voglajna, Dravinja, Pesnica, Ščavnica, Ledava) • Mediterranean pluvial (Pivka, Reka, Rižana)	Frantar and Hrvatin (2005; 2008)

in greater perspective. 40 years later Stele (1987) mapped the regimes, re-grouped the rivers, and pointed out the continental or Mediterranean emphasis on the regimes when naming them. For 1961–1990, there are two classifications: by Kolbezen (1998) and by Hrvatin (1998), which mainly differ in fragmentation of certain subtypes. The latest comprehensive analysis was done by Frantar and Hrvatin (2005; 2008) for the period 1971–2000, who reduced the number of (sub)types and reclassified certain elements.

Besides national discharge analyses, there have also been meso-regional analyses across the country in recent years for example in Slovene Alps (Hrvatin and Zorn 2017a), White Carniola (Plut et al. 2013), Carinthia (Kovačič and Brečko Grubar 2021), Slovene Istria (Trobec 2012; Kovačič 2016; Kovačič and Brečko Grubar 2019; Brečko Grubar and Kovačič 2021) and the Soča (Comici and Bussani 2007), Sava (Frantar 2003) and Vipava (Jelovčan and Šraj 2022) catchment areas, and local-level analyses for example in the Idrija Hills (Hrvatin and Zorn 2017b), the Kamniška Bistrica Valley (Trobec 2017), and the Jezersko (Trobec 2019) and Loški potok (Trobec 2022) municipalities.

2 Materials and methods

To preserve comparability with previous research regarding the Slovenian discharge regimes topic (Hrvatin 1998; Frantar and Hrvatin 2005) we performed a cluster analysis and carried it out in the SPSS environment. The same methodology was also applied to discharge regimes clustering in Croatia (Čanjevac 2013; Čanjevac and Orešić 2018). Five steps included in the cluster analysis (Ferligoj 1989) point out both materials and methods: analysis items selection, variables set determination, items' similarities calculation, classification method usage, and, lastly, results evaluation.

The criteria for selecting the 45 gauging stations on 36 streams (Table 2) were (i) distribution throughout the country and (ii) complete data on mean monthly discharges from 1991 to 2020 if existing, with a maximum tolerance of 24 missing months. The data was obtained from the webpage of the Slovenian Environmental Agency (2023). Twenty-five data sets for the selected stations are complete, whereas 20 are partially incomplete in minor scope. Some of the gauging stations were moved in the studied period and because of that Table 2 provides data on all of them, whereas further calculations are made for joint data.

Table 2: Gauging stations and their basic geographic parameters (Slovenian Environmental Agency 2023).

Station number	Station name	Unified station name used in this article	Stream name	Catchment area [km^2]	Mileage [km]	Monitoring start [year]	Complete or missing data [months (year)]
1060	Gornja Radgona I	Gornja Radgona	Mura	10197.20	106.64	1946	Complete
1140	Pristava I	Pristava	Ščavnica	272.77	5.78	1975	Complete
1220	Polana I	Polana	Ledava	209.37	44.33	1962	Complete
2010	HE Dravograd	HE Dravograd	Drava	12071.70	133.86	1965	Complete
2250	Otiški vrh I	Otiški vrh	Meža	552.60	1.35	1953	Complete
2390	Otiški vrh I	Otiški vrh	Mislinja	231.56	1.68	1973	3 (2015)
2650 & 2652	Videm I & Videm	Videm	Dravinja	767.08 & 767.34	4.38 & 4.16	1946	4 (2014)
2900	Zamušani I	Zamušani	Pesnica	479.76	9.86	1961	Complete
3080	Blejski most	Blejski most	Sava Dolinka	508.79	906.23	1963	12 (2007)
3200	Sveti Janez	Sveti Janez	Sava Bohinjka	94.35	32.80	1951	Complete
3420	Radovljica I	Radovljica	Sava	907.96	900.95	1953	Complete
3650 & 3660	Litija I & Litija	Litija	Sava	4849.33 & 4849.67	818.65 & 818.15	1895	Complete
3850	Čatež I	Čatež	Sava	10232.42	736.69	1976	Complete
4120	Kokra I	Kokra	Kokra	113.10	18.01	1957	3 (2015), 4 (2016)
4200	Suha I	Suha	Sora	568.86	7.98	1953	12 (1991)
4430	Vir	Vir	Kamniška Bistrica	208.58	9.58	1978	1 (1991), 5 (2014)

Station number	Station name	Unified station name used in this article	Stream name	Catchment area [km^2]	Mileage [km]	Monitoring start [year]	Complete or missing data [months (year)]
4740 & 4750	Rakovec I & Rakovec	Rakovec	Sotla	560.06 & 561.30	8.07 & 8.00	1926	Complete
4860	Metlika	Metlika	Kolpa	1966.27	181.50	1926	Complete
4969 & 4970	Gradac I & Gradac	Gradac	Lahinja	218.89 & 219.12	7.75 & 7.32	1952	Complete
5030	Vrhnika	Vrhnika	Ljubljanica	1135.12	38.73	1926	3 (2014)
5078 & 5080	Moste I & Moste	Moste	Ljubljanica	1777.96 & 1778.16	11.83 & 11.39	1924	Complete
5770	Cerknica I	Cerknica	Cerkniščica	49.50	4.60	1961	12 (1996), 4 (2015)
5880	Hasberg	Hasberg	Unica	Karst (catchment area cannot be assessed)	16.37	1926	Complete
6020	Solčava I	Solčava	Savinja	63.41	89.45	1959	4 (2015), 8 (2016), 12 (2018)
6060	Nazarje	Nazarje	Savinja	457.11	56.64	1926	Complete
6200	Laško I	Laško	Savinja	1668.16	14.34	1953	Complete
6240	Kraše	Kraše	Dreta	100.82	7.66	1959	2 (2015), 5 (2016)
6300	Šoštanj	Šoštanj	Paka	131.64	12.45	1920	8 (1991)
6720	Celje II	Celje	Voglajna	202.89	2.18	1967	4 (2015)
7029 & 7030	Podbukovje I & Podbukovje	Podbukovje	Krka	346.92 & 348.06	91.34 & 91.27	1959	7 (2015)
7160	Podbočje	Podbočje	Krka	2252.98	16.05	1926	Complete
7308 & 7310	Rožni Vrh I & Rožni Vrh	Rožni Vrh	Temenica	80.51 & 81.05	20.56 & 20.06	1956	12 (2002)
7340	Prečna	Prečna	Prečna	295.19	4.92	1953	Complete
7380	Škocjan	Škocjan	Radulja	108.14	7.03	1961	3 (2014), 3 (2015)
7440 & 7441	Sodražica & Sodražica I	Sodražica	Bistrica	28.19 & 30.13	12.84 & 12.44	1963	Complete
8030 & 8031	Kršovec & Kršovec I	Kršovec	Soča	157.90 & 158.07	118.50 & 118.41	1945	Complete
8080	Kobarid I	Kobarid	Soča	437.06	94.41	1941	Complete
8180	Solkan I	Solkan	Soča	1580.35	44.23	1980	12 (2004)
8350	Podroteja I	Podroteja	Idrijca	111.25	42.73	1977	4 (2015)
8500	Bača pri Modreju	Bača pri Modreju	Bača	143.06	1.54	1940	Complete
8560 & 8561	Vipava I & Vipava II	Vipava	Vipava	131.90 & 131.92	43.55 & 43.47	1960	Complete
8600 & 8601	Miren & Miren I	Miren	Vipava	589.96 & 588.29	2.47 & 2.42	1950	9 (2015)
9050	Cerkvenikov mlin	Cerkvenikov mlin	Reka	332.12	7.95	1952	Complete
9210	Kubed II	Kubed	Rižana	204.66	13.25	1965	3 (2015)
9300	Podkaštel I	Podkaštel	Dragonja	93.16	6.46	1955	12 (1997), 4 (2014)

The variables set, which were all of the same type, included mean monthly discharge coefficients, which were calculated according to the following equation:

—

where: is monthly discharge coefficient, is average period monthly discharge, is average period annual discharge, is the studied month and is the studied year. The monthly discharge coefficient explains the ratio between mean monthly and mean annual discharge for a selected period.

The similarity was calculated using squared Euclidian distance, which is similar to the Manhattan distance used by Hrvatin (1998) and Frantar and Hrvatin (2005) and the cluster analysis was performed using Ward's method.

The merging of the items into clusters was presented with a dendrogram, which is suitable for presenting gradual merging (Ferligoj 1989).

The results were evaluated by performing non-hierarchic *k*-means method analysis, where the number of the desired clusters was set in advance. When the number of clusters (*k)* was selected, the clusters were formed in a way that the variety among the clusters was the greatest whereas it was the smallest within them (Čanjevac 2013).

Subsequently, the clusters were named following the so far Slovene hydrogeographical terminology (Hrvatin 1998; Frantar and Hrvatin 2005) and described. The naming of the regimes is formed including macro- or mesoregional name followed by discharge regime type. The hydrographs in Figures 5 to 10 present the discharge coefficients per month. All of the gauging stations in the continuation of the text are named according to their initial names having their subsequent numbers omitted (e.g. the stations Vipava I and Vipava II are referred to as Vipava).

3 Results

After performing hierarchical statistical analyses on monthly discharge coefficients of the selected rivers, the coefficients were grouped into six groups at 1.5 levels of joining distance (Figure 4). If the distance is 2, there are four groups, at 4 three groups, and 5 two. The results were confirmed by the non-hierarchical k-means method. The clusters are presented as discharge regime groups in the continuation and with their corresponding symbols in Figure 11, where a specific colour is attributed to each regime type that we propose. To keep the established naming of the groups, we maintained the one proposed by Frantar and Hrvatin (2005; 2008) to the greatest extent (as specified in Table 1), updating it as per the now-established regionalisation of Slovenia (Žiberna et al. 2004).

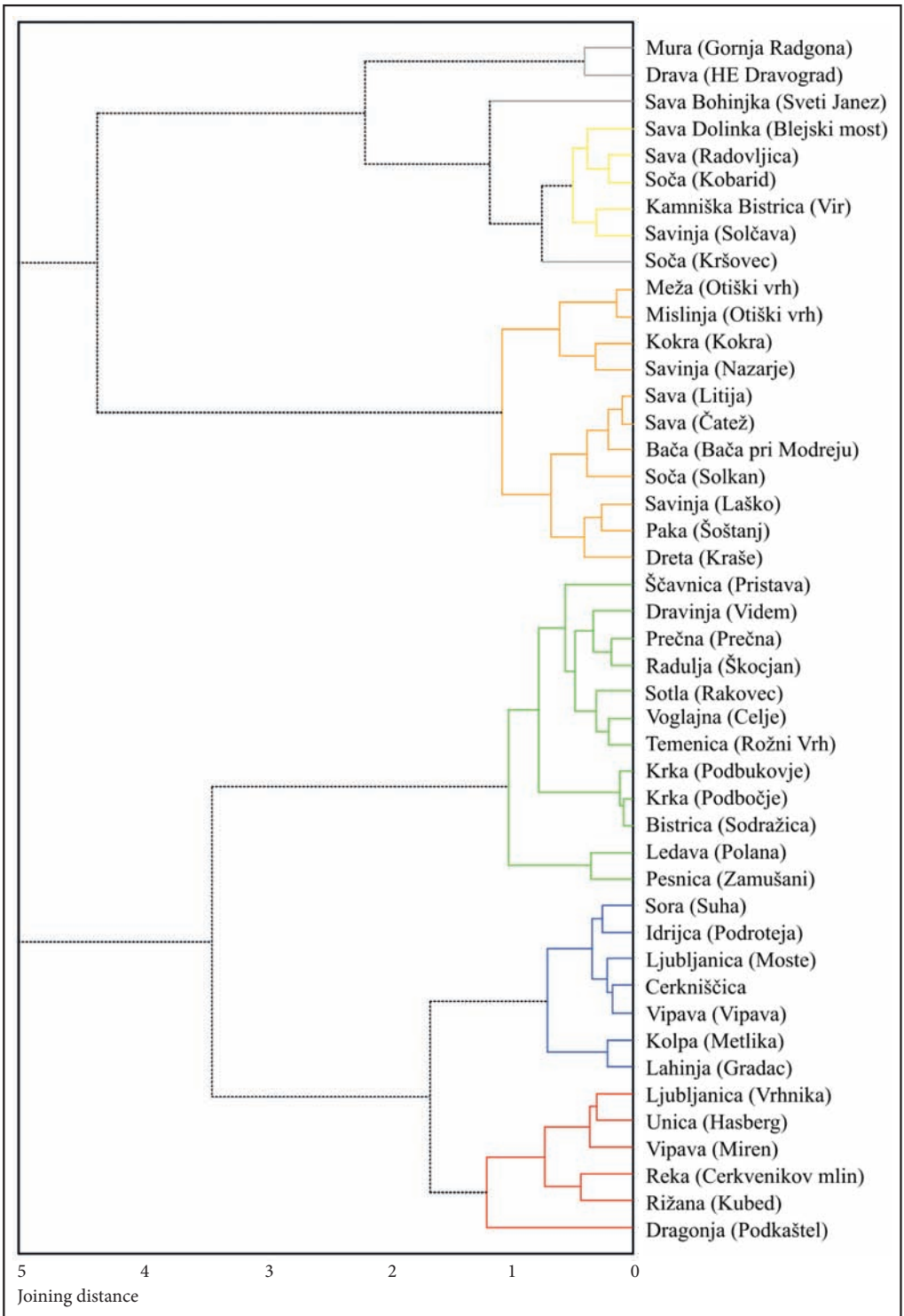
3.1 Alpine rivers

Slovenian rivers having the upper part of their catchment in the high mountains and gauging stations close to the spring or in the upper stream for the period 1991–2020 show more characteristics of the influence of the snow factor, but their flow regime could hardly be generally defined as the nival-pluvial regime.

Only the Mura hydrograph shows the characteristics of the snow regime, with a pronounced peak in May and June and a low from December to March. The Drava already shows a more pronounced above-average discharge in October and November, which is likely to be a secondary peak in the future, similar to the Sava Bohinjka and the Soča. The Soča in Kršovec has very even discharge peaks (discharge coefficient in May 1.55, in November 1.58), while the Sava Bohinjka has a more pronounced peak in spring (discharge coefficient in May 1.83, in November 1.62). The lows are more pronounced in both rivers in winter (flow coefficients in February 0.30 and 0.48) than in summer (flow coefficients 0.60 and 0.61). The hydrographs of the Drava (HE Dravograd), the Mura (Gornja Radgona), the Sava Bohinjka (Sveti Janez) and the Soča (Kršovec) were classified as the ones of the nival-pluvial discharge regime (Figure 5).

The Sava Dolinka (Blejski most), Sava (Radovljica), Soča (Kobarid), Savinja (Solčava) and Kamniška Bistrica (Vir) have lower spring peaks (May flow coefficients ranging from 1.36 to 1.17) than autumn peaks (November from 1.59 to 1.86), which is due to the lower contribution of snow to the discharge (Figure 6). Winter lows are also not pronounced or, except for the Mura, the Drava, the Sava Bohinjka and the Soča at the Kršovec gauging station, are very equal to or even higher than the summer lows. In the typification of the discharge regimes for the period 1971–2000, the rivers listed were classified in the Alpine nival-pluvial discharge regime, including the Mura and the Drava (Frantar and Hrvatin 2005; Frantar and Hrvatin 2008), which as a subcluster differed slightly from other streams in the aforementioned studies (ibid.) as well as this one. Their discharges differ from the others in the group because of the different catchments' locations in the Alpine areas and their sizes.

Figure 4: The dendrogram of the discharge clusters at 5 joining distance. ► p. 16


Mura (Gornja Radgona)
Drava (HE Dravograd)
Sava Bohinjka (Sveti Janez)
Sava Dolinka (Blejski most)
Sava (Radovljica)
Soča (Kobarid)
Kamniška Bistrica (Vir)
Savinja (Solčava)
Soča (Kršovec)
Meža (Otiški vrh)
Mislinja (Otiški vrh)
Kokra (Kokra)
Savinja (Nazarje)
Sava (Litija)
Sava (Čatež)
Bača (Bača pri Modreju)
Soča (Solkan)
Savinja (Laško)
Paka (Šoštanj)
Dreta (Kraše)
Ščavnica (Pristava)
Dravinja (Videm)
Prečna (Prečna)
Radulja (Škocjan)
Sotla (Rakovec)
Voglajna (Celje)
Temenica (Rožni Vrh)
Krka (Podbukovje)
Krka (Podbočje)
Bistrica (Sodražica)
Ledava (Polana)
Pesnica (Zamušani)
Sora (Suha)
Idrijca (Podroteja)
Ljubljanica (Moste)
Cerkniščica
Vipava (Vipava)
Kolpa (Metlika)
Lahinja (Gradac)
Ljubljanica (Vrhnika)
Unica (Hasberg)
Vipava (Miren)
Reka (Cerkvenikov mlin)
Rižana (Kubed)
Dragonja (Podkaštel)
5
4
3
2
1
0
Joining distance

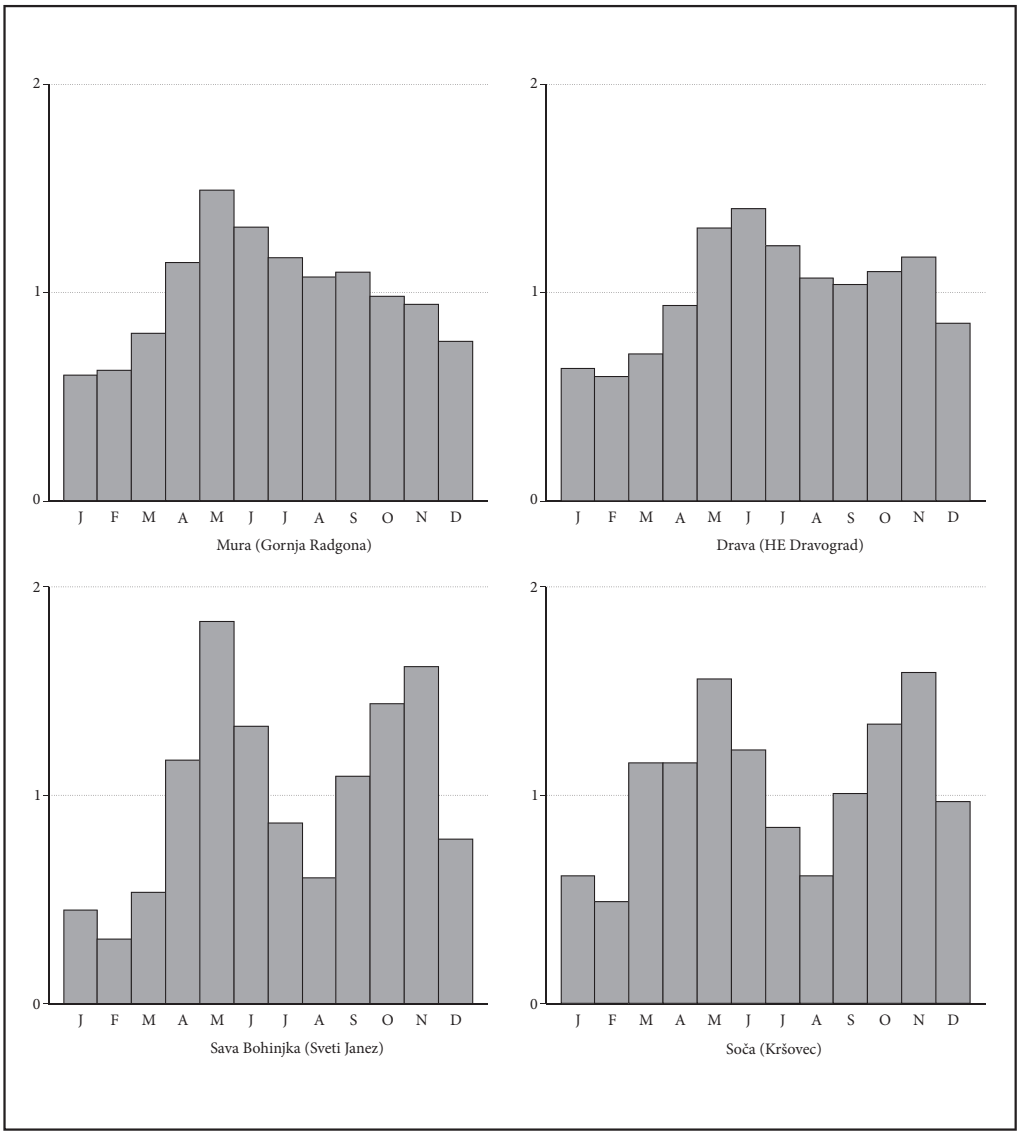
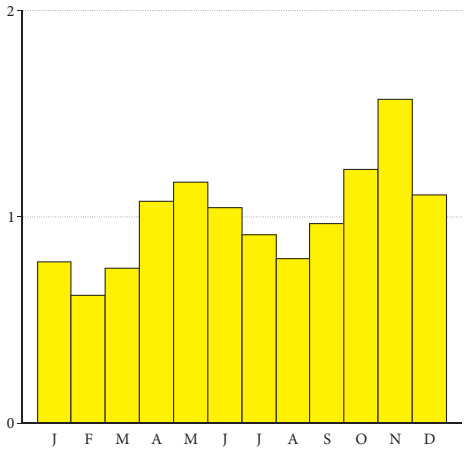
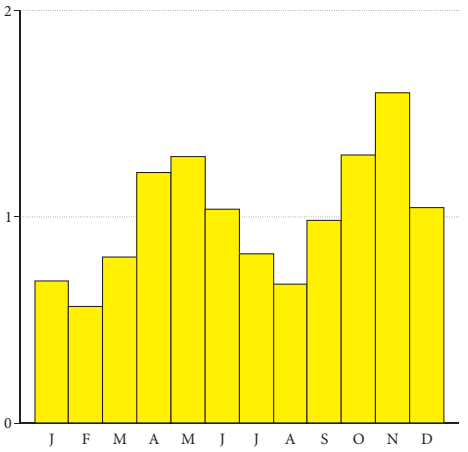


Figure 5: Hydrographs of the Alpine rivers with major nival influence.

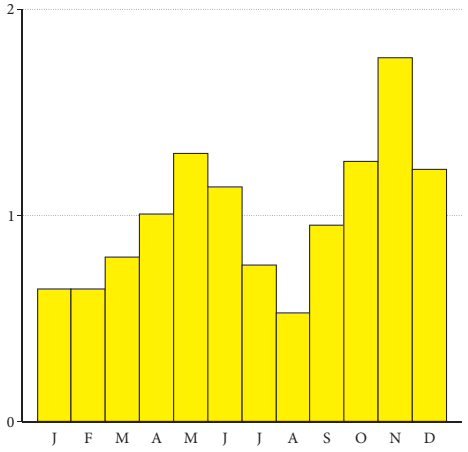
Figure 6: Hydrographs of the Alpine rivers with minor nival influence. ➤ p. 18



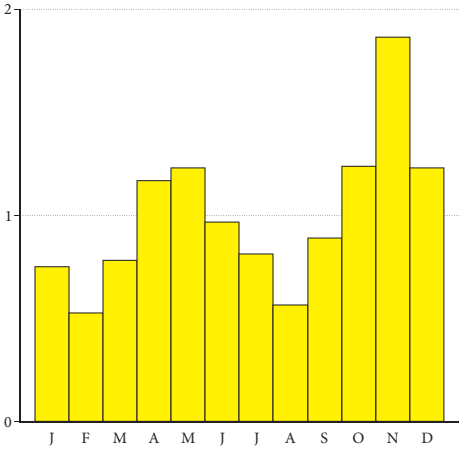
Sava Dolinka (Blejski most)



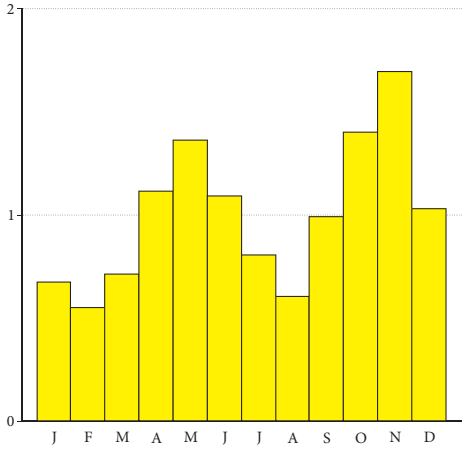
Sava (Radovljica)



Kamniška Bistrica (Vir)



Savinja (Solčava)



Soča (Kobarid)

3.2 Pre-Alpine rivers of northern and western Slovenia

The hydrographs of selected gauging stations on rivers in the northern and north-western part of Slovenia exhibit the characteristics of a pluvial-nival discharge regime with a pronounced autumn peak. The Soča (Solkan), Bača (Bača pri Modreju), Kokra (Kokra), Sava (Litija and Čatež), Meža (Otiški vrh), Mislinja (Otiški vrh), Paka (Šoštanj), Dreta (Kraše), Savinja (Nazarje and Laško) were classified in this group (Figure 7). In November, discharge coefficients ranged from 1.41 (Meža) to 1.74 (Soča Solkan), the spring peak in April was around the mean annual value for all rivers, and in May discharge coefficients were already below 1 in eight cases and higher in three. The winter low is also less prominent, with all 11 gauging stations having a lower discharge coefficient in August than in February. In February they ranged between 0.69 (Kokra) and 0.98 (Sava Čatež), while in August they ranged between 0.77 (Meža) and 0.48 (Bača and Soča at Solkan). In the typification of discharge regimes for the period 1971–2000, the rivers mentioned above were classified as belonging to the Alpine pluvial-nival discharge regime (Frantar and Hrvatin 2005; Frantar and Hrvatin 2008).

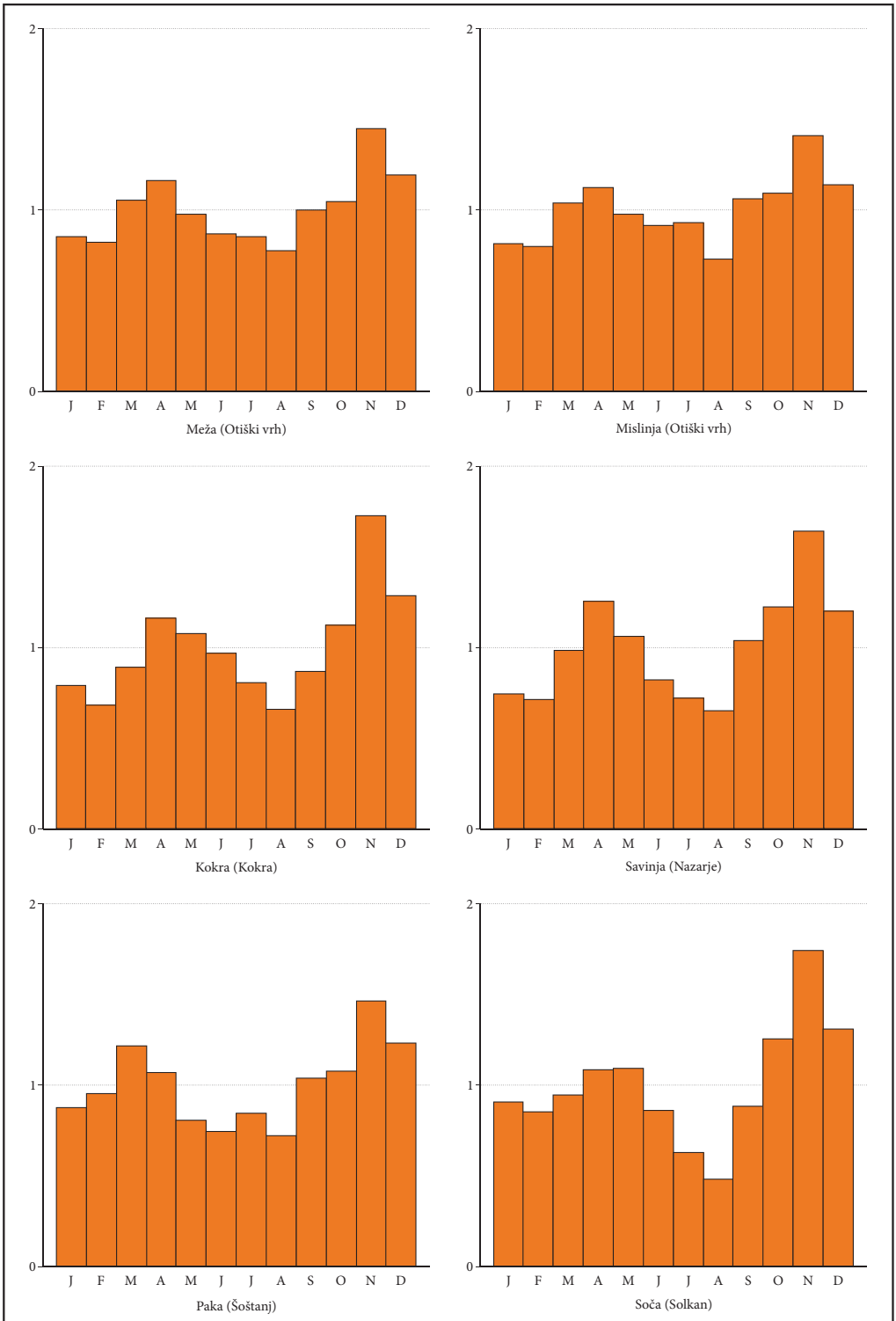
3.3 Sub-Pannonian rivers of north-eastern and south-eastern Slovenia

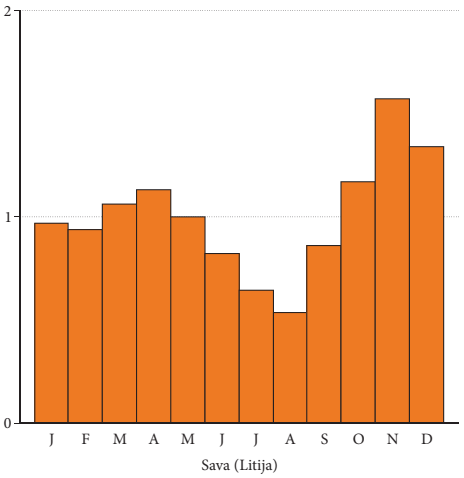
The hydrographs (Figure 8) for gauging stations on mostly smaller rivers in eastern and south-eastern Slovenia reflect the characteristics of a pluvial-nival discharge regime with a weak influence of the snow factor. The Ledava (Polana), the Ščavnica (Pristava), the Pesnica (Zamušani), the Dravinja (Videm), the Voglajna (Celje), the Sotla (Rakovec), the Prečna (Prečna), the Temenica (Rožni Vrh), the Radulja (Škocjan), the Krka (Podbukovje and Podbočje), and the Bistrica (Sodražica) fall into this group. The hydrographs show a pronounced summer low and an insignificant winter low, and a slightly higher autumn peak than the spring peak. The values of the discharge coefficients in August range from 0.38 (Sotla) to 0.72 for Ledava, where the influence of the reservoir is evident. The river with the second highest discharge coefficient in August is the Dravinja with 0.58. The summer below-average conditions for four rivers (Ledava, Ščavnica, Pesnica and Voglajna) last from April to September, and for the others from May to August. The autumn peak in November and December is more pronounced than the spring peak, despite the values of the flow coefficients being very similar. In March they ranged from 1.22 (Prečna) to 1.47 (Ledava), in November from 1.19 (Ledava) to 1.46 (Ščavnica) and in December from 1.34 (Dravinja) to 1.52 (Sotla). Of the 12 rivers, 7 have a flow coefficient higher in December than in November, 3 the same and only two (Krka at Podbukovje and Bistrica) slightly lower. All rivers also have above-average discharges in February and March; four have above-average and eight below-average discharges in January, with discharge coefficients close to the mean annual average. The winter low is thus almost non-existent. In the typification of flow regimes for the period 1971–2000, the Ledava, Ščavnica, Pesnica, Dravinja Voglajna, Sotla and Temenica rivers were classified as belonging to the Pannonian pluvial-nival discharge regime, and the Krka river to the Dinaric pluvial-nival discharge regime (Frantar and Hrvatin 2005; 2008).

3.4 Dinaric rivers of central and southern Slovenia

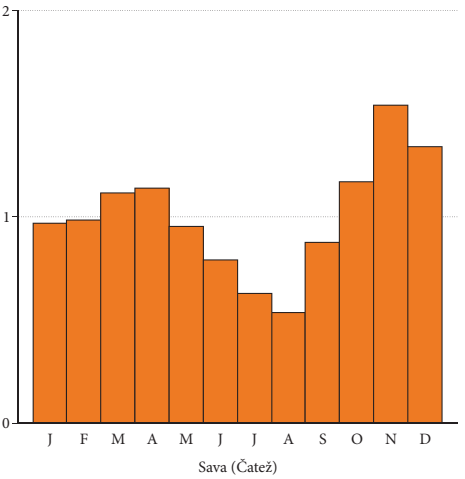
The gauging stations on rivers in central and southern Slovenia have very similar hydrographs. The Sora (Suha I), Ljubljanica (Moste), Idrijca (Podroteja), Vipava (Vipava), Cerkniščica (Cerknica), Kolpa (Metlika) and Lahinja (Gradac) are included in this group (Figure 9). In the typification of discharge regimes for the period 1971–2000, all of the rivers listed were classified as belonging to the Dinaric pluvial-nival discharge regime (Frantar and Hrvatin 2005; Frantar and Hrvatin 2008). The hydrographs for the period 1991–2020 show a completely undistinguished influence of the snow factor. Six of them have above-average mean monthly discharges from October to April, and only one (the Sora) is slightly below the average in January. The discharge coefficients in January are between 0.97 (Sora) and 1.16 (Ljubljanica), and in February between 1.04 (Sora) and 1.35 (Lahinja). In contrast to the previous group, the discharge coefficients are higher in

Figure 7: Hydrographs of the pre-Alpine rivers of northern and western Slovenia. ► p. 20–21
Figure 8: Hydrographs of the sub-Pannonian rivers of north-eastern and south-eastern Slovenia. ► p. 22–23
Figure 9: Hydrographs of the Dinaric rivers of central and southern Slovenia. ► p. 24

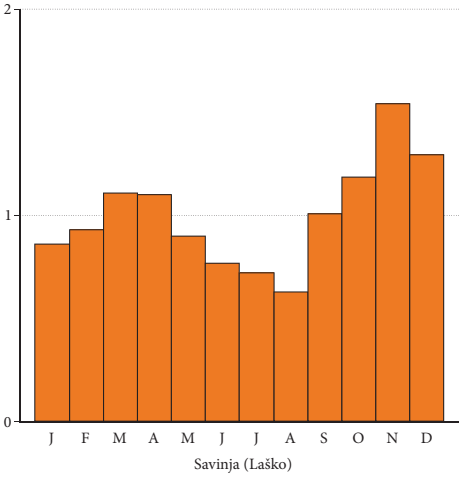

2
1
0
J F M A M J J A S O N D
Meža (Otiški vrh)
Mislinja (Otiški vrh)
Kokra (Kokra)
Savinja (Nazarje)
Paka (Šoštanj)
Soča (Solkan)



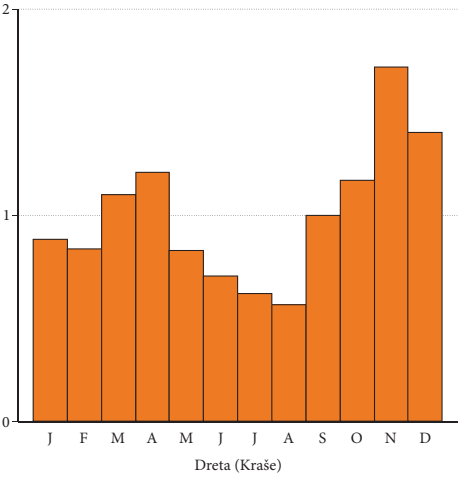
Sava (Litija)



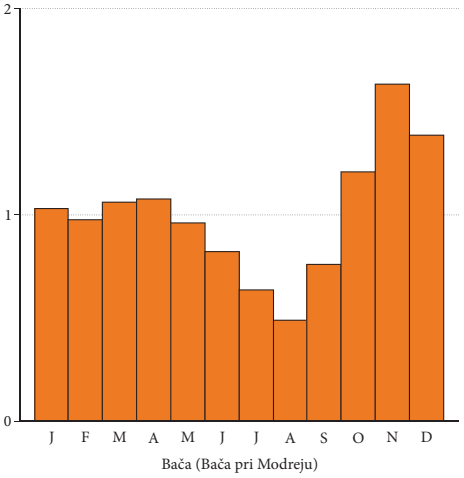
Sava (Čatež)



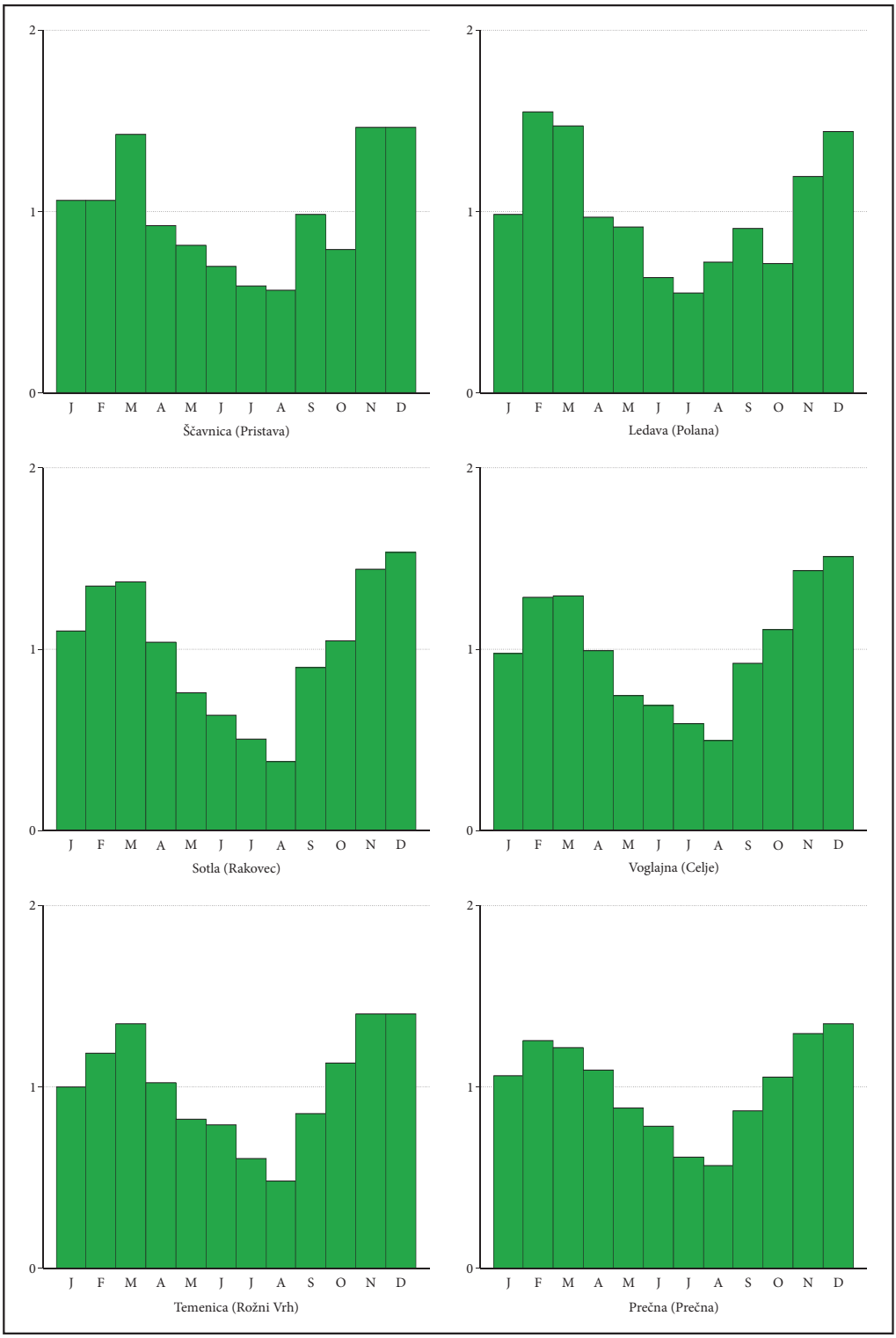
Savinja (Laško)

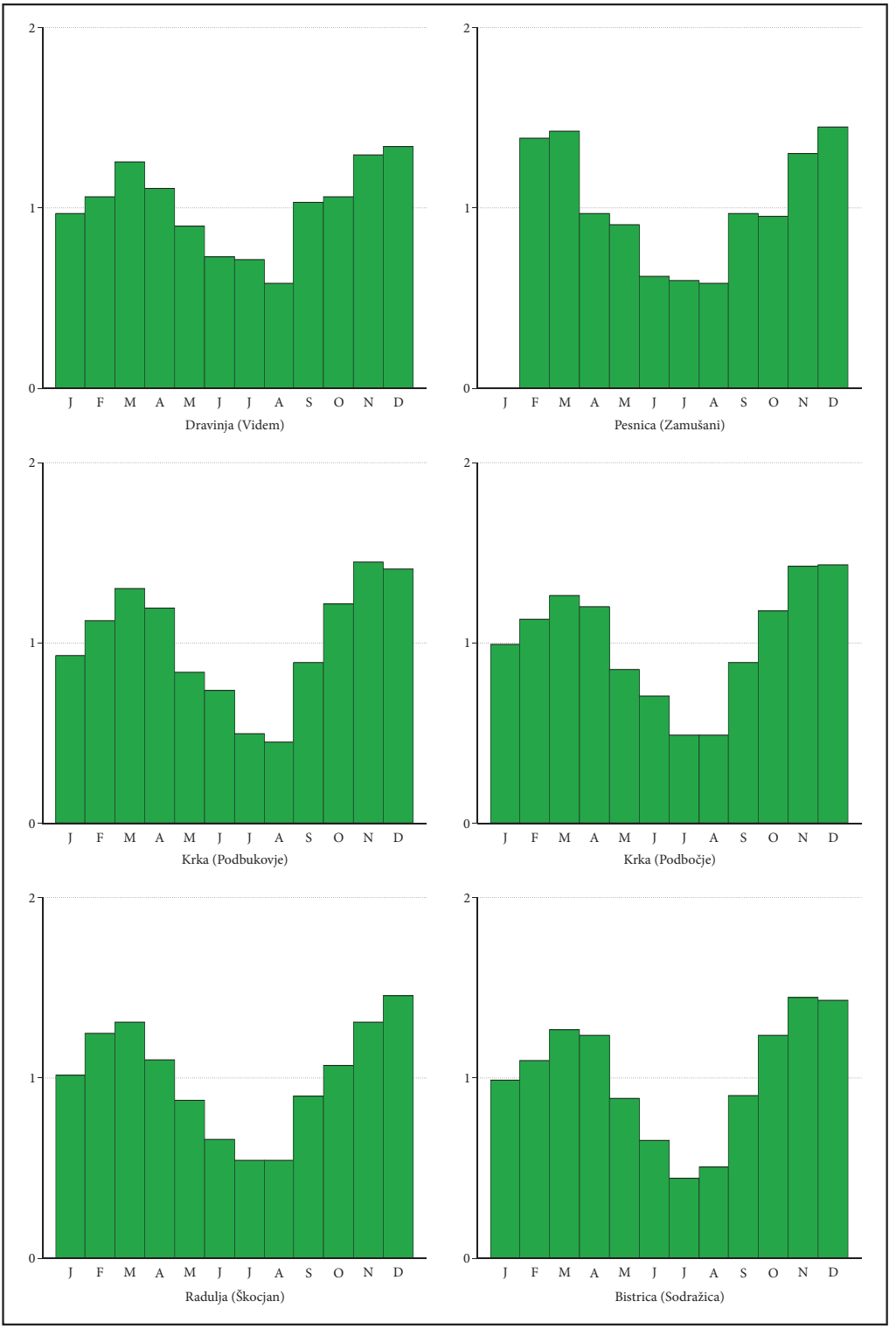


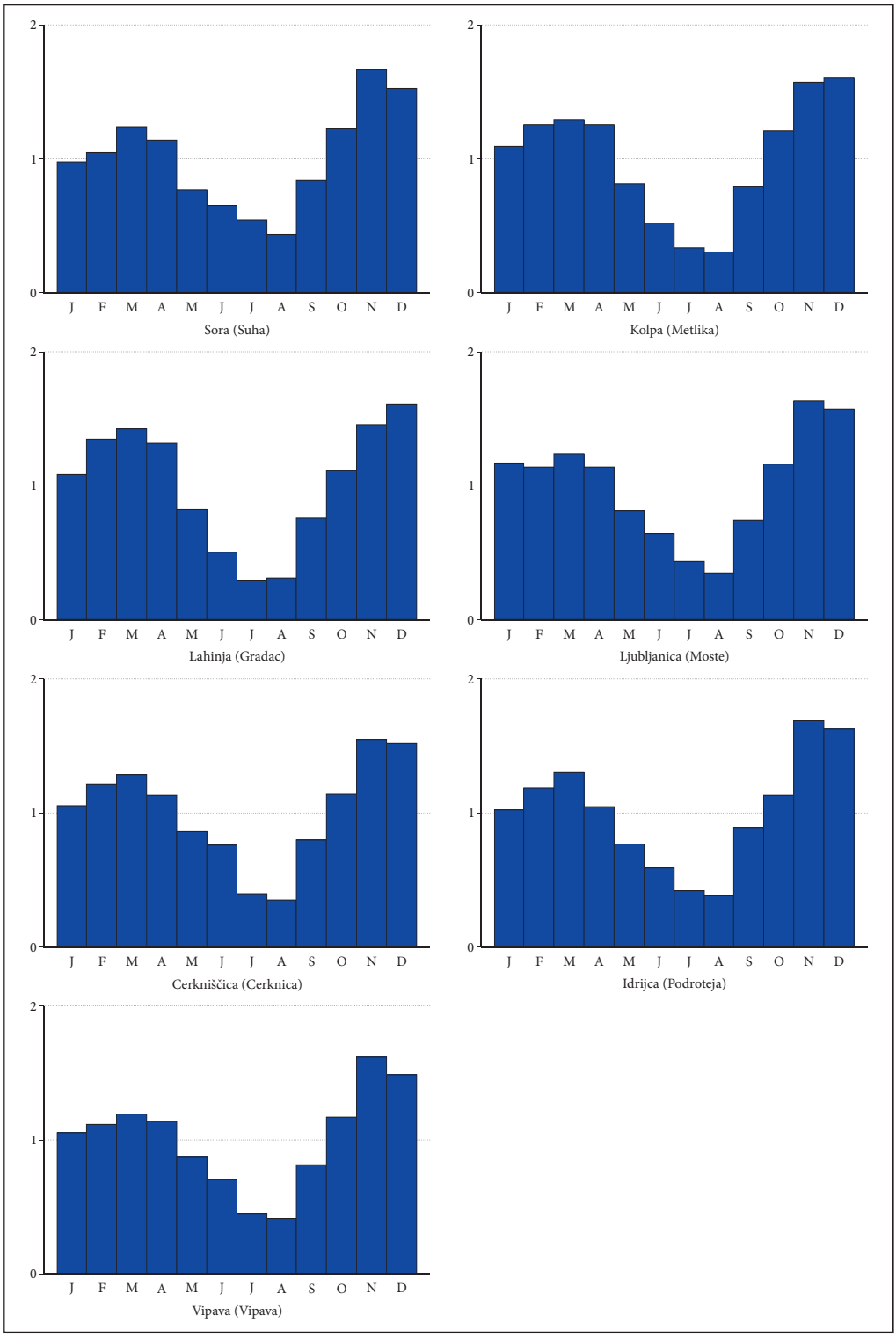
Dreta (Kraše)



Bača (Bača pri Modreju)


2
1
0
J F M A M J J A S O N D
Ščavnica (Pristava)
Ledava (Polana)
Sotla (Rakovec)
Voglajna (Celje)
Temenica (Rožni Vrh)
Prečna (Prečna)


2
1
0
J F M A M J J A S O N D
Dravinja (Videm)
Pesnica (Zamušani)
Krka (Podbukovje)
Krka (Podbočje)
Radulja (Škocjan)
Bistrica (Sodražica)


2
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J F M A M J J A S O N D
Sora (Suha)
Kolpa (Metlika)
Lahinja (Gradac)
Ljubljanica (Moste)
Cerkniščica (Cerknica)
Idrijca (Podroteja)
Vipava (Vipava)

November than in December, and the difference between the autumn and spring peaks is more pronounced. The discharge coefficients in November range from 1.45 (Lahinja) to 1.68 (Idrijca), and in March from 1.19 (Vipava) to 1.42 (Lahinja). The discharge coefficients in April are similar to those in February. The distinct summer low is similar to that of rivers in north-eastern and south-eastern Slovenia, with discharge coefficients of between 0.29 (Lahinja) and 0.54 (Sora) in July, and between 0.30 (Kolpa) and 0.43 (Sora) in August.

3.5 Rivers of south-western Slovenia

The last group consists of the rivers of south-western Slovenia, namely the Rižana (Kubed), the Dragonja (Podkaštel), the Reka (Cerkvenikov mlin), the Vipava (Miren), the Ljubljanica (Vrhnika) and the Unica (Hasberg) (Figure 10). In the typification of the discharge regimes for the period 1971–2000, except the last two, they were all classified as belonging to the Mediterranean pluvial discharge regime (Frantar and Hrvatin 2005; 2008). The hydrographs are characterised by an autumn peak with discharge coefficients in November between 1.49 (Dragonja) and 2.01 (Reka), and in December between 1.69 (Ljubljanica) and 1.96 (Dragonja). In the hydrographs of the Unica, the Rižana and the Dragonja, the discharge coefficients in December are higher than those in November. January values are lower than those for December for all rivers, including February for the Ljubljanica and the Unica. In January, the discharge coefficients range from 1.12 (Vipava) to 1.35 (Unica), and in February from 1.09 (Ljubljanica) to 1.77 (Dragonja). From March onwards, the discharge coefficients decrease, except for the Ljubljanica and the Unica, where this only occurs in April, and the group differs from the previous groups in this respect. All rivers have below-average discharges from May to September, and only the Rižana and the Dragonja in October. Summer flow coefficients range from 0.19 (Dragonja) to 0.35 (Vipava) in July, and from 0.09 (Dragonja) to 0.23 (Reka) in August. Of the other rivers with a slightly different hydrograph, the Dragonja stands out as the only one with a complete basin in Slovenian Istria. It has a high discharge coefficient in February (1.77) and an extremely low one in August (0.09).

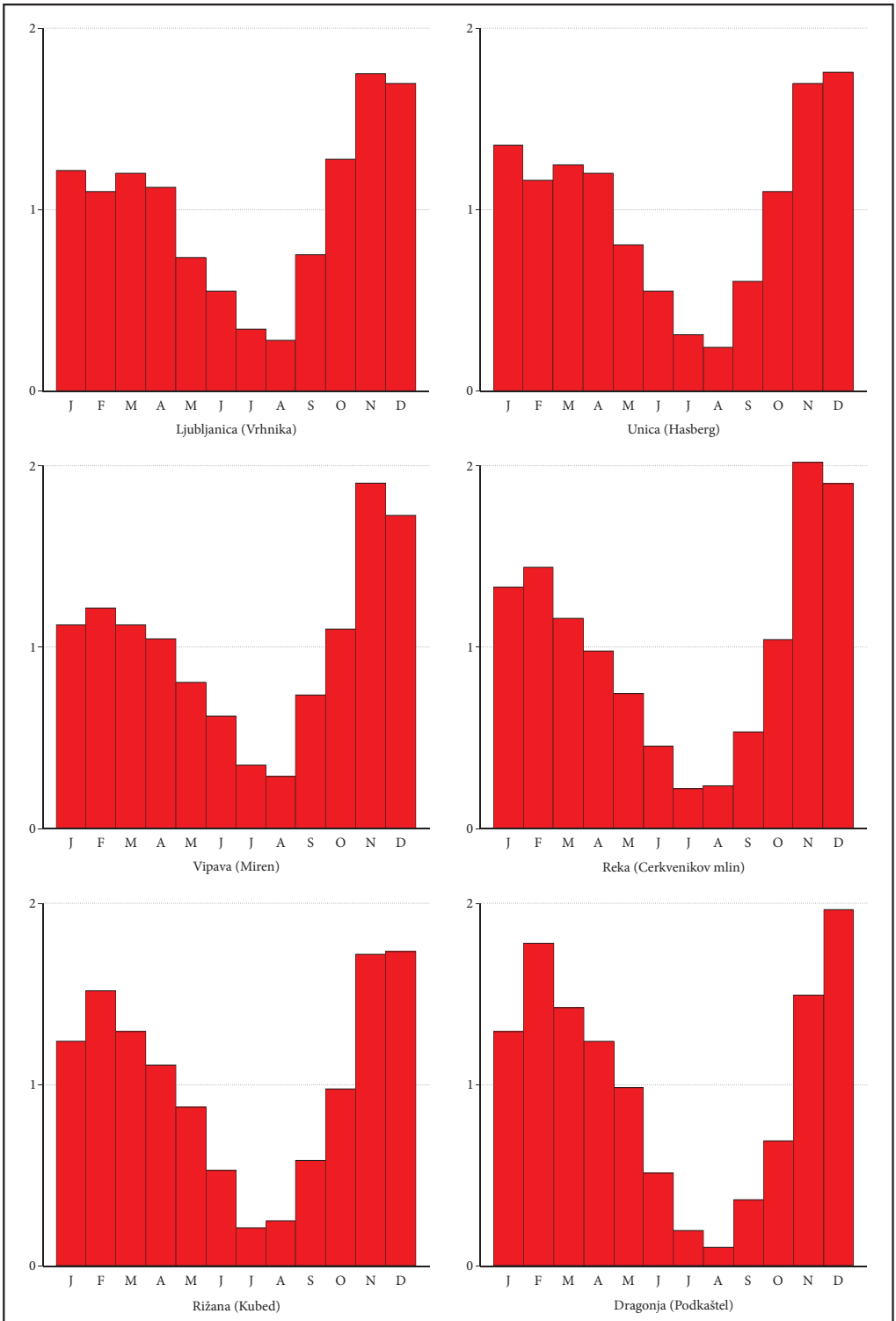
4 Discussion

As shown in the Results section, the discharge capacities of several streams changed, redistributing the coefficient values throughout the year. Secondly, the discharge characteristics changed in certain cases in such a drastic way, that the streams clustered differently as in the previous observation periods, as well as changed their discharge type changed. Hence, it is imperative to further elaborate on the changes, as well as to present an up-to-date classification of the streams according to their discharge regime characteristics.

4.1 Similarities and differences between the 1991–2020 period and previous periods

Comparing the hydrographs for the reference period 1991–2020 with those for 1960–1990 (Hrvatin 1998) and 1971–2000 (Frantar and Hrvatin 2008) – as can also be seen in Figures 1 and 2 – we observed that the influence of the snow factor has decreased at most gauging stations on Slovenian rivers. The exceptions are the rivers with a catchment and part of the catchment hinterland in the high mountains. In the last two periods, the February discharges have risen the most (Kobold 2022). Related to that, above-average discharges, where the influence of snowmelt was noticeable, have mostly decreased and become insignificant. Yet until 2010, the spring and autumn peaks had become similar (Hrvatin and Zorn 2017a), whereas since then – as shown in this study – the trend has continued. Conversely, autumn peaks, with a peak in November and/or December, have strengthened. Less pronounced are the winter lows, when, except for the rivers of the first group (Figure 5), the values of the flow coefficients are mostly above or slightly below the mean annual value. To take the example of the Otiški vrh gauging station on the Meža River, which has been similarly discussed by Kovačič and Brečko Grubar (2021): the flow coefficient decreased from 1.52 to 1.16 in April, from 1.20 to 0.97 in May, whereas increased from 1.17 to 1.44 in November

Figure 10: Hydrographs of the rivers of south-western Slovenia. ► p. 26


2
1
0
J F M A M J J A S O N D
Ljubljanica (Vrhnika)
Unica (Hasberg)
Vipava (Miren)
Reka (Cerkvenikov mlin)
Rižana (Kubed)
Dragonja (Podkaštel)

and from 0.86 to 1.19 in December. Similar changes are shown by the data for the Solkan I gauging station (Figure 7) on the Soča River, where the flow coefficient decreased from 1.29 to 1.08 in April, from 1.32 to 1.09 in May, from 1.16 to 0.86 in June, with noticeably lower coefficients in the summer months, while on the contrary, it increased from 1.36 to 1.74 in November, from 0.97 to 1.30 in December (Kolbezen 1998; Bat et al. 2008), which points at the intensification of the rain regime that has a crucial effect on the discharge of the major part of this river (Comici and Bussani 2007; Siché and Arnaud-Fassetta 2014), which is also under great influence of anthropogenic activities (e.g. channelisation and dams) (Siché and Arnaud-Fassetta 2014).

Authors have pointed at regime change downstream for several major Slovenian rivers, and at gaining effect of the pluvial factor through time, such as the Sava River (Frantar 2003). For the last monitoring period, many of the hydrographs of the catchment hinterland of gauging stations in north-eastern, south-eastern, central and south-western Slovenia, with hilly, moderately rugged or lowland terrain, increasingly show the characteristics of a rainfall flow regime. Differences between the characteristics of the autumn and spring above-average flow coefficients and the differences in the summer below-average flow coefficients have become apparent, which has not only been observed in this study but also by several other authors (e.g. Kovačič and Brečko Grubar 2019) who dealt with specific streams or regional/local analyses. The flows of the above-mentioned areas (i.e. north-eastern, south-eastern, central and south-western Slovenia) also form one of two major clusters – that is the cluster solely affected by rain, which is a major difference from the penultimate (Frantar and Hrvatin 2005; Frantar and Hrvatin 2008) and ante-penultimate (Hrvatin 1998) national analyses.

A comparison of the period 1991–2020 with the periods 1961–1990 and 1971–2000 shows that flow coefficients are noticeably lower in March and April and noticeably higher in November and December. Similar trends had already been established for earlier periods (Plut et al. 2013) and are pointed out by detailed contemporary studies comparing the same periods (Kobold 2022). To illustrate: at the Pristava gauging station on the Ščavnica River, the flow coefficient decreased from 1.51 to 1.06 in February, from 1.73 to 1.42 in March and from 1.30 to 0.92 in April, increased from 1.24 to 1.46 in November and from 1.16 to 1.46 in December. Another example is the Krka River in Podbočje, where the flow coefficient decreased from 1.48 to 1.19 in April and from 0.95 to 0.85 in May, while in November it increased from 0.97 to 1.17 and in December it increased from 1.18 to 1.43. Similar changes can be observed on other rivers of groups 3, 4 and 5 (Figures 8–10). On the Reka (Cerkvenikov mlin) (Figure 10), the discharge coefficient increased from 1.65 to 2.10 in November, and from 1.45 to 1.89 in December (Kolbezen 1998; Bat et al. 2008).

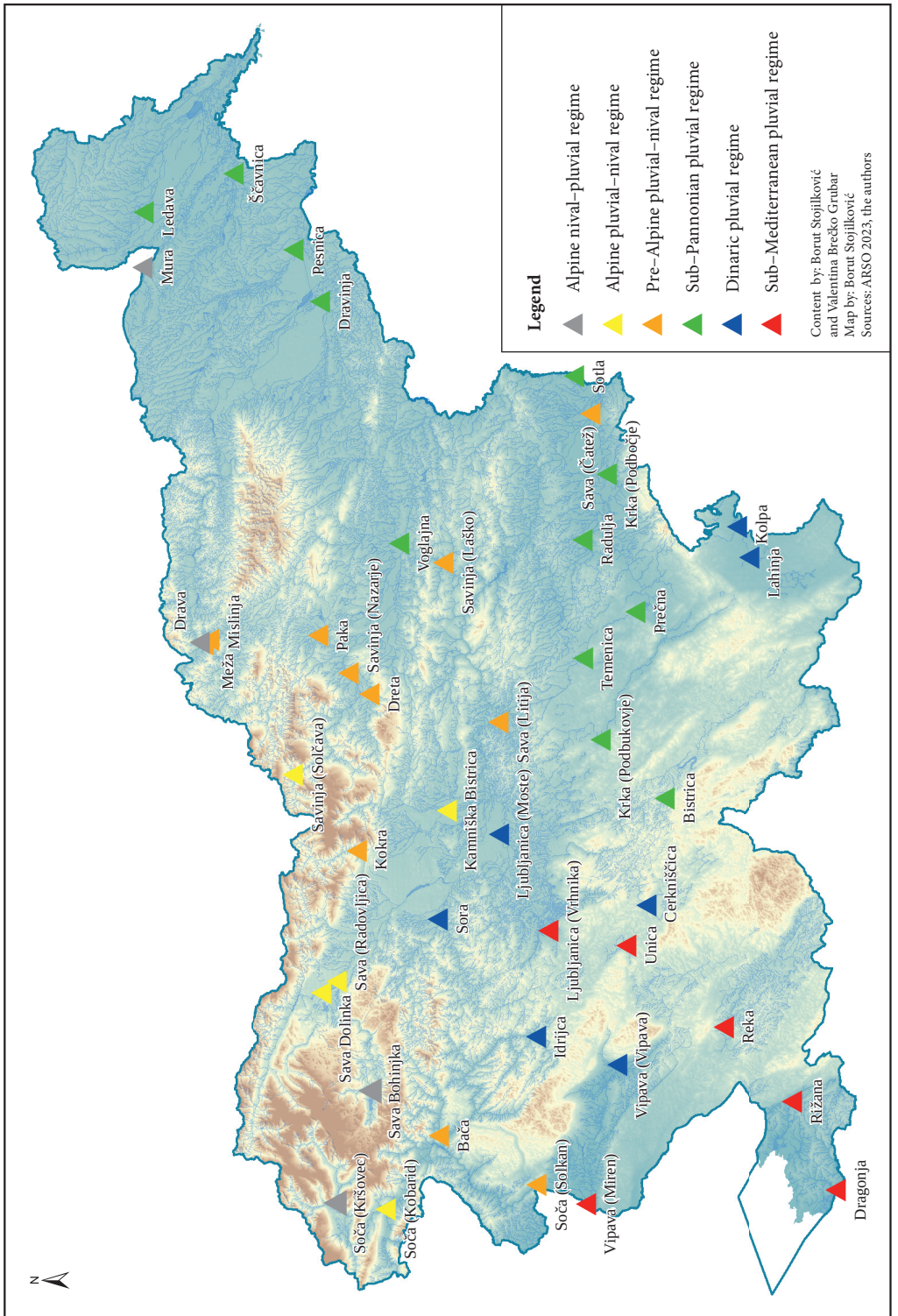
For most rivers, we also observed a variation between periods, with the 1971–2000 period showing lower or higher discharge coefficients than in the first and last periods. The reason for this is lower snow precipitation and snow residence (Hrvatin et al. 2020), as well as the rising share of forested land in Slovenia (Hrvatin and Zorn 2017a). Land use in particular is another factor that affects water discharge (Hrvatin and Zorn 2017a; Palmer and Ruhi 2019). From circa 1850 onwards, land use has changed greatly in Slovenia mainly due to political-economic evolution (Gabrovec and Kumer 2019). Still, more specifically, in the last two decades, land use has changed in many Slovenian regions following certain trends (Žiberna and Konečnik Kotnik 2020): arable land is getting smaller (from 13.2% to 11.6% in the period 2000–2020); in the vicinity of the cities it becomes built-up area due to suburbanisation, whereas in marginal areas firstly transform into pastures and then into forests. Unsustainable land use in areas of great flood hazard intensifies drastic responses in water resources (including runoff coefficient) in various areas in Slovenia (Žiberna 2014), which needs further empirical analysis, but exceeds the scope of this study.

4.2 Classification of discharge types in the period from 1991 to 2020

Based on the results, their analysis and the so-far literature (Hrvatin 1998; Frantar and Hrvatin 2005; Frantar and Hrvatin 2008), it is reasonable to divide the rivers and name the groups as suggested below and illustrated in Figure 11.

The first group (i.e. the Alpine rivers) should be split into two subgroups because the influence of the snow factor is more pronounced in the Mura, the Drava, the Sava Bohinjka and the Soča (Kršovec) than

Figure 11: Types of discharge regimes of Slovenian rivers (1991–2020). ➤ p. 28


Legend
Alpine nival–pluvial regime
Alpine pluvial–nival regime
Pre–Alpine pluvial–nival regime
Sub–Pannonian pluvial regime
Dinaric pluvial regime
Sub–Mediterranean pluvial regime
Content by: Borut Stojilković and Valentina Brečko Grubar
Map by: Borut Stojilković
Sources: ARSO 2023, the authors
N
Mura
Ledava
Ščavnica
Pesnica
Dravinja
Drava
Meža
Mislinja
Paka
Savinja (Nazarje)
Dreta
Voglajna
Savinja (Laško)
Savinja (Solčava)
Kokra
Kamniška Bistrica
Sora
Ljubljanica (Moste)
Sava (Litija)
Sava (Čatež)
Sotla
Radulja
Krka (Podbočje)
Temenica
Prečna
Kolpa
Lahinja
Krka (Podbukovje)
Bistrica
Cerkniščica
Unica
Ljubljanica (Vrhnika)
Idrijca
Sava (Radovljica)
Sava Dolinka
Sava Bohinjka
Soča (Kršovec)
Soča (Kobarid)
Soča (Solkan)
Bača
Vipava (Miren)
Vipava (Vipava)
Reka
Rižana
Dragonja

in the other rivers. The discharge regime of this group should be called **Alpine nival-pluvial regime** (si. *alpski snežno-dežni režim*), as in the classification of the discharge regimes for the period 1971–2000 (Frantar and Hrvatin 2005; Frantar and Hrvatin 2008).

For the other Alpine rivers, the influence of the rain factor is stronger or the snow factor is weaker and the label **Alpine pluvial-nival regime** (si. *alpski dežno-snežni režim*) would be more appropriate for their discharge regimes. This could lead to confusion when comparing the proposed classification with the previous classification, i.e. of Frantar and Hrvatin (2005; 2008), where rivers with an alpine pluvial-nival discharge regime are identified as rivers of our second group (i.e. pre-Alpine rivers of northern and western Slovenia).

For the next group, the influence of the snow factor is still evident and we suggest retaining the definition of the predominant pluvial-nival regime as in the previous classification (Frantar and Hrvatin 2005; Frantar and Hrvatin 2008) but referring to it by a different name. Given that the catchment hinterland is morphology-wise largely comprised of the hills or lower mountains and intermediate basins, we suggest its name to be **pre-Alpine pluvial-nival regime** (si. *predalpski dežno-snežni režim*).

The rivers of the third group (i.e. sub-Pannonian rivers of north-eastern and south-eastern Slovenia) have almost no winter low and could be classified as a rain-fed discharge regime. Given the established naming of the macro-regions of Slovenia (Žiberna et al. 2004), the name **sub-Pannonian pluvial regime** (si. *obpanonski dežni režim)* is appropriate.

Similar changes were also identified for the rivers of the fourth group (of the Dinaric rivers of central and southern Slovenia), which can be classified as having a pluvial regime, hence the **Dinaric pluvial regime** (si. *dinarski dežni režim)*.

Lastly, we confirm the fifth group to keep its category of a pluvial regime, but – given the widely accepted current regionalisation of Slovenia as well as accordance with regime classifications of neighbouring countries (Čanjevac 2013; Čanjevac and Orešić 2018) and lacking true Mediterranean climatological and hydrological characteristics (Skoulikidis et al. 2022) – the name **sub-Mediterranean pluvial regime** (si. *obsredozemski dežni režim)*.

5 Conclusion

Given the need to fill the gap in consecutive discharge regime analyses of Slovenian rivers after the monitoring period of 1991–2020 ended, it was essential to check if the streams still resemble the discharge characteristics they once had and if they cluster similarly. Hence the literature review on the topic in this paper was followed by completing the major aims of analysing the discharge data, determining as well as describing the clusters, and briefly summarising the changes and reasons for them.

Physical geographical characteristics changed in Slovenia in the last three decades significantly. That has been observed for climate (Ogrin et al. 2023) as well as it can be confirmed for river discharge. Minimising the snow residence effect, movement of the Mediterranean precipitation influence eastward and for other factors, discharges of many rivers have lost their nival component being a result of extremely short winter snow residence period, rain being the sole and major factor affecting their peaks and lows. As a result, five spatially most homogenous groups are present, the first including two discharge regime types, and the rest one: Alpine rivers (Alpine nival-pluvial and Alpine pluvial nival regimes), pre-Alpine rivers of northern and western Slovenia (with pre-Alpine pluvial-nival regime), sub-Pannonian rivers of north-eastern and south-eastern Slovenia (with sub-Pannonian pluvial regime), Dinaric rivers of central and southern Slovenia (with Dinaric pluvial regime), and Rivers of south-western Slovenia (with sub-Mediterranean pluvial regime).

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THE TRENDS IN VITICULTURE AND WINEMAKING IN THE CONTEXT OF WINE TOURISM DEVELOPMENT IN BOSNIA AND HERZEGOVINA

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Vineyards and wine tourists at the Jungić winery estate – Markovac, northern Bosnia wine region.

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The trends in viticulture and winemaking in the context of wine tourism development in Bosnia and Herzegovina

ABSTRACT: The article looks at viticulture, wine production and wine tourism in Bosnia and Herzegovina. The cluster analysis was carried out to identify the current situation and to explore the possibilities for the development of wine tourism as an additional segment that can contribute to a better positioning of both sectors and to the diversification of the income of wine producers in the country. The analysis identified three different groups (clusters) of wine producers with different capacities. Given the different structure of wineries, the possibility of diversifying agricultural and rural policy measures must be examined in order to contribute to a more intensive development of viticulture and winemaking which would also encourage the development of the tourist offer for each wine producer.

KEYWORDS: viticulture, wine production, wine tourism, cluster analysis, Bosnia and Herzegovina

Trendi v vinogradništvu in vinarstvu v kontekstu razvoja vinskega turizma v Bosni in Hercegovini

POVZETEK: Članek obravnava vinogradništvo, pridelavo vina in vinski turizem v Bosni in Hercegovini. Cluster analiza je bila izvedena z namenom ugotoviti trenutno stanje in raziskati možnosti za razvoj vinskega turizma kot dodatnega segmenta, ki lahko prispeva k boljšemu položaju obeh sektorjev in k diverzifikaciji prihodkov vinarjev v državi. Z analizo smo opredelili tri različne skupine (grozde) pridelovalcev vina z različnimi zmogljivostmi. Glede na različno strukturo vinarjev je treba preučiti možnost diverzifikacije ukrepov kmetijske in podeželske politike, da bi prispevali k intenzivnejšemu razvoju vinogradništva in vinarstva, kar bi spodbudilo tudi razvoj turistične ponudbe pri vseh vinarjih.

KLJUČNE BESEDE: vinogradništvo, pridelava vina, vinski turizem, cluster analiza, Bosna in Hercegovina

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1 Introduction

Viticulture and wine production have a long tradition in Bosnia and Herzegovina. According to Nurković (2017), the first grapevines were brought to this area by the Thracians, while there is evidence of grape cultivation and wine production dating back to Illyrian times. Today, viticulture, together with wine production, is considered an important branch of the agricultural and processing industry in Bosnia and Herzegovina. Compared to other crops (e.g. cereals and fodder plants), viticulture employs a larger number of people and achieves higher yields per unit area. The intensive development of viticulture is of undeniable importance for the economic progress of the entire country, especially in rural areas, for various reasons: economic contribution, tourism, sustainability, socio-cultural aspect, support for young producers etc. Although small vineyard areas may limit the economic contribution at the national level, they can have local and cultural benefits for the community. For further progress and planning, it is crucial to be familiar with vineyard areas, varietal structure, plant age, and the potential of different viticultural regions.

The viticulture sector in Bosnia and Herzegovina is dominated by small vineyards, with areas ranging from 0.3 to 0.4 hectares, and a very small number of vineyards exceeding 10 hectares in a single plot. Small vineyards are mostly owned by family farms, and there is little data available on their exact number, as there is still no register of grape and wine producers (Banjanin et al. 2016). According to data from the Ministry of Foreign Trade and Economic Relations of Bosnia and Herzegovina (2018), the number of agricultural estates – grape producers who mainly produce wine – is estimated at around 11,000, the majority of which are small producers for their own consumption and the local market with fluctuating prices. Just over half, i.e. 55%, of the wines produced are white wines, while the remaining part are red wines, and only a very small amount is processed into rosé wines, which accounts for less than 1% (Vukojević et al. 2022). Although many old grape varieties have been abandoned in favour of internationally recognized varieties, an analysis shows that current wine production is primarily focused on high-quality wines made predominantly from native grape varieties such as *Žilavka* (white) and *Blatina* (red). These two varieties are particularly suitable for cultivation in the local climatic conditions and are deeply rooted in local tradition and cultural heritage (Vukojević et al. 2022). Other important indigenous grape varieties that are cultivated here include *Krkošija, Bena, Trnjak, Dobrogostina*, and *Mala Blatina*. The autochthonous Montenegrin majority variety *Vranac* is also very common on the territory of Herzegovina. In addition to these varieties, larger wine producers also produce wines from international grape varieties such as *Cabernet Sauvignon, Merlot, Syrah, Chardonnay, Pinot Blanc, Pinot Noir, Cabernet Franc*, and *Sauvignon Blanc*. The vineyard area in Bosnia and Herzegovina amounts to 4,873 hectares (Figure 1).

The vineyard areas in Bosnia and Herzegovina are commercial plantations. There is no winery that produces its grapes and wine according to the principles of organic farming. Bosnia and Herzegovina has favourable locations with satisfactory agro-ecological and land conditions for the expansion of vineyard areas. In the wine region of Herzegovina, there are an estimated to 20,000 hectares of potential vineyards, while the wine region of northern Bosnia has the potential for about 50,000 hectares of vineyards (Beljo et al. 2018), which is considered a good prerequisite for the expansion of the total vineyard area in Bosnia and Herzegovina.

Wine tourism has been an important part of the wine industry in an increasing number of countries and regions for decades in different ways. The sector is not only important for the local and regional economy, but also preserves heritage, landscape, history, tradition and culture (Oltean and Gabor 2022). Wine tourism could therefore be the key element for the sustainable development of wine regions worldwide.

Carlsen and Charters (2006) have found that the benefits of wine tourism extend beyond the wine cellar, to virtually all sectors of the regional economy, including the urban areas from which most wine tourists originate. Wine, food, tourism and art are the key elements of wine tourism and provide the lifestyle package that an increasing number of tourists aspire to and want to experience (Carlsen 2004). According to O'Neill and Palmer (2004), this form of tourism is recognized as one of the few tourism sectors that is truly concentrated outside of metropolitan areas and therefore plays an important role in regional tourism development, employment, business growth, and corporate investment. In fact, food and wine are often the primary reason for travelling to a particular region and are not necessarily a secondary activity of the visit, as some commentators suggest (Cava Jimenez et al. 2022). Wine tourism is a rapidly growing industry worldwide, attracting over 40 million travellers (Giacosa et al. 2019; Oltean and Gabor 2022). In recent decades, research interest has focused on the changes in consumer markets in which tourism plays significant role (Sun and

Drakeman 2022). Wine tourism, as one of the special interest tourisms, is often associated with relaxation, socialising with friends, and hospitality with travellers wanting to enjoy a diverse rather than monocultural environments (Carmichael 2005; Castillo-Canalejo et al. 2020; Oltean and Gabor 2022).

According to Hall et al. (2000) and Nedelcu et al. (2018), this form of tourism can be defined as tourism that includes visits to vineyards, wineries, wine exhibitions, and wine festivals, where the main motivation of tourists is to experience attractions in the wine-growing region and to consume different wines.

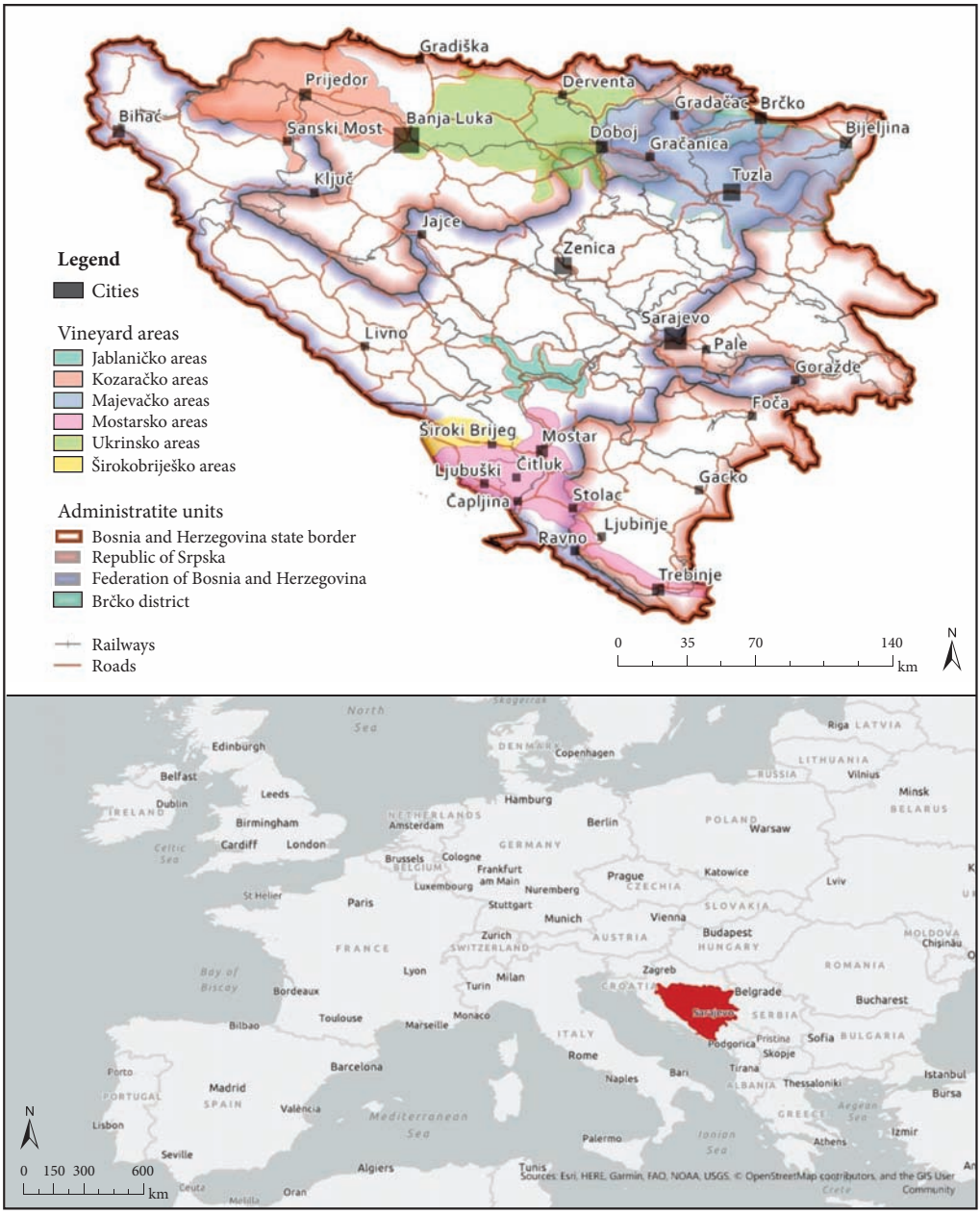

Figure 1: Vineyard areas of Bosnia and Herzegovina (Vukojević et al. 2022).

Wine is an agricultural product that is inherently linked to the rural environment, and wine tourism is closely linked to rural tourism. Wine tourism is most developed worldwide in the form of wine routes, which can be defined as a specific form of promotion agricultural, hospitality and tourism products in a wine region, where family farms together with other legal and natural persons offer their products (primarily wine and homemade brandy, but also other autochthonous products and specialities). On the other hand, as Kerma and Gačnik (2015) note, we can also see paradoxical examples of wine tourism in urban centres outside wine-growing areas.

Wine tourism offers an educational dimension that allows visitors to learn about different grape varieties, winemaking techniques, and the geographical, ethnographic and historical characteristics specific to a particular wine region (Vukojević and Pivac 2022). In addition, the growth of wine tourism plays an important role in positioning and promoting a particular tourist area, establishing its reputation, and creating a competitive advantage in the tourism industry (Hall et al. 2000).

The development of wine tourism enhances rural areas by creating new jobs and reducing migration to urban areas, as well as increasing profits for other traders and producers (Maksimović et al. 2021). Therefore, the involvement of agricultural producers and other stakeholders from rural communities in the development is of great importance given its multifaceted impact.

Participation in wine tourism is of great importance for producers, as it allows them to generate higher income through direct sales that enable immediate payment for their products. Family members are also employed in the off-season when labour in the vineyard and winery is minimal, helping to improve their livelihoods. They can also offer visitors additional services such as the sale of other agricultural products, accommodation, catering and more (Pivac et al. 2020).

Although Bosnia and Herzegovina can look back on a long tradition in viticulture and winemaking, only a few authors have analysed the status and potential for improvement in these sectors. This is all the more true if the context of wine tourism is also taken into account when reviewing the literature. In their study, Vukojević et al. (2021) argue that Bosnia and Herzegovina has considerable potential in both the catering and wine sectors, but the research results show that the country is not well presented abroad and the potential has therefore not yet been fully exploited.

Jalić et al. (2021) analysed the trade exchange of wine products between Bosnia and Herzegovina and the most frequent countries of destination, namely the countries of the former Yugoslavia (Serbia, Croatia, North Macedonia, Slovenia, and Montenegro). These countries account for 60–95% of total trade. The most significant import partner is Serbia with a share of 28.2%, while the largest export partner is Croatia with 52.3% of total exports from Bosnia and Herzegovina. In order to improve the competitiveness of this sector, the authors recommend the application of marketing approaches in production and distribution. They also emphasise that in addition to the production of quality wines, packaging, design, branding and wine names also contribute significantly to the competitiveness of the sector.

Hudelson (2014) analysed wine tourism in Bosnia and Herzegovina and concluded that this country has decisive advantages for its development, including favourable labour and production costs, natural beauty, and the region's ability to produce distinctive wines. The author concludes that most of the problems facing the sector can be solved with sufficient investment of time, money, expertise, and willingness.

Ivanković et al. (2012) analysed the economic feasibility of establishing vineyards on reclaimed land in Bosnia and Herzegovina. They identified suitable areas for reclamation, such as flat terrain and scrubland with sporadic forest vegetation. The authors emphasise that profitable production is achieved under the condition of expected yields and successful wine sales. They also conclude that the applied model is inefficient when it comes to the sale of bulk wine, which is often the case in Herzegovina.

Jahić (2016) analysed the state and prospects of wine tourism and wine routes in the Herzegovina-Neretva Canton and found that this part of Bosnia and Herzegovina has vineyards with an area of 977.8 hectares, with the most commonly cultivated grape varieties being *Žilavka* and *Blatina*. The author identified poor transportation connections between the vineyards, wine cellars and the main urban centres of the canton as a major obstacle to the further development of wine routes.

When it comes to predicting the further development of the sector, it is important to mention the research conducted by Trbić et al. (2021), which analyses the impact of climate change on grapevines in Bosnia and Herzegovina. The authors found that, in addition to the predominantly negative effects of climate change on agricultural production, positive effects on grapevines can also be expected due to a longer growing season as a result of higher temperatures. This can lead to higher yields and greater ripening potential as

heat storage is improved. The authors also predict the introduction of new grape varieties in the future, which are characteristic of regions with drier and warmer climates and therefore offer greater opportunities for the development of the sector.

The aim of this study is to examine and analyse the trends of viticulture and wine production in Bosnia and Herzegovina in terms of production capacities and market conditions during the observed period. The study also aims to analyse the current situation and explore opportunities for the development of wine tourism (in terms of expanding the existing tourist offer, the types of wine produced, development in the technical and technological sense) as an additional segment that can contribute to the better positioning of both sectors and the diversification of wine producers' income.

2 Material and methods

In order to determine the development trends in viticulture and winemaking in terms of production capacity and market conditions during the observed period, methods were used as primary analytical tools in addition to basic descriptive statistical indicators. Trend modelling using trend functions was carried out with Microsoft Excel.

The field research was conducted in a sample of 34 wineries (33 from the Republic of Srpska and one from the Brčko District), out of a total of 38 identified in this area. The data was collected using an electronic questionnaire in the period from August to October 2020. The structure of the questionnaire used can be divided into two parts. The first part of the questionnaire (approximately 57%) consisted of questions focussing on the production capacity of vineyards and wineries, the production structure, and the production results achieved. The second part of the questionnaire analysed the commitment to wine tourism and the structure of the tourism offer. Based on the data collected and the application of cluster analysis techniques (Kruzlicova et al. 2013; Stevanović et al. 2016; Birovljev et al. 2017; Stevanović et al. 2018; Zapryanova 2019; Svoboda et al. 2020), groups of wineries with similar characteristics were formed within each cluster. For each of the 34 observed objects, 26 different qualitative variables (categorical variables) were considered, resulting in an initial matrix of size 34 × 26. The hierarchical clustering method was used, which involves the calculation of similarity measures for all observation units and the subsequent formation of groups. The groups were formed using agglomerative techniques, with squared Euclidean distance serving as a measure of similarity. As these were qualitative variables, the correlation coefficient between the r-th and s-th rows of the matrix was calculated according to the formula (Kovačić 1994):

$$q_{rs} = \frac{\frac{f_{rs}}{K} - \left(\frac{p}{K}\right)^2}{\frac{p}{K}\left(1 - \frac{p}{K}\right)}$$

Where:
K – the number of artificial variables resulting from the sum of all modalities out of a total number of p variables used;
f_{rs} – the number of qualitative variables for which the observed two rows contain the same quality (pair 1-1), and the squared Euclidean distance was calculated using the following formula:

$$d_{rs}^2 = 2K(1 - q_{rs}) = 2K\left(\frac{p}{K} - \frac{f_{rs}}{K}\right) = 2(p - f_{rs})$$

The statistical software Statistica 12 was used for data analysis purposes.

3 Results and discussion

In accordance with the defined research objectives, the results of the research are presented in two parts. In the first part, the state of viticulture and winemaking in Bosnia and Herzegovina was analysed, while in the second part a cluster analysis was used to group the wineries according to commonalities in terms of wine tourism development.

3.1 The state of viticulture and the wine market in Bosnia and Herzegovina

Viticulture and winemaking in Bosnia and Herzegovina are underdeveloped and characterised by fragmentation and a large number of small agricultural producers. As such, they have a predominantly local or regional market character and contribute only weakly to both the country's own development and its high potential. Its international reputation is underdeveloped (Ivanković et al. 2018).

According to the International Organization of Vine and Wine (OIV) in 2021, Bosnia and Herzegovina had a vineyard area of 4,873 hectares, putting it in 62nd place in the world ranking. The countries with the largest vineyard area are Spain with 1,123,644 hectares, followed by China (797,935 ha), France (752,837 ha), Italy (675,818 ha), and Turkey (417,041 ha) (Yüzbaşioğlu 2021).

In the period from 2001 to 2020, the average vineyard area in Bosnia and Herzegovina was 4,904.75 hectares, while the average yield in the same period was 5,540.13 kg/ha (Figure 2).

Vineyard area did not vary significantly in the period mentioned, as the coefficient of variation of 13.30% shows. The development trend of vineyard area is defined by a polynomial equation (fourth-degree polynomial) which accounts for approximately 60% of the total variation ($R^2 = 0.6056$). Grape yields showed a slightly higher coefficient of variation (33.94%), and the increase in vineyard area can be defined by a polynomial equation (second-degree polynomial) with a high coefficient of determination ($R^2 = 0.9224$). In contrast to the vineyard area, which showed no growth in the second half of the period, but rather the opposite, grape yields increased with occasional fluctuations from 2010 onwards. Some of the possible reasons for this are a more efficient implementation of agrotechnical measures and the introduction of more productive grape varieties in the production process. In addition to the factors mentioned above, grape yield is significantly influenced by inter-row and intra-row spacing in newly established vineyards coming into production, harvest conditions, grape variety, age of grapevines, climatic conditions, and more (Jones et al. 2005; Risco et al. 2014; Irimia et al. 2018; Perria et al. 2022). Based on the predicted values of the trend line and the most recent yield values in the last years of the observation period, it is realistic to expect yields of over 8 tons per hectare in the next period.

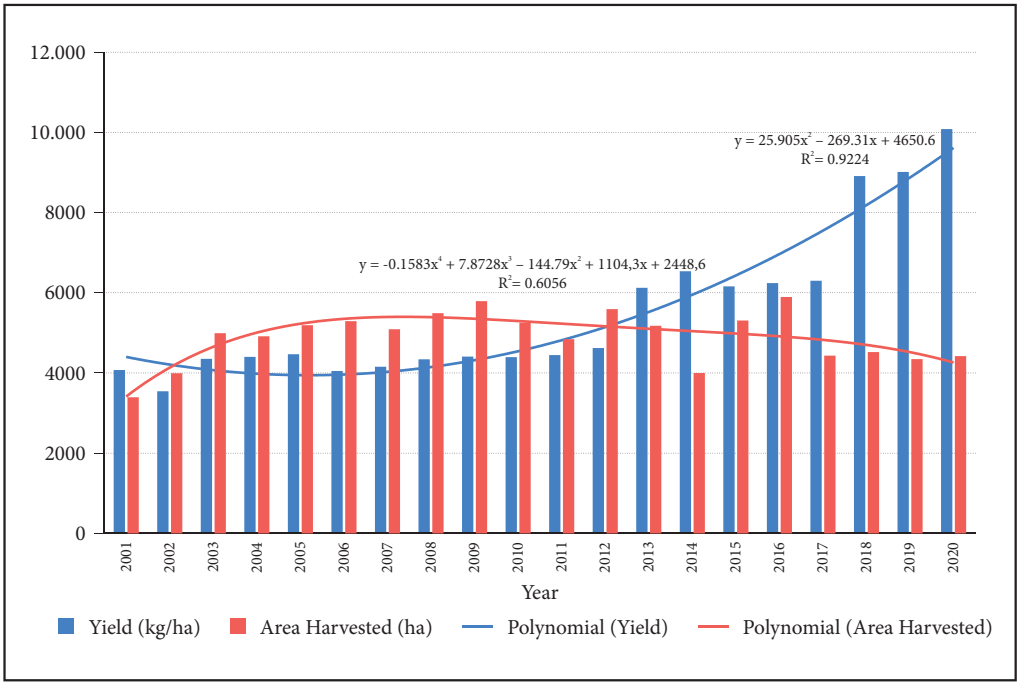

Figure 2: Vineyard areas and grape yields in Bosnia and Herzegovina 2001–2020 (provided by FAOSTAT).

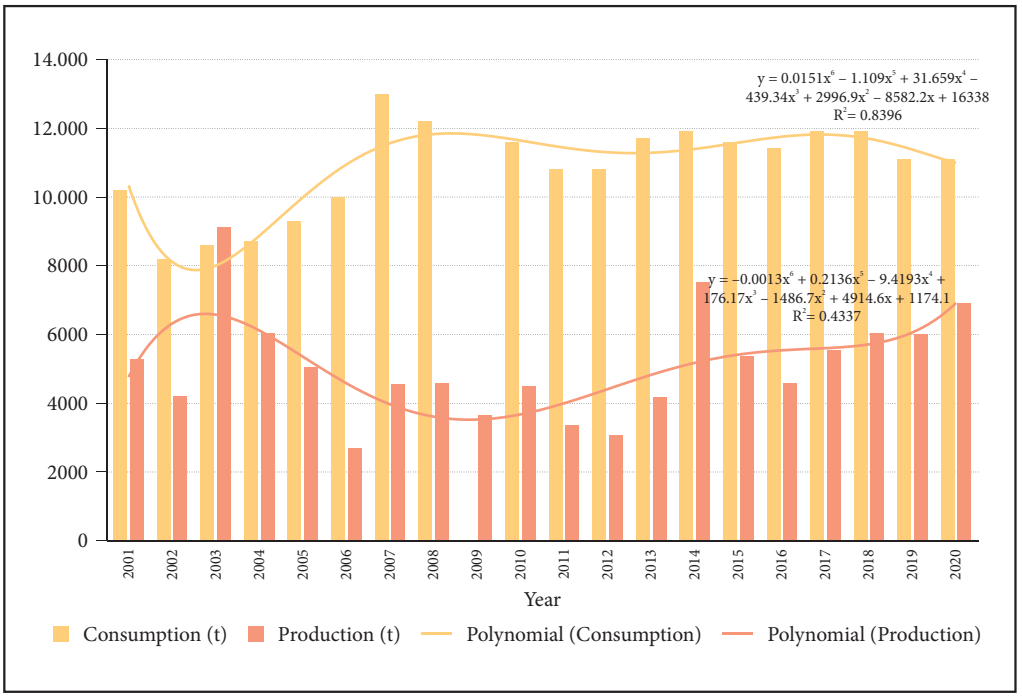

Figure 3: Production and consumption of wine in Bosnia and Herzegovina 2001–2020 (provided by FAOSTAT, OIV).

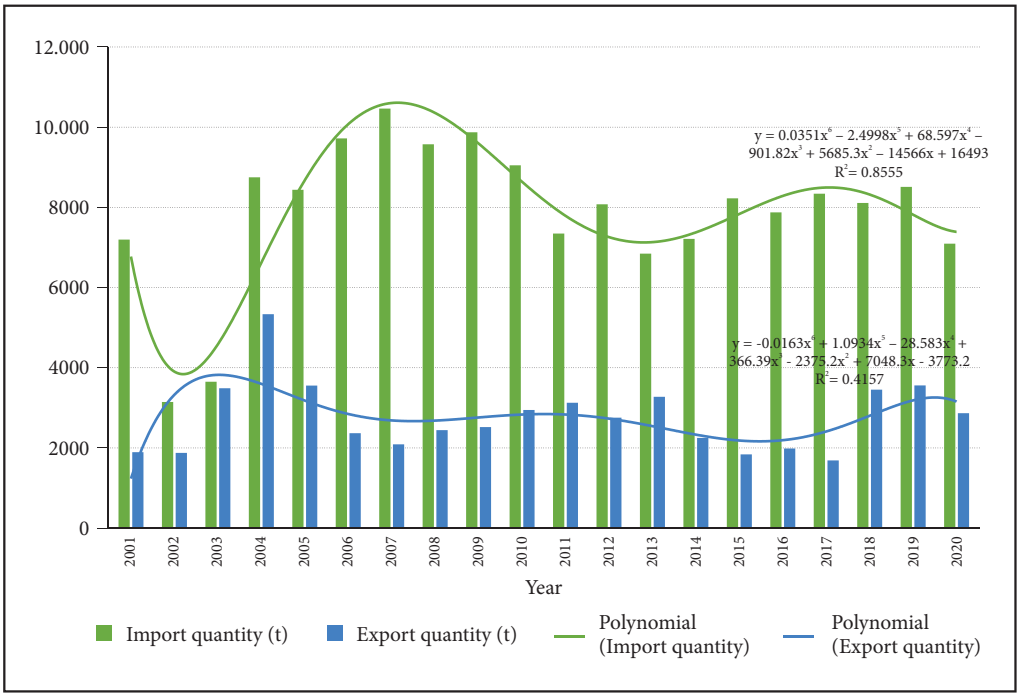

Figure 4: Wine export and import volumes, Bosnia and Herzegovina (2001–2020) (provided by FAOSTAT).

According to the Food and Agriculture Organization (FAO), wine production in Bosnia and Herzegovina fluctuated from year to year during the past twenty-year period (2001–2020), reaching an average of 5,112.62 tons with a coefficient of variation of 30.51% (Figure 3).

The lowest production in this period was recorded in 2006 with a volume of 2,695 tons, while the year with the highest production volume was 2003 with 9,125 tons. Due to the frequent fluctuations in production volumes during the observed period, the trend function (6th-degree polynomial) has a relatively low coefficient of determination ($R^2 = 0.4337$) which makes it difficult to make accurate predictions for wine production in the coming period.

In the same period, wine consumption in Bosnia and Herzegovina was twice as high as production, averaging 10,890 tons, according to data from the OIV. Wine consumption showed less fluctuation, as evidenced by the coefficient of variation of 12.13%. The trend function that best describes the development trend is a sixth-degree polynomial which explains about 84% of the total variations.

From the available consumption data, it can be concluded that the wine market is relatively small. For comparison, wine consumption in Bosnia and Herzegovina in 2020 accounted for only 0.48% of total wine consumption in France, 0.46% in Italy and 0.56% in Germany, which are among the largest wine consumers on the European continent. Although the wine sector can be considered relatively small, it is important for western and southern parts of Herzegovina due to its geographical distribution in several municipalities and cities of the country (Goncharuk and Figurek 2017).

The average amount of imported wine in the mentioned period (2001–2020) was 7,879.46 tons, while the average export was 2,771.04 tons (Figure 4).

The coefficient of variation for wine imports was 23.17%, while the trend function that best describes the development trend is a sixth-degree polynomial which accounts for approximately 86% of the total variation ($R^2 = 0.8555$). Wine exports showed a higher variability (CV = 31.53%), and the trend function explains only 41.57% of the total variations, making it difficult to project future values.

The fact that wine consumption is twice as high as production, with an average import-export coverage of about 35.17%, and that approximately 54.2% of the volume of wine produced is exported, is a positive signal for domestic wine producers to increase production volumes without significant risks in terms of product placement.

Another important factor for the increase in wine production and the development of wine tourism is the fact that the neighbouring countries Croatia and Slovenia have a significantly higher per capita wine consumption, and tourists from these countries like to visit Bosnia and Herzegovina. According to the data from OIV (2021), the per capita consumption of wine in Slovenia is 37.3 litres, in Croatia 25.8 litres, in North Macedonia is 15.0 litres and in Serbia 13.3 litres, which is nine, six and three times higher, respectively, than in Bosnia and Herzegovina, where the average per capita consumption is 4 litres. It is important to mention that the potential for prosperity on the international tourism market requires a precise definition of the tourism product and a well-structured tourist destination that is compatible with international standards and adequately supported by marketing measures (Tasić 2018).

Since wine tourism is multidimensional by nature, it is necessary to recognise and connect all involved stakeholders such as farms, wineries, tourist destinations, private and public enterprises and associations, environmental NGOs, protected areas management, cultural heritage institutions, government and local self-government units through clustering and involve them in marketing planning and the process of developing a wine tourism destination (Popović and Živanović-Miljković 2012).

Various wine-related events can contribute to the attractiveness and quality of wine tourism. In this regard, it is important to strive to improve existing events of this type and promote them appropriately, as well as organise new events in the coming period.

3.2 Cluster analysis of production and tourism capacities of the selected wine cellars

The field research on the production and tourism potentials of wine cellars was conducted by analysing wineries on the territory of the Republic of Srpska, one of the entities of Bosnia and Herzegovina, and the Brčko District. The individual differences between these wineries, both in terms of production capacities and the structure of the tourist offer, make it a challenge to classify them into a smaller number of groups due to the numerous criteria variables taken into account. Therefore, cluster analysis was applied to identify homogeneous groups of wineries, taking into account a large number of criteria for their comparison, as shown in the Table 1.

By applying cluster analysis and identifying homogeneous groups, it is possible to gain a clearer understanding of the existing differences between them and to recognise the limitations and shortcomings of members belonging to specific groups. The following dendrogram illustrates the linking of wine cellars into groups.

The distances between the individual groups were determined using the Complete Linkage method. There are no standard procedures for determining the optimal number of clusters that guarantee optimal results. The distance between the groups being merged in each step is a useful indicator. It allows the number of

Table 1: The structure of the variables used for the cluster analysis.

Question	Variable type	Number of possible answers
Q1: Legal form of the winery	categorical variables	4
Q2: Employment of trained workers (oenologists and agronomists)	categorical variables	2
Q3: Previous experience in the wine industry	categorical variables	3
Q4: Planned capacity expansion	categorical variables	2
Q5: Method of wine sales	categorical variables	3
Q6: Training needs for wine tourism (different seminars)	categorical variables	2
Q7: Equipped tasting rooms – facilities	categorical variables	2
Q8: Accommodation services	categorical variables	2
Q9: Inclusion in tourism packages	categorical variables	2
Q10: Visitor structure	categorical variables	2
Q11–Q16: Accessibility and availability of tourism services	categorical variables	2
Q17–Q26: Methods of winery promotion	categorical variables	2

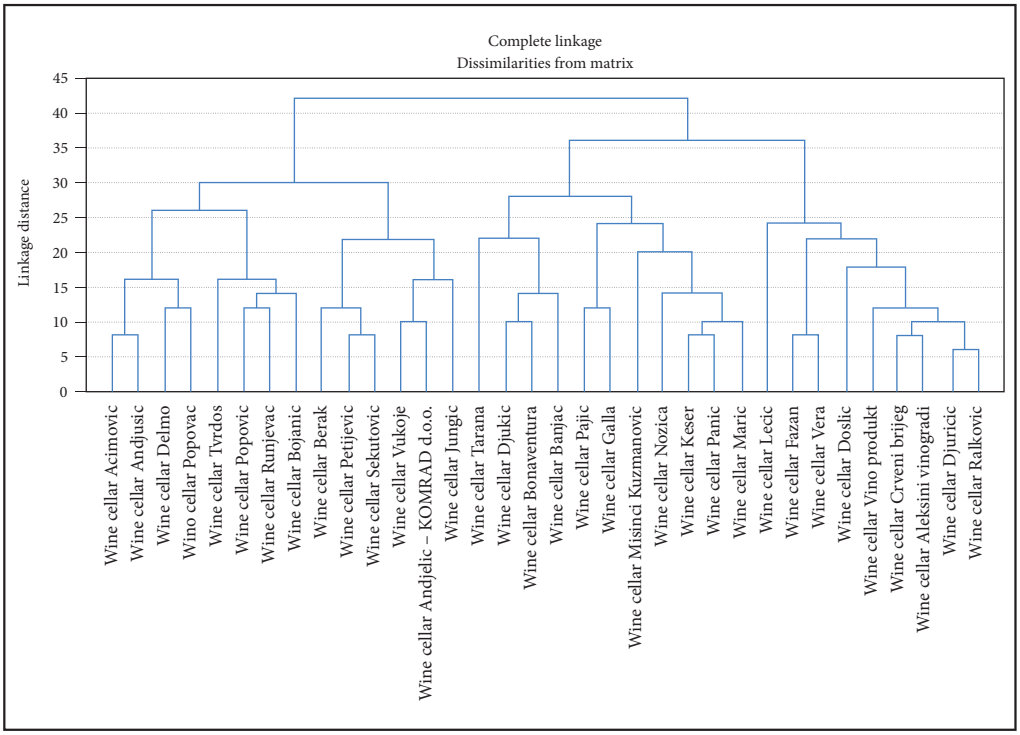

Figure 5: Dendrogram of the linking of wine cellars into groups.

groups to be adjusted by observing the step when the aggregation distance exceeds a certain threshold (Gatti et al. 2002) or when it suddenly increases its value compared to the existing trend, as is the case in this study. Figure 5 shows that the linkage distance jumps from a value of 30 to 36 in the 32nd step. Therefore, the merging process was stopped at this step.

Based on the information provided, three clusters were determined as the optimal number, the structure of which is shown in Table 2.

It can be seen that the most extensive cluster is Cluster 1, which comprises 41.18% of the wineries. This is followed by Cluster 2 with 32.35%, while the smallest cluster is Cluster 3 with 9 wineries (26.47%).

Regarding the variables used, Cluster 1 has a perfect or almost perfect homogeneous structure. For example, more than 3/4 of the wineries (78.57%) belonging to this cluster have an annual wine production of

Table 2: Structure of the obtained clusters.

The name of the wine cellar	Cluster 1		Cluster 2		Cluster 3	
	Aćimović	Bojanić	Tarana	Kuzmanović	Lečić	Crveni Brijeg
	Anđušić	Berak	Đukić	Nožica	Fazan	Alexa's vineyards
	Đelmo	Petijević	Bonaventura	Keser	Vera	Đuričić
	Popovac	Sekulović	Banjac	Panić	Dostić	Ratković
	Tvrdoš	Vukoje	Pajić	Marić	Vino produkt	_____
	Popović	Andjelić	Gala	_____	_____	_____
	Runjevac	Jungić	_____	_____	_____	_____

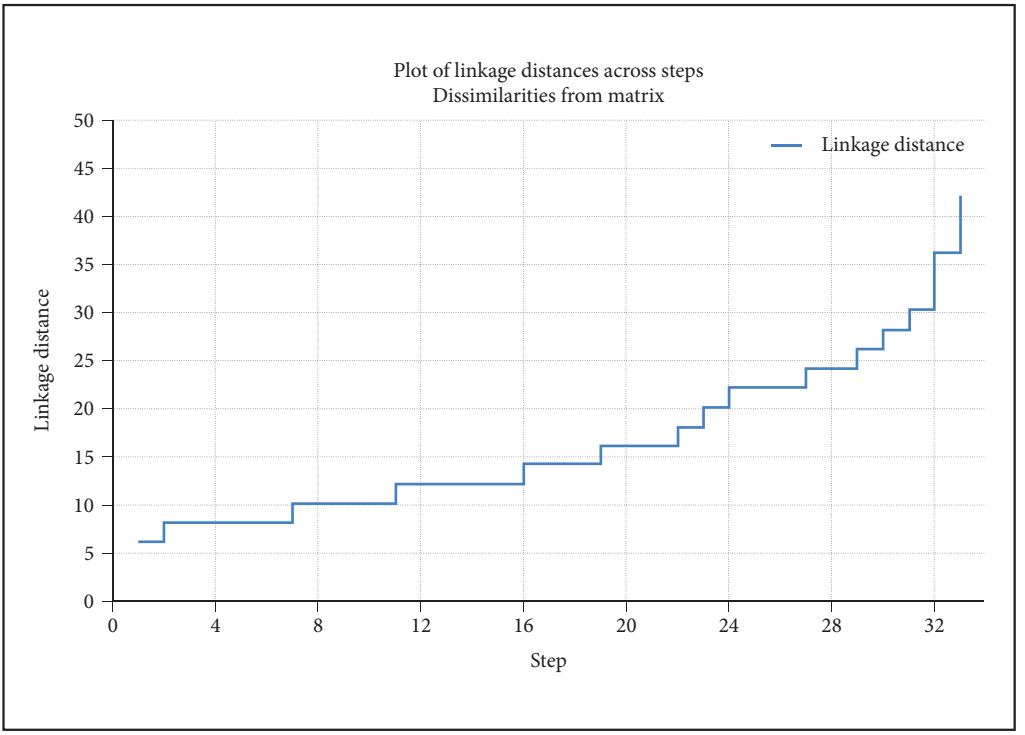

Figure 6: Plot of the linkage distances over steps.

more than 15,000 litres and at least 1 ha of vineyards (85.71%). Most of the wineries in the first cluster (85.71%) belong to the eastern part of Herzegovina region (south of the Republic of Srpska). All owners of wineries belonging to the first cluster are trained in wine tourism (through various seminars organised by local and state institutions and international organizations) and have vineyards and wineries open for visits (100%). In addition, all wineries belonging to this cluster promote their products and services and are open for tastings and sales, while 92.86% of them have a tasting room (Table 3). In terms of promotion methods, 92.86% of the wineries belonging to this cluster use internet presentations (own websites and other types of internet presentations), TV and radio advertising for promotion and participate in various wine fairs.

In addition, more than 3/4 of the wineries in Cluster 2 (90,91%) are involved in some of the various tourism arrangements and produce their own brochures as one of the advertising methods of promotion. In Cluster 2, 81.82% of wineries have a smaller annual wine production of 30,000 litres, while 63.64% of the wineries have a smaller production of 15,000 litres. Cluster 2 also shows a homogeneous structure for certain variables. In terms of visitor structure, 90.91% of wineries are visited by domestic tourists, and the same percentage of wineries are open for visits and tastings and use available methods to promote their services, including participation in fairs. All wineries have a tasting room, but none of them offer accommodation

Table 3: Characteristics of production and tourism in the clusters obtained.

Indicator	Relative participation (%)		
	Cluster 1	Cluster 2	Cluster 3
Vineyard area (<1 ha)	14.29	27.27	33.33
Vineyard area (1–3 ha)	50.00	54.55	44.44
Vineyard area (>3 ha)	35.71	18.18	22.23
Annual wine production (<15,000 l)	21.43	63.64	77.78
Annual wine production (15,000–30,000 l)	28.57	18.18	0.00
Annual wine production (>30,000 l)	50.00	18.18	22.22
Legal form (limited liability company – LLC)	64.29	27.27	33.33
Legal form (family farm)	35.71	18.18	55.56
Legal form (sole proprietorship and cooperative)	0.00	54.55	11.11
Employed trained staff (oenologists and agronomists)	50.00	45.45	66.67
Experience in the domestic wine industry	14.29	27.27	0.00
Professional experience in the foreign wine industry	14.29	0.00	44.44
No previous experience in the wine industry	71.42	72.73	55.56
Type of wine sales (direct)	42.86	81.82	55.56
Type of wine sales (direct + distributor)	57.14	18.18	44.44
Training for wine tourism activities	100.00	27.27	44.44
Availability of tasting rooms	92.86	100.00	22.22
Inclusion in tourist packages	78.57	18.18	0.00
Visitor structure (domestic visitors)	50.00	90.91	88.89
Openness to guided tours	100.00	90.91	11.11
Openness to tastings and sales	100.00	90.91	11.11
Sale of other products	71.43	9.09	11.11
Hospitality services	42.86	45.45	0.00
Meetings, weddings, and similar events	50.00	18.18	0.00
Accommodation and lodging services	35.71	0.00	11.11
Wine cellars without service promotion	0.00	9.09	0.00
Participation in (trade) fairs/exhibitions	92.86	90.91	66.67
Promotion through self-produced brochures	78.57	63.64	22.22
Brochures from tourism organizations	64.29	18.18	11.11
Promotion via email	21.43	9.09	0.00
Internet presentations	92.86	36.36	33.33
Information boards	50.00	9.09	11.11
Wine magazines	71.43	9.09	22.22
TV and radio advertising	92.86	18.18	22.22
Other advertising methods	7.14	27.27	0.00

services or have experience in the foreign wine industry. The most common sales method of the wineries in this cluster is direct wine sales (81.82%). About 3/4 of the wineries belonging to Cluster 2 (72.73%) are located in the northern part of the Republic of Srpska. More than 3/4 of the wineries in Cluster 3 (77.78%) have an annual wine production of less than 15,000 litres. All members of this cluster state that they promote their products and services by available means, mainly by participating in fairs (2/3 of the total), while they are usually not open for visits, tastings and sales. They do not offer accommodation services, do not sell other goods and have a small number of informative signs (11.11%). In this cluster, there are no wineries with experience in the domestic wine industry, nor do they provide hospitality services, organization of meeting, weddings and similar services.

From the data presented, it can be concluded that the most frequent producers in Cluster 1 have larger production capacities, while the opposite is true for Cluster 3. Cluster 1 differs significantly from the others, as 71.43% of wineries also sell other goods on their premises. The members of Cluster 1 are also distinguished by a high-quality and comprehensive tourist product as well as various methods of promoting it. The fact that all members of Cluster 1 are trained in wine tourism certainly contributes to this. In contrast, the members of Cluster 2 are characterised by the fact that they are mainly involved in direct wine sales without selling other goods. The promotion of products and services is not particularly pronounced. They rely mainly on wine fairs for promotion, occasionally accompanied by their own brochures, while advertising through wine magazines, informative signs, email, TV and radio is less common. Apart from the characteristics already mentioned, Cluster 3 is characterised by the fact that they mainly sell wine to domestic visitors without offering other goods or additional tourist services. It is often wholesale or bulk wine sales, which means that value maximization is not achieved by bottling and marketing the final product on the domestic and foreign markets. About 2/3 of the members of Cluster 3 are individuals, who are usually registered as family agricultural households for viticulture and wine production.

4 Conclusion

Despite favourable locations with satisfactory agro-ecological and land conditions, the vineyard area in Bosnia and Herzegovina has not increased significantly in the twenty-year period observed. It fluctuated around an average of 4,904.75 hectares. The negative trends in the viticulture and winemaking sector have causes that can be found in the entire production, processing, and wine marketing chain.

The wine market in Bosnia and Herzegovina is characterised by consumption that is twice as high as production and is less than 0.5% of wine consumption in France and Italy, the largest European consumers. The average coverage of imports by exports is 35.17%.

The products imported into the domestic market receive considerably more support in exporting countries, which creates additional competitive pressure. In addition, the sector's competitiveness in foreign markets is hampered by numerous non-tariff protection mechanisms such as regulations on quality and food and safety in the environment.

The application of cluster analysis allowed for a detailed analysis of the state of both production capacity and wine tourism in the studied area, which is a key prerequisite for its further improvement. The results indicate the existence of heterogeneous production systems, in particular three different groups of wine producers that differ significantly from each other. Given the different structure of wineries in terms of production and tourism capacities, the possibility of diversifying agricultural and rural policy measures must be examined in order to contribute to a more intensive development of viticulture and winemaking and ultimately to achieve a higher level of competitiveness. A diversification of measures to improve the situation in the wine tourism sector would also encourage the development of the tourist offer for each wine producer.

Producers registered as family agricultural households (mostly Cluster 3) have limited sources of support. As individuals, they are often unable to apply for funding from European and other development programmes for viticulture, wine tourism and the improvement of rural tourism. They are mostly dependent on the support of state and local institutions for vineyard production, which in combination with their own resources is not sufficient to increase competitiveness. This key limiting factor needs to be addressed through additional local and state support. For producers belonging to Cluster 2, it is necessary to organise educational (training) activities on wine tourism and activate additional promotional activities and offer

more complex products and services through supportive measures. Within each of the mentioned clusters, there are opportunities to improve the existing level of production and tourism capacities. However, the greatest impact is possible if the restrictions mentioned for Cluster 1 are lifted.

Factors limiting the research are the narrowing of the research focus to only one entity in Bosnia and Herzegovina (together with Brčko District) when it comes to cluster analysis on the state of wine tourism. Therefore, it would be desirable to include the wineries of another entity in Bosnia and Herzegovina (the Federation of Bosnia and Herzegovina) in further research in order to get a clearer and comprehensive picture of wine tourism at the state level and the possibilities of improving its development.

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LAND USE CHANGES IN SOUTHERN CROATIA (DALMATIA) SINCE THE BEGINNING OF THE 20TH CENTURY

Anđela Vrkić, Ante Blaće

GEOPORTAL, CROATIAN GEODETIC ADMINISTRATION

Ba(v)ljenac islet in Šibenik-Knin County. Intensive dry stone walling occurred in the late 19th century due to the cultivation of vineyards, resulting in its present-day nickname, »Fingerprint Island«.

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Land use changes in Southern Croatia (Dalmatia) since the beginning of the 20th century

ABSTRACT: This research analyzed land use changes in Southern Croatia over the past 120 years. The methodological approach employed analysis and chronological comparison of archival and statistical data, and geoprocessing of the Corine Land Cover geodatabase. In the period spanning from 1900 to 1945, agriculture was the main activity, accompanied by a notable decline in vineyards. The subsequent era, from 1945 to 1991, was characterized by the dominance of rapid industrialization, onset of land abandonment, and the reversion of former agricultural areas to natural vegetation. Since 1991, the trend of land abandonment and deruralization has persisted and intensified. As a result, shrubs and forests now claim the largest share of the researched area, solidifying a new landscape configuration.

KEYWORDS: land use, Southern Croatia, agriculture, land abandonment, succession of vegetation

Spremembe v rabi tal v južni Hrvaški (Dalmaciji) od začetka 20. stoletja

POVZETEK: Članek proučuje spremembe v rabi tal v južni Hrvaški v zadnjih 120 letih. Uporabljeni metodološki pristop vključuje analizo in kronološko primerjavo arhivskih in statističnih podatkov ter obdelavo prostorskih podatkov iz podatkovne zbirke Corine Land Cover. Med letoma 1900 in 1945 je bila glavna gospodarska dejavnost na tem območju kmetijstvo, značilen je bil tudi precejšen upad vinogradov. Obdobje med letoma 1945 in 1991 so zaznamovali prevlada hitre industrializacije, začetek opuščanja zemljišč in zaraščanje nekdanjih kmetijskih površin. Od leta 1991 se nadaljuje in krepi trend opuščanja zemljišč in deruralizacije. Posledično danes na večini proučevanega območja prevladujeta grmičevje in gozd, ki spreminjata podobo pokrajine.

KLJUČNE BESEDE: raba tal, južna Hrvaška, kmetijstvo, opuščanje zemljišč, ekološka sukcesija

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1 Introduction

Land use is a fundamental human activity, with diverse needs and requirements that vary across different regions of the Earth's surface (Ramankutty et al. 2006). Almost all of the Earth's surface have been altered, either directly or indirectly, by anthropogenic activities, particularly in the context of modern socio-economic development. The greatest impact is visible in areas that are permanently or intermittently inhabited, i.e. in the areas most economically valued and utilized (Marušić 2017). Land use and land cover changes (LULCC) stand out in recent studies as the two central processes through which human influence on the environment is most evident (Lambin et al. 2000). Originally rooted in the natural sciences, the study of LULCC changes now embraces an interdisciplinary approach due to the intricate interaction between humans and their environment. Land cover refers to biophysical structures on Earth's surface and just below it (Lambin et al. 2006). Remote sensing methods such as satellite images and photogrammetry are primarily used in land cover studies (Alqurashi and Kumar 2013; Colditz et al. 2014; Pricope et al. 2019; Buchner et al. 2020; MohanRajan et al. 2020; Zhu et al. 2022; Chen 2023). Unlike land cover, which is biophysically determined, land use is more complex defined by human activities aimed at creating, altering, or maintaining specific land covers (FAO 1998). The methodological approach is broader, encompassing remote sensing, cadastral data, fieldwork, surveys, agricultural statistics, and more (Meiyappan and Jain 2012; Lieskovský et al. 2018; Liu et al. 2018; Ettehadi Osgouei et al. 2022; Wang et al. 2022). In land use research smaller spatial units such as counties are usually studied, while land cover research is carried out for larger areas like countries or even continents. However, land use and land cover are used interchangeably, and the distinction between them often diminishes (Foški et al. 2018).

Large portion of land is devoted to agricultural production, currently covering approximately 43% of the Earth's surface (Ramankutty et al. 2018). But agriculture is marked by two opposing processes: the expansion of agricultural areas driven by the demand for agricultural products (food) and the abandonment of agricultural areas, especially in developed countries (Levers et al. 2018). Although significant urbanization took place globally in the 20th and 21st centuries, large areas continue to serve agricultural production.

Studies on land use changes on the territory of Southern Croatia were relatively rare, and often limited to smaller spatial units such as microregions, settlements and islands (Blaće 2014; Durbešić and Fuerst-Bjeliš 2016; Blaće 2017). Those studies often revolved around landscape changes and relied on data from cadastres, old maps, and agricultural censuses. Recent research has incorporated GIS technology. Šetka et al. (2021) analysed land use changes in the Lower Neretva river area (a region within Southern Croatia) using satellite imagery for the period from 1990 to 2020. Subsequently, they simulated LULCC changes in the same area up to 2035 based on various criteria (Šetka et al. 2023). In contrast, numerous studies have dealt with land use changes in other Mediterranean areas, such as parts of Italy (Falcucci et al. 2007), Spain (Millington et al. 2007; Cervera et al. 2019; Delgado-Artés et al. 2022), Mediterranean coast of France (Abadie et al. 2018) and Greece (Tzanopoulos and Vogiatzakis 2011; Schaich et al. 2015; Kefalas et al. 2019; Dimopoulos and Kizos 2020; Kefalas et al. 2020; Chouvardas et al. 2022). Coastal areas exhibit an increase in built-up areas at the expense of former agricultural and forested land, while inland regions often witness the conversion of agricultural land into urban areas and forests (Di Fazio et al. 2011; Salvati et al. 2014; Gallardo et al. 2023). Conversely, certain areas experience an expansion of agricultural land (Ruiz-Benito et al. 2010; Gemitzi et al. 2021; Gallardo et al. 2023) and peri-urban zones (Ustaoglu and Aydınoglu 2019). Additionally, agricultural land tends to become increasingly fragmented (Topal and Konakoğlu 2023). Despite variations in chronological scope and methodologies among these studies, they collectively underscore similarities in land use dynamics across diverse Mediterranean regions.

The paper aims to analyze land use changes in Southern Croatia from the early 20th century to the present, to quantify these changes and identify the most important drivers. This research fills the gap in comparison with other Mediterranean countries where LULCC studies are numerous. Our main hypothesis is that agricultural areas prevailed until the mid-20th century, while today the largest part of the land is covered by shrub/macchia and forest in various stages of development. These changes directly and indirectly reflect the large socio-economic shifts that occurred in Southern Croatia during the studied period and even indicate some environmental changes, such as forest fires.

2 Research area and methods

2.1 Research area

The research area, Southern Croatia, refers to the four southernmost Croatian counties: Zadar, Šibenik-Knin, Split-Dalmatia and Dubrovnik-Neretva (Figure 1, Table 1). This county division has been in place since 1997. However, considering the territorial changes during the 20th century, it was necessary to align the previous territorial units, which existed in the research area before 1997, with today's county boundaries. Southern Croatia is nearly coterminous with the historical region of Dalmatia, which was a territorial until 1918 and today exists only as a vernacular region.

The dominant geological features in Southern Croatia are limestone and dolomite layers, resulting in prevalent karst landforms and lack of arable land. Hypsometrically, the majority of the land lies at elevations up to 500 meters above sea level (Magaš 2013). Agricultural activities primarily took place in dolomite and flysch zones, while proper karst areas composed of limestone were used for grazing. Southern Croatia exhibits a varied climate, with temperate, warm, humid conditions featuring hot summers (Cfa) in the hinterland and Mediterranean climate with hot summers (Csa) along the coastline and islands. These climate and pedological differences reflect specifies of the agricultural production. The coastal regions and islands are renowned for their cultivation of vines and olives, while the hinterland has been more suitable for arable farming and livestock cultivation (Maleš and Mladar 1996). Therefore, the predominant land use categories throughout the studied period were pastures, ploughfields, vineyards, orchards, and olive groves, accompanied by the prevailing land cover of shrubs and forests.

2.2 Materials and methods

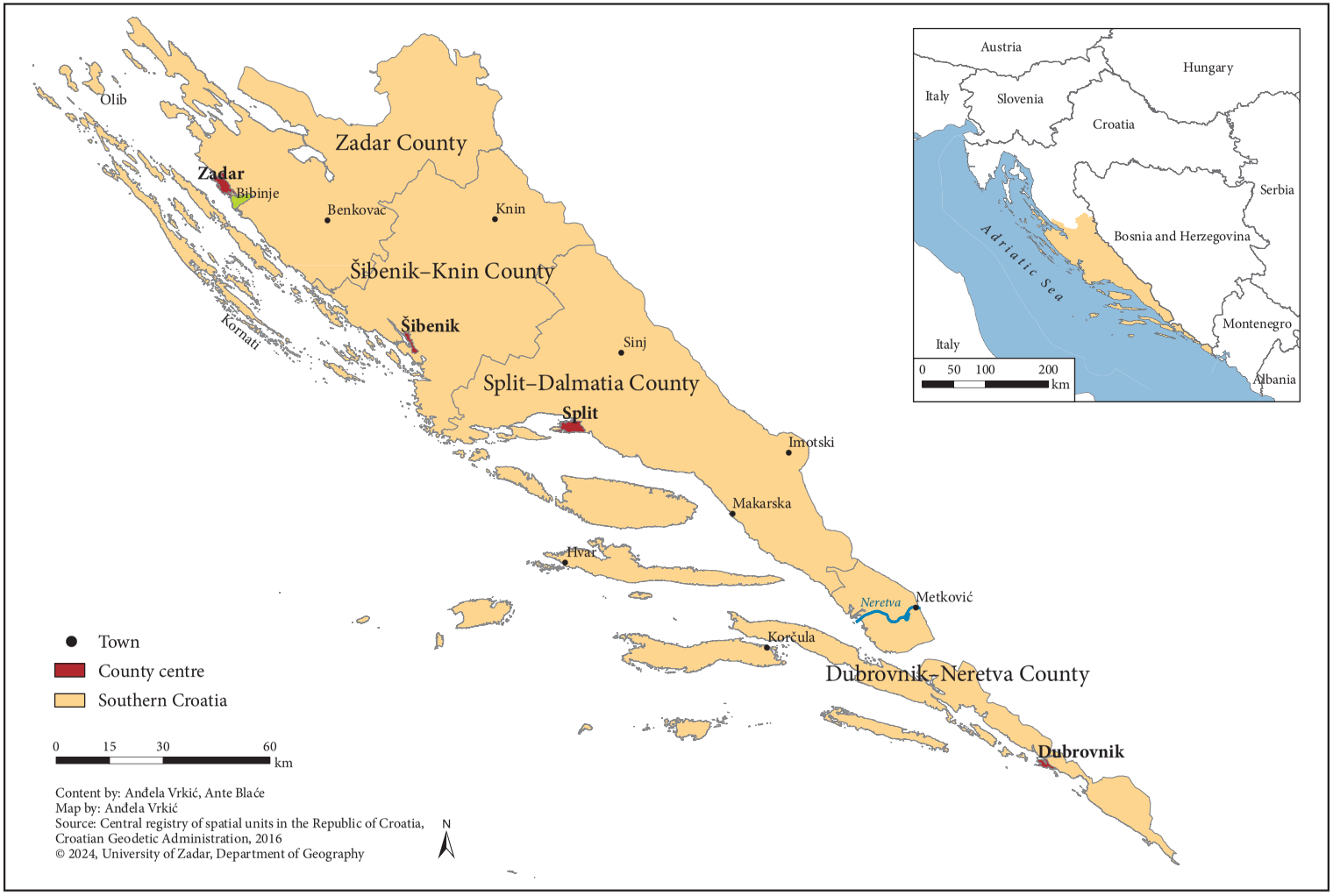
For the purpose of this research, various data sources related to land use during the 20th and 21st centuries were collected and compared. Due to variations in methodologies across different sources and time periods, some categories were adapted to suit better overall research.

For the period from 1900 to 1945, the main source used was the *Općinski rječnik za kraljevine i zemlje zastupane u Carevinskom vijeću* (C. KR. središnja … 1908). This source was processed based on the results of the national census conducted on December 31, 1900, reflecting the land use situation in 1896. Until 1950s, there were no more systematic census and data from the statistical reports on land use for 1921 and 1929 were utilized (Obrađena zemlja … 1924; Kolar Dimitrijević 1990). Subsequently, data from the Statistical yearbooks of the Federal/Socialist Republic of Yugoslavia during the 1945–1991 period were consulted (provided by Savezni zavod za statistiku). The Statistical yearbooks of Dalmatia (1976–1987) were used to illustrate land categories in 1970 and 1980 (provided by Zavod za društveno planiranje Zajednica Općina Split). It is important to note that data from the statistical yearbooks should be interpreted with caution

Table 1: Southern Croatia's counties, number of inhabitants and population density in 2021 (provided by the Croatian Bureau of Statistics 2022).

County	Area (km^2)	Population in 2021	Population density (inhabitants per km^2)
Zadar	3,646	160,340	44.0
Šibenik-Knin	2,984	96,624	32.4
Split-Dalmatia	4,540	425,412	93.7
Dubrovnik-Neretva	1,781	115,862	65.1
Total	12,951	798,238	61.6

Figure 1: Research area – Southern Croatia (Dalmatia) and localities mentioned in the text. ➤ p. 53


Olib
Zadar County
Zadar
Bibinje
Benkovac
Knin
Šibenik–Knin County
Šibenik
Kornati
Sinj
Split–Dalmatia County
Split
Imotski
Makarska
Hvar
Neretva
Metković
Korčula
Dubrovnik–Neretva County
Dubrovnik
Town
County centre
Southern Croatia
0 15 30 60
km
Content by: Anđela Vrkić, Ante Blaće
Map by: Anđela Vrkić
Source: Central registry of spatial units in the Republic of Croatia, Croatian Geodetic Administration, 2016
© 2024, University of Zadar, Department of Geography
N
Austria
Hungary
Italy
Slovenia
Croatia
Serbia
Bosnia and Herzegovina
Adriatic Sea
Montenegro
Italy
Albania
0 50 100 200
km

since they are estimates, but they nonetheless provide valuable insights into land use trends during the latter half of the 20th century.

The Corine Land Cover (CLC) database, initiated by the European Union, was used to analyze land use in 1990, 2006, and 2018 as well as the changes that occurred during those periods. The creation of the CLC database relies on the visual interpretation of Landsat satellite images following the standard CLC methodology. The minimum mapping area is 25 hectares, with a 5-hectare threshold for the category cover change. The CLC nomenclature includes 44 categories at the EU level, divided into three levels, each representing a different land cover type (García-Álvarez et al. 2023).

The databases for all three years were retrieved from the Copernicus Land Monitoring Service website in geodatabase format. Subsequently, the data underwent geoprocessing within a GIS software (ArcGIS Desktop). Initially, the transformation of the projection coordinate system from ETRS 1989 LAEA to the projection coordinate reference system of the Republic of Croatia, HTRS96/TM, utilizing the *Project tool* was done. Following this step, the focus area of South Croatia, comprising four counties, was delineated by applying the *Clip tool*. To facilitate a clearer understanding of land use changes and enable comparison with previous periods, the original 36 CLC categories existing in Southern Croatia were reclassified into 8 distinct categories (Table 2). The reclassification was carried based on the methodology outlined by Kušan (2015). Subsequently, land cover and land use changes spanning from 1990 to 2006 and from 2006 to 2018 were analyzed and extracted using the *Intersect tool*.

All data and results were chronologically compared, displayed in tables and a graph, while the results from Corine Land Cover (for the period 1990–2018) were additionally depicted cartographically.

As a case study area, we selected Bibinje Municipality, located in the coastal part of Zadar County (Figure 1). We compared land cover of Bibinje derived from the Corine Land Cover (CLC) 2018 dataset with digital orthophoto (DOF) images from 2014–2016. The DOF is the official state map of Croatia and is produced at a scale of 1:5,000 for the entire territory of the country, with a pixel resolution of 0.50 meters. The CLC data was extracted from Figure 5, while the DOF images served as the basis for manual vectorization of land use categories using ArcGIS software.

Table 2: Reclassification of original Corine Land Cover categories.

Original CLC nomenclature	Reclassified categories
211 Non-irrigated arable land, 212 Permanently irrigated land, 242 Complex cultivation patterns, 243 Land principally occupied by agriculture, with significant areas of natural vegetation	Mixed agricultural land with natural vegetation
221 Vineyards	Vineyards
222 Fruit trees	Orchards
223 Olive groves	Olive groves
231 Pastures, 321 Natural grasslands	Pastures and grasslands
311 Broad-leaved forest, 312 Coniferous forest, 313 Mixed forest, 323 Sclerophyllous vegetation 324 Transitional woodland-shrub	Shrubs (macchia)* and forests**
111 Continuous urban fabric, 112 Discontinuous urban fabric, 121 Industrial or commercial units, 122 Road and rail networks and associated land, 123 Port areas, 124 Airports, 131 Mineral extraction sites, 132 Dump sites, 133 Construction sites, 141 Green urban areas, 142 Sport and leisure facilities, 322 Moors and heathland, 331 Beaches, dunes, sand, 332 Bare rocks, 333 Sparsely vegetated areas, 334 Burnt areas, 411 Inland marshes, 421 Salt marshes, 422 Salines, 423 Intertidal flats	Infertile land
511 Water courses, 512 Water bodies	Water bodies

* macchia = mediterranean shrubs

** forests = in different degradation stages

3 Results

3.1 Land use 1900–1945

In the period until 1918, the basic territorial units of the Kingdom of Dalmatia, which was part of the Austro-Hungarian Monarchy, were districts (Table 3). The primary source of the data at the beginning of the 20th century was the revision of land use from 1896 which, like other Austrian territories, was documented separately for the Kingdom of Dalmatia (Blaće 2015). The Dalmatian economy was mainly based on extensive agriculture, resulting in underdeveloped state of the region (Bralić and Kraljev 2011). Key activities were livestock farming in combination with arable farming, viticulture and olive growing (Ozimec et al. 2015).

The most common land use category was pastures, accounting for 46.1% of the area (Table 3). Traditionally, livestock farming was an important activity, especially in the hinterland (Matas 2015). Ploughfields covered the largest share of arable land, but in the districts of Šibenik, Split, Hvar, and Korčula, vineyards took precedence. Gardens represented 2.8% of the total area, a large figure primarily due to the 1896 revision's grouping of gardens with olive groves and orchards into a single category (Blaće 2015). Infertile land was calculated by subtracting all other categories from the total land area within each district, encompassing built-up areas, swamps, and karstified terrain. The Metković district was noteworthy for its infertile land, due to the predominantly swampy Neretva river delta at the time.

Table 3: Land use in Southern Croatia in 1900 (in ha) (Općinski rječnik . . . 1908).

		Arable land						
Districts	Total	Ploughfields	Gardens	Vineyards	Meadows	Pastures	Forests	Infertile
Zadar	143,503	15,655	4,864	10,354	1,285	75,619	30,600	5,126
Benkovac	158,086	20,507	422	2,240	586	61,305	66,080	6,946
Šibenik	96,229	7,917	4,455	14,099	212	51,450	15,094	3,002
Knin	140,807	21,711	534	4,488	1,554	73,082	36,289	3,149
Split	188,939	19,215	8,085	25,268	121	83,127	49,219	3,904
Sinj	133,615	17,904	308	629	5,098	69,373	37,915	2,388
Makarska	53,739	4,292	2,023	3,263	0	25,150	18,172	839
Imotski	64,641	9,544	242	1,192	704	37,392	14,120	1,447
Hvar	41,320	1,788	1,700	8,474	0	8,322	20,033	1,003
Metković	38,395	3,905	223	880	53	18,278	7,036	8,020
Korčula	59,023	1,001	4,477	6,386	0	12,783	33,262	1,114
Dubrovnik	77,748	5,827	5,958	2,854	23	35,047	26,084	1,955
TOTAL	1,196,045	129,266	33,291	80,127	9,636	550,928	353,904	38,893
Share (%)	100.0	10.8	2.8	6.7	0.8	46.1	29.6	3.3

Table 4: Land use in Southern Croatia in 1921 (in ha) (Obrađena zemlja . . . 1924).

		Arable land						
	Total	Ploughfields	Vineyards	Orchards	Meadows	Pastures	Forests	Infertile
	1,272,900	110,041	29,407	10,993	8,670	545,049	378,300	190,440
Share (%)	100.0	8.6	2.3	0.9	0.7	42.8	29.7	15.0

Land use in 1921 refers to the area of several newly established oblasts (territorial units) that mostly covered approximately same area as the abolished Kingdom of Dalmatia (Table 4). Notably, there was a considerable reduction in vineyard area, indicating significant vineyard loss due to the phylloxera epidemic at the end of the 19th century (Blaće et al. 2024), a phenomenon not apparent in the 1896 data. The most significant divergence lay in the infertile land categories between the two periods. In 1921, infertile land was computed by subtracting the sum of all other areas from the total. This notable increase is likely attributed to methodological differences in the census and spatial coverage. The 1896 revision was based on clearly specified tax zones, while 1921 lacked such clear spatial definitions.

The data for 1929 covered the area of Split and Dubrovnik oblasts within the Kingdom of Yugoslavia. This source differed methodologically from previous sources because land use data was obtained from the district-level data and each category's data was computed as absolute values from relative values. All categories were categorized as arable land, with forest and infertile land calculated by subtracting arable land from the total. Unlike 1921, the total land area was once again smaller. Due to the absence of forests, it is presumed that their area was included in the »residue« category, along with infertile land. Additionally, vineyard areas expanded, indicating a gradual recovery from the phylloxera epidemic (Table 5). Unlike 1900, where gardens held a larger share, this was not the case in 1929 primarily due to the fact that only gardens were listed here (probably along with some olive and fruit trees).

Pasture areas accounted for almost 50% of the area, especially in the hinterland and on the islands, reflecting the importance of livestock farming during the interwar period (Kolar-Dimitrijević 1990).

3.2 Land use 1945–1991

Following World War II, Croatia became a part of the Socialist Federal Republic of Yugoslavia. In Southern Croatia from the early 1900s until the 1960s, agriculture was the key economic activity. Predominantly rural populations often emigrated to coastal cities or abroad in search of improved living conditions. The 1960s marked a pivotal period when significant shifts began occurring, characterized by concurrent industrialization and land abandonment (Defilippis 2006).

Since 1960s, agricultural land in the Socialist Republic of Croatia experienced a slow but steady decline (Table 6). Ploughfields decreased while meadows and pastures expanded. These shifts were driven by land abandonment and the expansion of extensive land use (Malić 1983). Data from 1970 and 1980, encompassing the former Community of Municipalities of Split (new type of administrative units), indicated decreased agricultural areas across most categories, yet an increase in pastures, meadows, and grasslands, consistent with trends observed throughout the Socialist Republic of Croatia (Malić 1983). The total area of agricultural land in 1970 increased compared to 1960, mainly due to the inclusion of the pasture category. While reforestation processes due to land abandonment and depopulation were ongoing, extensive land use practices continued. The infertile land category primarily included fish ponds, reeds, and swamps, with a slightly increased share. The low share of infertile in 1970 and 1980 in comparison to 1960 is probably the consequence of different methodological procedures, and less of actual change.

Land use since 1990 was analyzed using the CLC methodology (Figure 2). All land categories related to agricultural production saw a considerable decrease in comparison to 1980, especially pastures and grasslands (Table 7). Shrubs and forests, which made up the largest share, were not limited to this specific category and were also present in the »mixed agricultural land with natural vegetation« category (Table 7). Due to the complex mosaic of small land plots where cultivated areas and Mediterranean vegetation intermingle, it is challenging to pinpoint their exact share. Nonetheless, it is assumed that shrubs and forests

Table 5: Land use in Southern Croatia in 1929 (in ha) (Kolar-Dimitrijević 1990).

	Total	Ploughfields	Gardens	Vineyards	Orchards	Meadows	Pastures	Swamps	Forests and infertile
	1,158,802	132,772	7,704	34,364	28,877	10,081	568,000	17,296	359,708
Share (%)	100.0	11.5	0.7	3.0	2.5	0.9	49.0	1.5	31.0

occupied at least 50% of these plots. Although vineyards, orchards, and olive groves also declined, they were also embedded within the mixed agricultural land with natural vegetation category. The extent of these categories was recorded only if they exceeded 25 hectares in size. The largest areas of olive groves, due to climatic conditions, were located on the coastline and islands. Vineyards were also cultivated in hinterlands, utilizing large acres of arable land, like in the vicinity of the town of Imotski. Ploughfields experienced a pronounced decline, but due to their inclusion in complex cultivation patterns, their total area could not be precisely quantified either. Infertile land, despite comprising a broader range of CLC categories, primarily consisted of urban (built-up) areas along the coastline and rocky karstic terrains.

3.3 Land use since 1991

This period commenced with destruction and population migration during the Croatian War of Independence (1991–1995), leading to large areas of land remaining uncultivated. After the war concluded, the processes of urbanization and coastal development continued, with mainly adverse demographic and economic consequences for the islands and the hinterland.

According to the CLC 2006 data, there were pronounced changes in land use in the whole research area compared to 1990 (Figure 3). Notably, the share of mixed agricultural land with natural vegetation, olive groves, shrubs and forests increased, while other land use categories experienced a decline (Table 8).

Table 6: Land use in Southern Croatia in 1960, 1970 and 1980 (in ha) (provided by the Croatian Bureau of Statistics).

		Arable land						
Year	Total	Ploughfields	Vineyards	Orchards	Meadows	Pastures	Forests	Infertile
1960	1,204,714	130,613	39,165	30,807	9,888	455,762	477,245	61,234
Share (%)	100.0	10.8	3.3	2.6	0.8	37.8	39.6	5.1
1970	1,205,818	123,200	32,502	27,543	8,271	548,089	459,777	6,436
Share (%)	100.0	10.2	2.7	2.3	0.7	45.5	38.1	0.5
1980	1,163,992	118,244	31,086	25,100	8,669	517,493	453,186	10,214
Share (%)	100.0	10.2	2.7	2.2	0.7	44.5	38.9	0.9

Table 7: Land use in Southern Croatia in 1990 (calculated from Corine Land Cover).

Category	Area (ha)	Share (%)
Mixed agricultural land with natural vegetation	243,474	18.7
Vineyards	15,767	1.2
Orchards	5,395	0.4
Olive groves	17,283	1.3
Pastures and grasslands	252,343	19.4
Shrubs (macchia) and forests	660,648	50.8
Infertile land	97,190	7.5
Water bodies	8,778	0.7
TOTAL	1,300,878	100.0

Figure 2: Land use in Southern Croatia in 1990. ➤ p. 58


Zadar
Šibenik
Split
Dubrovnik
Land use
Mixed agricultural land with natural vegetation
Vineyards
Orchards
Olive groves
Pastures and grasslands
Shrubs and forests
Infertile land
Water bodies
0 15 30 60 km
N
Content by: Anđela Vrkić, Ante Blaće
Map by: Anđela Vrkić
Source: Corine Land Cover, Copernicus Land Monitoring Service, 2020
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An interesting shift occurred in the category of olive groves, with an increase in their area, primarily due to more precise categorization compared to 1990. The shift in agricultural land was characterized not by an increase in complex cultivation patterns, but by land predominantly characterized as mixed arable land with substantial areas of natural vegetation. This change reflected the continued progression of vegetation succession, leading to an increase in the share of shrubs and forests. This was especially so in the hinterlands of Zadar and Šibenik-Knin Counties, heavily affected by war. Simultaneously, a decrease in the share of pastures and grasslands was likely due to the same reasons.

The total change in 2006 compared to 1990 was 160,198 ha. The ten largest changes accounted for 86.5% of the total changes (Figure 4, Table 9). The most prominent change included the transition from shrubs and forests to mixed agricultural land with natural vegetation. This transformation was not driven by intensified agriculture but rather the improved technical capabilities, especially satellite imagery, which allowed for a clearer distinction between areas previously categorized as shrubs and forests in 1990 and those more accurately classified as mixed agricultural land with natural vegetation in 2006. This process was evident on Olib Island (in Zadar County), where a substantial portion of shrubs and forests transformed into land primarily used for agriculture, with large areas of natural vegetation (Figures 4). Notably, native and non-native plants colonized areas formerly occupied by gardens, vineyards, and olive groves (Faričić and Magaš 2009).

Table 8: Land use in Southern Croatia in 2006 (calculated from Corine Land Cover).

Category	Area (ha)	Share (%)
Mixed agricultural land with natural vegetation	254,085	19.5
Vineyards	12,939	1.0
Orchards	4,391	0.3
Olive groves	20,212	1.6
Pastures and grasslands	248,731	19.1
Shrubs (macchia) and forests	662,205	50.9
Infertile land	90,628	7.0
Water bodies	8,770	0.7
TOTAL	1,301,960	100.0

Table 9: Largest land use changes in Southern Croatia 1990–2006 (calculated from Corine Land Cover).

Category change	Area (ha)	Share (%)
Shrubs and forests → Mixed agricultural land with natural vegetation	24,964	15.6
Pastures and grasslands → Shrubs and forests	24,404	15.2
Mixed agricultural land with natural vegetation → Shrubs and forests	17,995	11.2
Shrubs and forests → Pastures and grasslands	16,857	10.5
Infertile land → Pastures and grasslands	16,179	10.1
Infertile land → Shrubs and forests	9,241	5.8
Pastures and grasslands → Mixed agricultural land with natural vegetation	8,947	5.6
Shrubs and forests → Infertile land	7,786	4.9
Mixed agricultural land with natural vegetation → Infertile land	6,702	4.2
Pastures and grasslands → Infertile land	5,564	3.5

Figure 3: Land use in Southern Croatia in 2006. ► p. 60
Figure 4: Land use changes in Southern Croatia 1990–2006. ► p. 61


Zadar
Šibenik
Split
Dubrovnik
Land use
Mixed agricultural land with natural vegetation
Vineyards
Orchards
Olive groves
Pastures and grasslands
Shrubs and forests
Infertile land
Water bodies
0 15 30 60 km
N
Content by: Anđela Vrkić, Ante Blaće
Map by: Anđela Vrkić
Source: Corine Land Cover, Copernicus Land Monitoring Service, 2020
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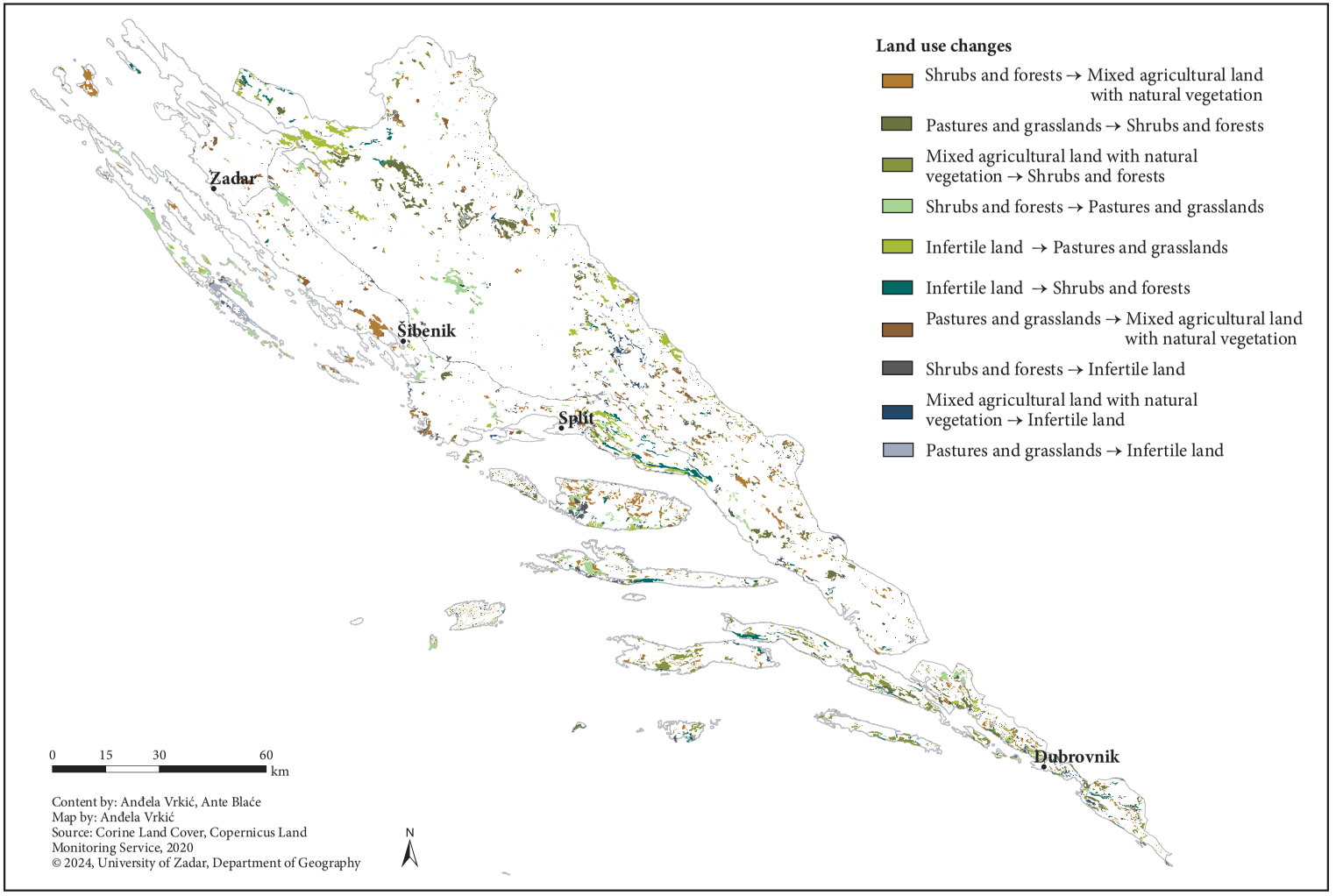
Land use changes
Shrubs and forests → Mixed agricultural land with natural vegetation
Pastures and grasslands → Shrubs and forests
Mixed agricultural land with natural vegetation → Shrubs and forests
Shrubs and forests → Pastures and grasslands
Infertile land → Pastures and grasslands
Infertile land → Shrubs and forests
Pastures and grasslands → Mixed agricultural land with natural vegetation
Shrubs and forests → Infertile land
Mixed agricultural land with natural vegetation → Infertile land
Pastures and grasslands → Infertile land
Zadar
Šibenik
Split
Dubrovnik
0 15 30 60
km
N
Content by: Anđela Vrkić, Ante Blaće
Map by: Anđela Vrkić
Source: Corine Land Cover, Copernicus Land Monitoring Service, 2020
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The shift from pastures and grasslands to shrubs and forests was most noticeable in the hinterland of Zadar and Šibenik-Knin Counties whereas changes from mixed agricultural land with natural vegetation to shrubs and forests were more widespread in the broader area of Dubrovnik-Neretva County. While the changes in Zadar and Šibenik-Knin were expected due to the continuous land abandonment and reforestation, the changes in Dubrovnik-Neretva reflected not only these trends but also the methodological challenges of distinguishing between these two categories. Changes of pastures and grasslands to infertile land were most pronounced on the Kornati Islands (Figure 4) where natural grasslands were transformed into areas with sparse vegetation. Given the rocky terrain and limited vegetation on the Kornati Islands, this categorization was appropriate, most likely as a result of improved classification.

The socio-economic processes that took place at the end of the 20th century continued in the early 21st century. The service sector, particularly tourism, became the main economic activity, with a strong presence along the coast and islands (Kapusta and Wiluś 2017). Simultaneously, the hinterland began developing a tourist-oriented offer only in recent years, centred on vacation homes (Ralica and Blaće 2021).

Compared to 2006, the vineyards and forests in 2018 had a smaller decrease in share, while the orchards, olive groves, and infertile land categories recorded an increase (Table 10). The increase in orchards and olive groves resulted from more precise categorization in comparison to mixed agricultural land with natural vegetation. Moreover, the expansion of crops producing high-value products such as olive oil and wine contributed to this increase. This was again noticeable along the coastline and on the islands within Split-Dalmatia and Dubrovnik-Neretva Counties. Apart from favourable physical conditions, these areas have a long tradition of cultivation, but the commercial aspect emerged only after Croatia's accession to the EU. The growth in the infertile land category was primarily associated with burnt areas, covering 14,405 hectares in 2018 (Figure 5).

Land use changes from 2006 to 2018 (Figure 6) were less extensive than in the preceding period. These changes encompassed 62,324 hectares, with the ten largest changes accounting for 83.9% of the total change (Table 11). The most substantial shift involved the transition from shrubs and forests to infertile land. This change primarily occurred in Zadar and Šibenik-Knin Counties, with a smaller portion taking place in Split-Dalmatia County (Figure 6). These transitions were mainly attributed to areas affected by wildfires. Additionally, a minor portion of this change was associated with the ongoing construction of the A1 highway in Split-Dalmatia and Dubrovnik-Neretva Counties. Wildfires are result of complex human-nature interactions and recognised as important driver of land cover in Mediterranean environments (Darques 2016). The findings regarding wildfire occurrences in Southern Croatia reveal that grasslands and shrubs (macchia) are the most susceptible vegetation types to fires, attributed to socio-demographic shifts such as agricultural abandonment and the growing impact of tourism, as well as climatic extremes such as heatwaves and droughts (Pavlek et al. 2017; Jajtić et al. 2019; Blaće et al. 2024). Based on our research, shrubs (including forests) and grasslands covered nearly 70% of Southern Croatia in 2018, indicating large areas vulnerable to wildfires.

Table 10: Land use in Southern Croatia in 2018 (calculated from Corine Land Cover).

Category change	Area (ha)	Share (%)
Mixed agricultural land with natural vegetation	247,240	19.0
Vineyards	11,694	0.9
Orchards	6,185	0.5
Olive groves	25,116	1.9
Pastures and grasslands	249,073	19.1
Shrubs (macchia) and forests	643,295	49.4
Infertile land	110,329	8.5
Water bodies	9,176	0.7
TOTAL	1,302,109	100.0

Figure 5: Land use in Southern Croatia in 2018. ► p. 63


Zadar
Šibenik
Split
Dubrovnik
Land use
Mixed agricultural land with natural vegetation
Vineyards
Orchards
Olive groves
Pastures and grasslands
Shrubs and forests
Infertile land
Water bodies
0
15
30
60
km
N
Content by: Anđela Vrkić, Ante Blaće
Map by: Anđela Vrkić
Source: Corine Land Cover, Copernicus Land Monitoring Service, 2020
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3.4 Case study – land use in Bibinje

The land use pattern in Bibinje reflects the characteristics typical for other coastal parts of Southern Croatia. Residential areas and tourist facilities are predominantly situated along the coastline, while the hinterland comprises primarily agricultural land, pastures, grasslands, shrubs and forests (Figure 7). Comparing CLC data with the DOF images (Figure 8, Table 12) reveals a notable difference in details. Due to the varying scales of 1:100,000 for CLC and 1:5,000 for DOF 2014–2016, this discrepancy is expected. However, despite this difference, the generalization of categories in the CLC data was deemed appropriate. Although CLC failed to explicitly classify pastures and grasslands, this can be attributed to the vegetation's resemblance to shrubs and forests, into which they were categorized. Similarly, vineyards and olive groves went undetected but often fell under the category of mixed agricultural land with natural vegetation. Additionally, some areas identified as vineyards, olive groves, and mixed agricultural land with natural vegetation were erroneously classified as infertile land. While CLC data may not be suitable for detailed analyses of smaller areas such as Bibinje, encompassing 1,446 hectares, it can still be valuable for studying larger regions like Southern Croatia. It seems that further advancement in remote sensing and the usage of UAVs (unmanned aerial vehicle) for small areas will yield more reliable results in land cover assessment. Comparison with cadastral maps is possible but it heavily depends on the alignment of the cadastral data with on-ground conditions, which is, for now, a rare case in Croatia.

The previously explained phenomena of shrub and forest expansion, as well as the increase in infertile (built-up) land, are visible in Figure 8. Over a 50-year period agricultural land has been decreasing, mirroring trends seen in many parts of Southern Croatia.

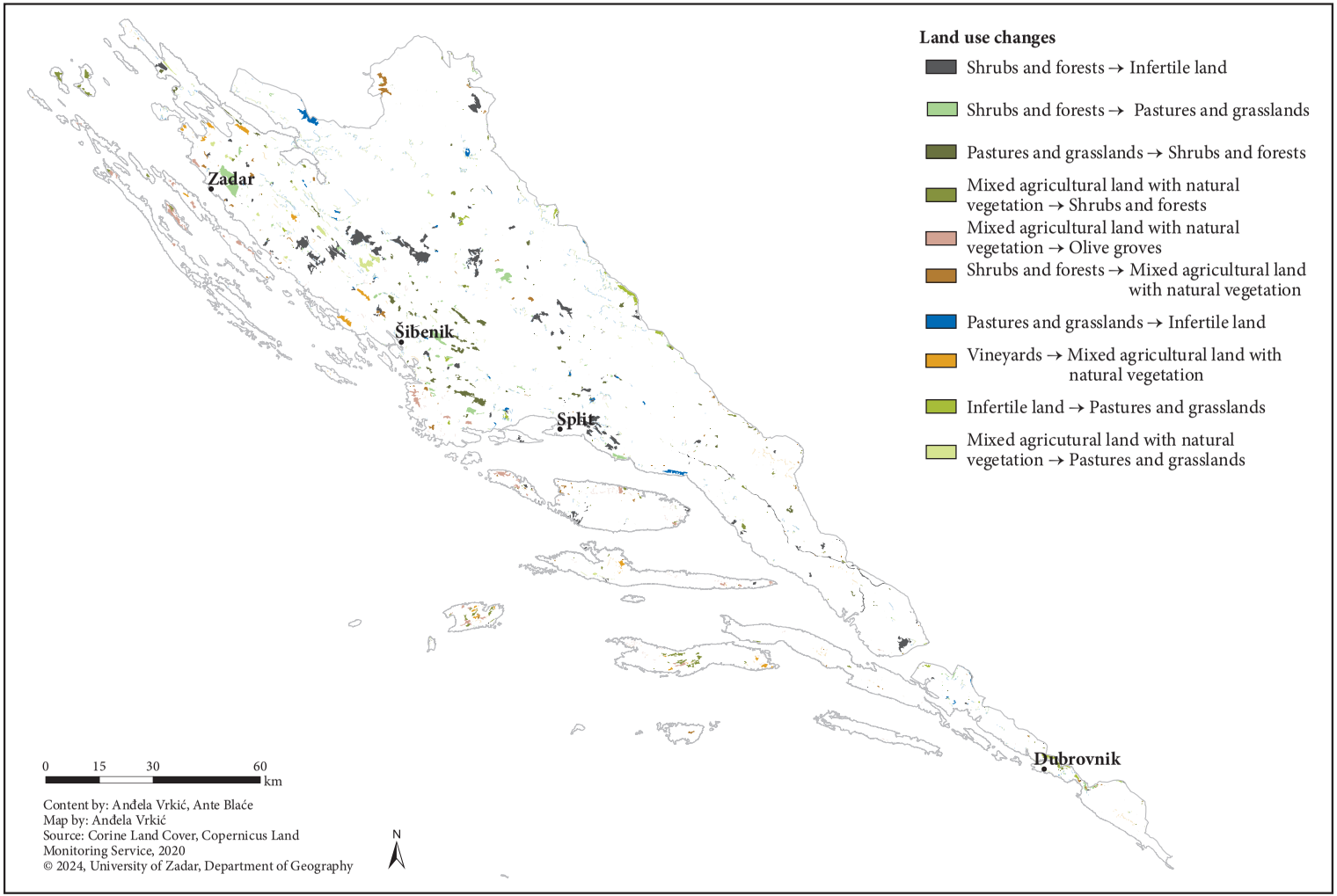
Table 11: Largest land use changes in Southern Croatia 2006–2018 (calculated from Corine Land Cover).

Category change	Area (ha)	Share (%)
Shrubs and forests → Infertile land	18,980	30.5
Shrubs and forests → Pastures and grasslands	6,195	9.9
Pastures and grasslands → Shrubs and forests	6,136	9.8
Mixed agricultural land with natural vegetation → Shrubs and forests	4,120	6.6
Mixed agricultural land with natural vegetation → Olive groves	4,053	6.5
Shrubs and forests → Mixed agricultural land with natural vegetation	3,052	4.9
Pastures and grasslands → Infertile land	2,629	4.2
Vineyards → Mixed agricultural land with natural vegetation	2,554	4.1
Infertile land → Pastures and grasslands	2,423	3.9
Mixed agricultural land with natural vegetation → Pasture and grasslands	2,162	3.5

Table 12: Land use in Bibinje (calculated from Corine Land Cover).

Category	DOF 2014-16 Area (ha)	Share (%)	CLC 2018 Area (ha)	Share (%)
Mixed agricultural land with natural vegetation	181	12.5	559	38.6
Vineyards	21	1.5	0	0.0
Olive groves	56	3.9	0	0.0
Pastures and grasslands	558	38.6	0	0.0
Shrubs and forests	401	27.7	514	35.5
Infertile land	228	15.8	373	25.8
TOTAL	1446	100.0	1446	100.0

Figure 6: Change in land use in Southern Croatia 2006–2018. ➤ p. 65
Figure 7: Land use in Bibinje. ➤ p. 66
Figure 8: Aerial photos of Bibinje for 1968 (top) and 2016 (bottom). ➤ p. 67


Land use changes
Shrubs and forests → Infertile land
Shrubs and forests → Pastures and grasslands
Pastures and grasslands → Shrubs and forests
Mixed agricultural land with natural vegetation → Shrubs and forests
Mixed agricultural land with natural vegetation → Olive groves
Shrubs and forests → Mixed agricultural land with natural vegetation
Pastures and grasslands → Infertile land
Vineyards → Mixed agricultural land with natural vegetation
Infertile land → Pastures and grasslands
Mixed agricutural land with natural vegetation → Pastures and grasslands
Zadar
Šibenik
Split
Dubrovnik
0 15 30 60
km
N
Content by: Anđela Vrkić, Ante Blaće
Map by: Anđela Vrkić
Source: Corine Land Cover, Copernicus Land Monitoring Service, 2020
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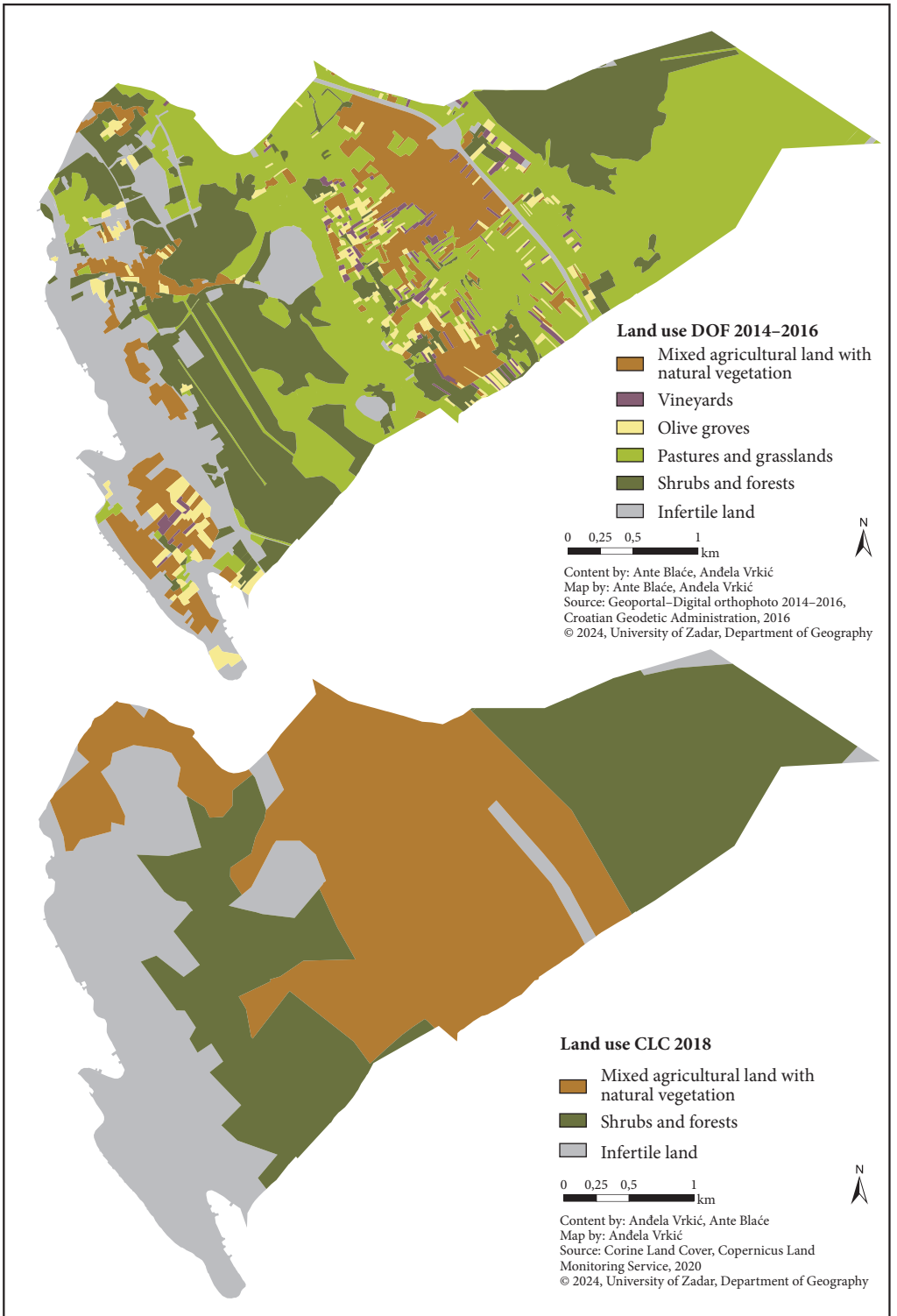
Land use DOF 2014–2016
Mixed agricultural land with natural vegetation
Vineyards
Olive groves
Pastures and grasslands
Shrubs and forests
Infertile land
0 0,25 0,5 1
km
N
Content by: Ante Blaće, Anđela Vrkić
Map by: Ante Blaće, Anđela Vrkić
Source: Geoportal–Digital orthophoto 2014–2016, Croatian Geodetic Administration, 2016
© 2024, University of Zadar, Department of Geography
Land use CLC 2018
Mixed agricultural land with natural vegetation
Shrubs and forests
Infertile land
0 0,25 0,5 1
km
N
Content by: Anđela Vrkić, Ante Blaće
Map by: Anđela Vrkić
Source: Corine Land Cover, Copernicus Land Monitoring Service, 2020
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Bibinje Municipality
0 0.25 0.5 1
km
N
Map by: Anđela Vrkić, Ante Blaće
Source: Geoportal, Digital ortophoto 2014–2016
Croatian Geodetic Administration, 2016
© 2024, University of Zadar, Department of Geography
GEOPORTAL
Bibinje Municipality
0 0.25 0.5 1
km
N
Map by: Anđela Vrkić, Ante Blaće
Source: Geoportal, Digital ortophoto 2014–2016
Croatian Geodetic Administration, 2016
© 2024, University of Zadar, Department of Geography

4 Discussion

In the first research period (1900–1945), Southern Croatia experienced pronounced changes in land use driven by political, economic, and social factors. The devastating impact of phylloxera led to a substantial loss of vineyards. The overcrowding of agrarian areas fuelled emigration from the islands and the hinterland to abroad. The second period (1945–1991) witnessed the profound alterations in land use, coinciding with major political and economic transformations. With the integration into socialist Yugoslavia, economic development in Southern Croatia concentrated around the coastal urban centers (Vresk 1985; Matas 2015). The process of land abandonment, initiated during the interwar period, accelerated from the 1960s onwards due to industrialization and partially collectivization of the land (Defilippis 2006). The third period (from 1991) began with the destructive impact of war, further exacerbating the processes of the previous era. Coastal cities continued to develop, while the islands and hinterland experienced a decline in both population and cultivated land. Political factors were manifested through the consequences of the war and the transition to a market economy. Economically, littoralization prevailed, leaving the hinterland at the periphery of economic development. Nowadays tourism is especially strong driver of land use changes, reflected in construction of numerous apartments for renting (Opačić 2012).

Changes in the land use categories by selected years clearly indicate a substantial decline in agricultural land often replaced by shrubs and forests (Figure 9). Vineyards, devastated by phylloxera, never fully recovered, leading to the cultivation of other crops (Faričić 2012). The exceptional increase in the infertile land category in 1921 can be attributed to different data collection methodologies rather than a drastic surge in built-up areas, swamps, etc.

Pastures and grasslands made up the largest share until the 1960s, started to decline. The expansion of olive trees and orchards was not only due to the more efficient detection of certain land categories through the CLC methodology but also due to increased cultivation. This was fuelled by subsidies in agriculture

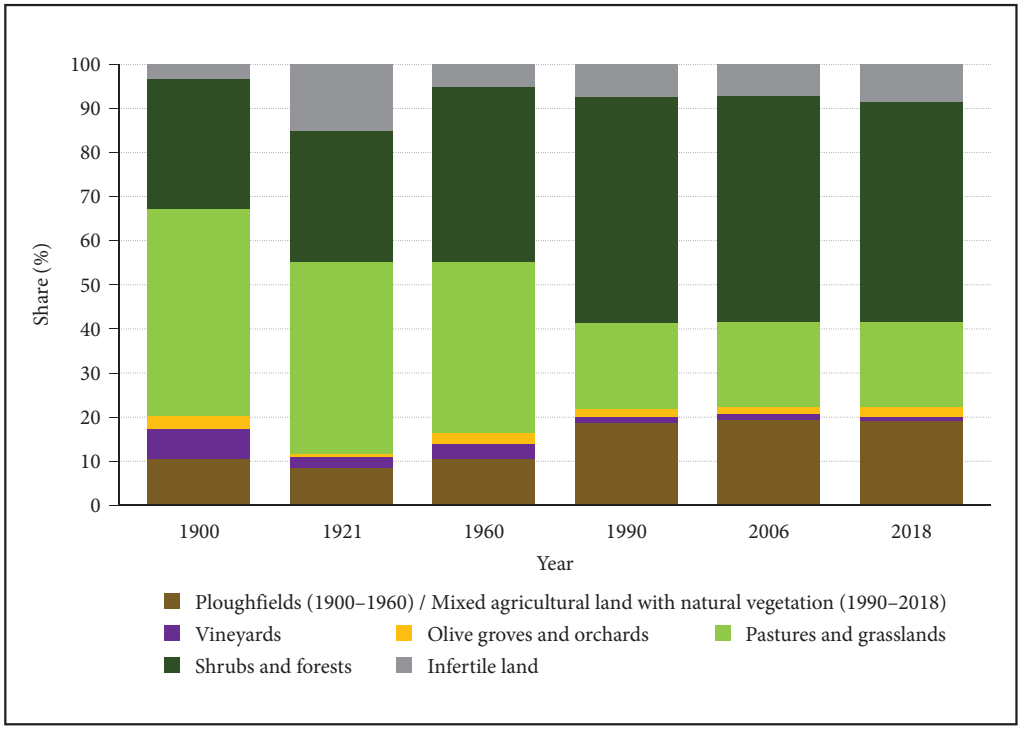

Figure 9: Share of land use categories in Southern Croatia 1900–2018.

(Očić et al. 2018), especially after Croatia joined the EU in 2013. Despite the apparent increase in ploughfields since 1990, it primarily consisted of mixed agricultural land with natural vegetation, where at least 50% was dominated by vegetation succession. Consequently, most categories during the studied period experienced reductions in their areas, while shrubs and forests expanded thus supporting the main hypothesis of this research.

Land use/land cover change research from other Mediterranean countries indicate primarily the expansion of shrubs and forests and the abandonment of agricultural areas due to social and economic factors (Peñuelas and Sardans 2021). Although the Mediterranean region had only a 10% share of forests in 2015, the distribution of forests varied by country. For instance, Israel had a 6% forest share, while Slovenia had 61% (Nocentini et al. 2022) as a consequence of different natural conditions. Forest expansion is evident, with Slovenia seeing its forested area grow from 39% in the first half of the 19th century to 61% in 2015 (Gabrovec and Kumer 2019).

Regionally, specific trends have emerged. Research conducted between 1960 and 2000 in Mediterranean parts of Italy (Falcucci et al. 2007) indicated the cessation of pasture grazing, reforestation, and the growth of urban areas, driven by tourism development and demographic growth. Greek island studies (Tzanopoulos and Vogiatzakis 2011; Schaich et al. 2015; Kefalas et al. 2019; Dimopoulos and Kizos 2020; Kefalas et al. 2020) indicated two major patterns: an increase in forests and scrublands and urbanization in lowland and coastal areas, primarily due to tourism. This is very similar to the processes in Southern Croatia.

In the Mediterranean Alicante region in Spain approximately one-third of agricultural land was abandoned and turned into macchia and urban areas between 1950s and 2000s. Forested areas doubled in size although their total area remained small (Symeonakis et al. 2007). Catalonia faced a long-term shift from deforestation and overexploitation during the 19th and first half of the 20th century followed by subsequent forest transitions driven by land abandonment since the 1950s (Cervera et al. 2019).

Abadie et al. (2018) found that in the French Mediterranean region, forest recovery occurred from 1860 to 2010 due to the abandonment of traditional agriculture and pastoralism. These changes were more prominent on remote and unproductive land, while accessible urban areas witnessed an increase in built-up areas. Gabrovec and Kumer (2019) and Gabrovec et al. (2020) concluded that the most significant land-use changes in Slovenia took place in the second half of the 20th century, driven by industrialization. Slovenia's accession to the EU in 2004 introduced common policies that influenced land use, with specificities like land fragmentation and dispersed settlements. Bičík et al. (2019) conducted somewhat similar study to this one, comparing land use changes in Czechia and Slovenia over the last two centuries, indicating much larger shares of arable land compared to Southern Croatia, reflecting the different physical and social characteristics of the study areas.

Research on land use changes in Southern Croatia also pointed to certain difficulties with data sources. The oldest source, Općinski rječnik (C. KR. središnja … 1908) turned out to be the most reliable. All other data sources up to CLC 1990 mainly relied on estimates and should be interpreted cautiously. However, they indicate certain land use trends that have occurred over the last 120 years. While the CLC methodology for 1990, 2006, and especially 2018 (benefiting from advancements in remote sensing) provided more reliable data on land use categories and changes between periods, it is not entirely precise database. Due to its mapping methodology, numerous changes in areas smaller than 5 hectares couldn't be adequately represented, leading to some generalization of results. This is expected because the CLC is by definition a generalized database whose primary task is the comparison of land use in Europe (Aune-Lundberg and Strand 2021). Another issue is related to mixed classes. Mixed classes tend to lack clear-cut information regarding the state of the land surface, necessitating researchers to carefully weigh the results. Although the reliability of CLC data at the sub-national level may raise concerns, its usage becomes justifiable in cases where other data sources are unavailable (Popovici et al. 2013). These issues with CLC are evident in our research, particularly concerning specific categories. For instance, the category of pastures and grasslands represents predominantly grasslands due to the limited extent of cattle breeding in Southern Croatia (Ozimec et al. 2015). Delineating between shrubs and forests poses a challenge, as it reflects agricultural abandonment, further complicating the differentiation between the two vegetation types. The category of mixed agricultural land with natural vegetation probably stands as the most intricate, embodying a mosaic of utilized and abandoned land, exacerbated by the 25 ha threshold. These dynamics and transitions are observable across the study area, particularly in hinterlands, mountainous regions, and sparsely populated areas within Zadar and Split-Dalmatia counties (Figure 4 and Figure 6). Southern Croatia, and

especially its rural areas, has dispersed settlements and diverse vegetation. Due to this, EU countries are developing national LULCC databases in large scale to provide reliable information for making political and professional decisions and for citizen's personal matters (Foški et al. 2018).

Corine Land Cover still remains the most dependable source for land classification in Croatian territory. Nonetheless, the implementation of the new LIFE CROLIS (CROatian Land Information System) will improve data integration and processing regarding land use and land cover from diverse sources. Except for management on different levels, it should also serve as a tool for reporting and calculating greenhouse gas emissions and sinks from the land use, land conversion and forestry sector (LULUCF). It is expected that LIFE CROLIS will become operational sometime after 2024.

5 Conclusion

In this research, we explored land use changes within Southern Croatia spanning from the early 20th century to 2018. Our analysis is structured into three distinct periods (1900–1945, 1945–1991, and post-1991) to align with the key socio-economic changes that unfolded throughout the 20th century. Over the course of the 20th century, the region witnessed profound transformations in land use. These changes were driven by a complex interaction of social and economic factors. The continuous advancement of remote sensing and the availability of comprehensive databases, offer promising opportunities for ongoing and more precise monitoring of land use trends in Southern Croatia and elsewhere. Despite the limitations of this study, it contributes to our better understanding of the intricate issues related to land use and landscape changes in the context of Croatia and the Mediterranean. Namely, the studied trends are more important than the precise quantification of land categories in each period because they are reflection of numerous social, economic, and environmental changes and problems that affect them.

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MONITORING THE IMPACT OF THE CORONA PANDEMIC ON NITROGEN DIOXIDE EMISSIONS AT LARGE SCALES VIA GOOGLE EARTH ENGINE

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The monitoring of vast expanses is a key function of Earth observation satellites.

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Monitoring the impact of the Corona pandemic on nitrogen dioxide emissions at large scales via Google Earth Engine

ABSTRACT: Advances in Earth observation capabilities and the expanded accessibility of data provide the opportunity to monitor air pollution on a global scale. The Google Earth Engine (GEE) enables the efficient conduct of such large-scale research. This article examines the impact of the COVID-19 pandemic on NO_2 emissions at various supranational scales, with particular consideration of the Human Development Index of the countries, using GEE. The findings for the first three months of 2020 indicating a reduction in emissions of more than 4% per month, demonstrate that not only were the restrictions and closures imposed by governments effective in the global decline of NO_2 levels, but also voluntary restrictions imposed by people on their own mobility with the motive of protection from the pandemic.

KEYWORDS: remote sensing, Earth observation, Sentinel-5P, tropospheric NO_2, Google Earth Engine, Human Development Index

Spremljanje vpliva pandemije koronavirusa na emisije dušikovega dioksida v velikem merilu s programom Google Earth Engine

POVZETEK : Napredek v zmogljivostih opazovanja Zemlje in večja dostopnost podatkov omogočata spremljanje onesnaženosti zraka na svetovni ravni. Google Earth Engine (GEE) omogoča učinkovito izvajanje takšnih obsežnih raziskav. Ta članek z uporabo GEE preučuje vpliv pandemije covida-19 na emisije NO_2 na različnih nadnacionalnih ravneh, s posebnim upoštevanjem indeksa človekovega razvoja v državah. V prvih treh mesecih leta 2020 je prišlo do zmanjšanja za več kot 4 % na mesec, kar kaže, da pri globalnem zmanjšanju ravni NO_2 niso bile učinkovite le omejitve in zaprtja, ki so jih uvedle vlade, temveč tudi prostovoljne omejitve, ki so jih ljudje uvedli za lastno mobilnost z motivom zaščite pred pandemijo.

KLJUČNE BESEDE: daljinsko zaznavanje, opazovanje Zemlje, Sentinel-5P, troposferski NO_2, Google Earth Engine, indeks človekovega razvoja

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1 Introduction

First reported in Wuhan, China, in January 2020, the COVID-19 epidemic spread rapidly around the world. Soon after the outbreak, almost every country introduced various measures to contain the spread of the disease, including travel restrictions and curfews, with varying degrees of severity (Hale et al. 2021; Singh and Chauhan 2020). Some governments implemented a complete quarantine, while others opted for partial lockdowns or mobility restrictions (Zhang et al. 2021). For instance, while the Chinese central government implemented a complete shutdown in Wuhan, the Turkish government enacted a nationwide but partial shutdown (Bacak et al. 2020; Lian et al. 2020). The implementation of these measures has resulted in a notable decline in human mobility. Since the majority of air pollutants are of anthropogenic origin and closely related to human mobility, there has also been a significant reduction in air pollution during the pandemic period. For example, Tobías et al. (2020) observed a notable decline in PM10, NO_2, SO_2 and CO levels in Barcelona during the one-month quarantine period. Isaifan (2020) also demonstrated a significant reduction in NO_2 and carbon emissions associated with quarantines in China. Karuppasamy et al. (2020) observed a 55% reduction in NO_2 during the period of quarantine in India. Another study (Otmani et al. 2020) revealed reductions of 75%, 49% and 96% in PM10, SO_2 and NO_2, respectively, in Morocco. Moreover, a significant reduction in air pollution was reported in Iran during the outbreak (Nemati et al. 2020).

The majority of the studies mentioned above employed air quality monitoring stations (terrestrial instruments) to assess air quality. Such instruments are capable of taking point measurements with high temporal resolution, rendering them suitable for use in situations where ambient change is rapid. Nevertheless, they lack convenience and practicality, as they necessitate the deployment of a substantial number of instruments to collect data on extensive areas. For instance, Karuppasamy et al. (2020) employed data from over 12,000 stations in a global-scale study. In contrast, airborne or spaceborne remote sensing instruments are capable of providing information on large areas of the Earth's surface, albeit at less frequent intervals. These tools provide valuable, easily accessible and reliable data for studies in a multitude of fields (Avdan et al. 2021; Kuruca et al. 2021; Matcı and Avdan 2020; Matci et al. 2020; Praticò et al. 2021; Tok and Kaya 2014; Zhe 2018). One such tool is the TROPOspheric Monitoring Instrument (TROPOMI), developed by the European Space Agency with the objective of monitoring and predicting air quality, ozone, radiation and climate. It is an instrument on the Copernicus Sentinel-5 Precursor satellite that provides high spatial and temporal resolution data on tropospheric concentrations of ozone (O_3), methane (CH_4), formaldehyde (HCHO), carbon monoxide (CO), nitrogen dioxide (NO_2) and sulphur dioxide (SO_2) in netCDF (Network Common Data Form) format since July 10th, 2018. All Sentinel-5P data is freely available from The Copernicus Data Space Ecosytem in near real-time and offline.

One Sentinel-5P image encompasses approximately 100 million square kilometres of the Earth's surface and occupies over 500 megabytes of memory space. This implies that a one-year survey of the entire Earth utilising Sentinel-5P products as data would necessitate approximately 65,000 images and in excess of 30 terabytes of storage. Conducting such a survey in the traditional manner, by accessing, downloading and processing data one at a time, is a highly time-consuming, resource-intensive, and error-prone process. However, these issues can be overcome using Google Earth Engine (GEE), a cloud-based computing platform designed primarily for the analysis of Earth-scale environmental data. It combines petabytes of satellite imagery and geospatial datasets and allows users to easily access, process and visualize them (Kumar and Mutanga 2019). GEE has been applied and its capabilities explored in various fields related to earth sciences (Jalayer et al. 2023; Nejad et al. 2022; Nghia et al. 2022; Waleed et al. 2023; Xiong et al. 2017). The impact of the coronavirus pandemic on air pollution parameters such as tropospheric NO_2 levels has also been investigated in this way using Sentinel-5P data by Sannigrahi et al. (2021) and Sharifi and Felegari (2022). These city-scale studies, which also utilised in-situ data from ground stations, demonstrated improvements in air quality in various cities during the pandemic.

Although the effects of pandemic lockdowns on NO_2 concentrations and distributions have been demonstrated at various scales, there is no study examining the changes in countries with different levels of development. In order to conduct such a study, it is necessary to determine the category boundaries according to a development index, rather than an administrative criterion. One such index is the Human Development Index (HDI), a measure of the level of development of countries, which has been calculated by the United Nations Development Programme (UNDP) for almost every country since 1990. A number of parameters, including life expectancy, health, access to education and per capita income, are taken into account in the calculation

of the HDI. The HDI has been employed in a multitude of academic contexts, including investigations into its correlation with health, obesity, CO_2 emissions, and the economy (Ataey et al. 2020; Long et al. 2020; Sarkodie and Adams 2020).

The primary objective of this study is to ascertain the extent to which tropospheric NO_2 concentrations are influenced by pandemic measures implemented by countries with disparate Human Development Index (HDI) categories. In order to achieve this objective, tropospheric NO_2 concentrations for the entire Earth were obtained using Sentinel-5P data through GEE for the years 2019, 2020 and 2021. The NO_2 levels are then evaluated and interpreted for countries grouped by HDI. Furthermore, the study encompasses the temporal variation of NO_2 concentrations over the specified period across the globe, geographical continents, and three neighbouring Southern European countries with disparate HDI categories (Slovenia, Croatia and Bosnia and Herzegovina).

2 Materials and methods

In this study, tropospheric NO_2 concentrations over the study areas between 2019 and 2021 were determined by utilising Sentinel-5P's TROPOMI NRTI NO_2: Near Real-Time Nitrogen Dioxide data, provided by the Copernicus Data Space Ecosystem through GEE. The product calculates tropospheric NO_2 concentrations by subtracting stratospheric contributions from the total columns. The TROPOMI/Sentinel-5P instrument, with a swath width of 108° (approximately 2,600 km on the ground), provides daily coverage of over 95% of the Earth's surface. The spatial resolution of the product is 5.5 km in the satellite flight direction and 3.5 km in the perpendicular direction at nadir. However, data released prior to August 6th, 2019 had a resolution up to 7.0 km in the flight direction. Statistical analyses of the comparison between TROPOMI and ground-based measurements (e.g., ZSL-DOAS SAOZ NO_2 data) demonstrate an excellent correlation (correlation coefficient = 0.94) between the two data sets. Furthermore, the histogram of the differences exhibits an almost Gaussian shape, with a small negative bias for TROPOMI (Verhoelst et al. 2020). The methodology in this study, developed entirely on the GEE platform, is schematised in Figure 1 and has been applied on various large-scale study areas. The methodology comprises three principal stages: data acquisition, pre-processing and processing. The process commences with the introduction of the study area to the software. In the study, the boundaries of the study areas are in geospatial vector data (shapefile) format. The boundaries of the HDI classes were delineated using the borders of each country and the respective HDI values. Subsequently, Sentinel-5P Level 3 data is accessed from the GEE data archive and the NRTI NO_2 band is selected. Due to the fact that pixels in Level 2 data are defined by latitude and longitude, it is difficult to combine multiple images in this type of data. Conversely, Level 3 data products are obtained by resampling the Level 2 ones to regular spatial pixel grids, rendering them suitable for combining. In the following stage, a time series of NRTI NO_2 is constructed by collecting the data acquired within the specified temporal range. The study employs monthly and annual time intervals. The process concludes with the calculation of the average of the time series, producing a map of the time-averaged NO_2 values of the study area.

The present study examines tropospheric NO_2 levels in the following study areas: the Earth, the continents, countries grouped according to HDI, and the triad of Slovenia, Croatia, and Bosnia and Herzegovina. Figure 2 provides a visual representation of the study areas. The investigation encompasses almost the entire Earth (including seas and oceans) with the exception of Antarctica. In the HDI-related part of the study, countries were examined by dividing them into categories of *Very High*, *High*, *Medium* and *Low* developed in accordance with the UNDP Reports catalogue for the year 2019 (the *Others* category was omitted). The list of countries, as classified by HDI, is presented in Table 1.

The study was conducted on a computer equipped with an Intel i9 7900X CPU (Central Processing Unit), an Nvidia GTX 1080 GPU (Graphics Processing Unit), 128 GB of Random-Access Memory (RAM), and a 1000 Mbps internet connection speed. In order to calculate the one-year average NO_2 for the largest study area, that of the Earth, a total of 64,188 Sentinel-5P images were used. The processing time was approximately 60 seconds.

The limitations of the methodology employed in this study can be considered from two distinct perspectives: data resolution and computational complexity. As the method is reliant on TROPOMI data for the measurement of atmospheric NO_2 emissions, the spatial resolution of the data is $3.5 \times 7.0\,km^2$ until

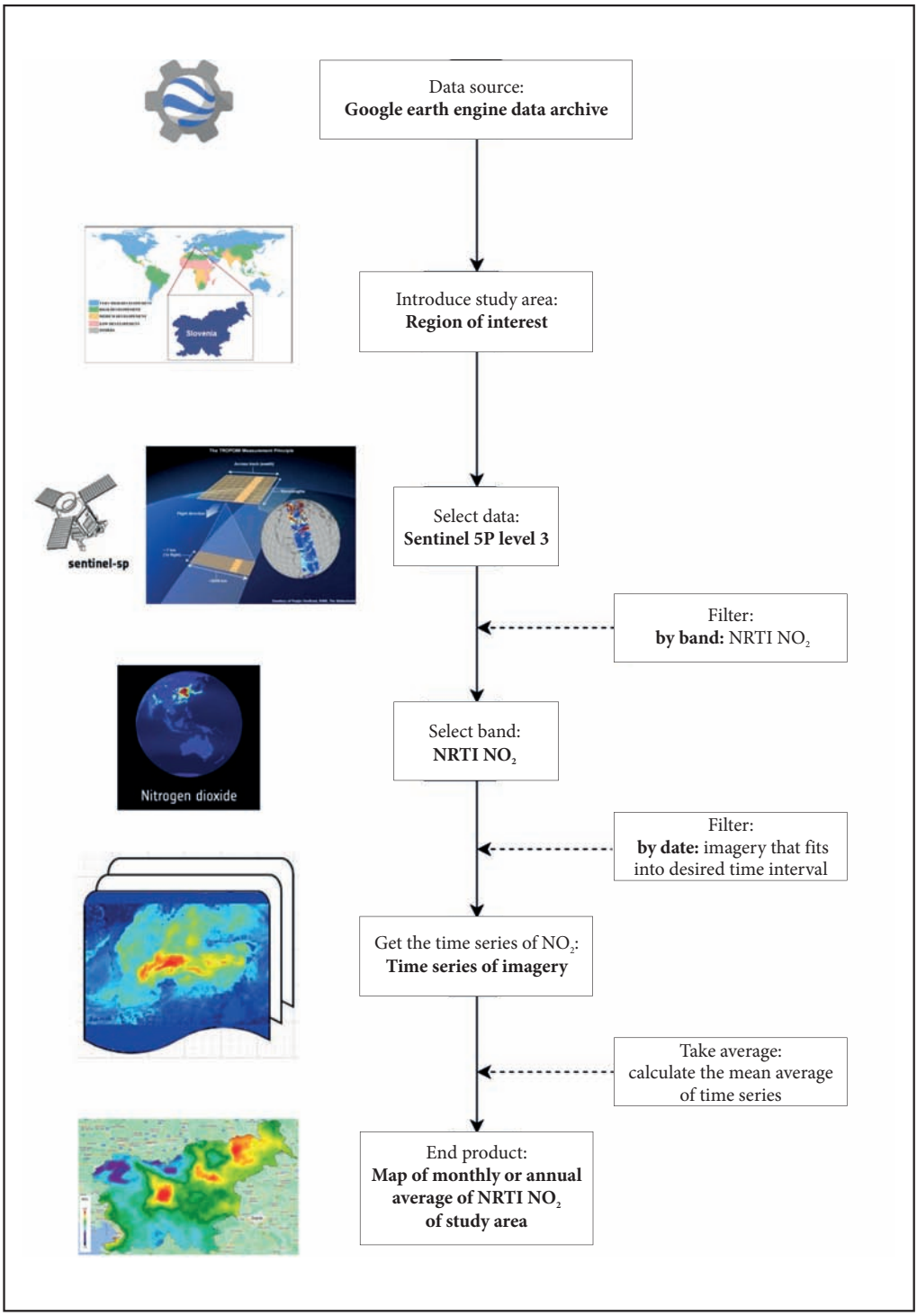


Figure 1: The workflow of the presented method.

August 6th, 2019 and $3.5 \times 5.0\ km^2$ thereafter. Therefore, it is not possible to capture changes at finer scales. Nevertheless, these data, which are highly correlated with reliable ground measurements in previous studies, are still useful for examining relative variability and trend analysis between years and months.

Furthermore, the algorithm employed in this study is only capable of handling shapefiles of the study areas up to a specific fineness of resolution, contingent on the size of RAM available. In this study, the algorithm, which was executed on a computer with 128 GB of RAM, was capable of processing shapefiles with a maximum resolution of 500 metres. For finer, more detailed shapefiles, the available memory was insufficient.

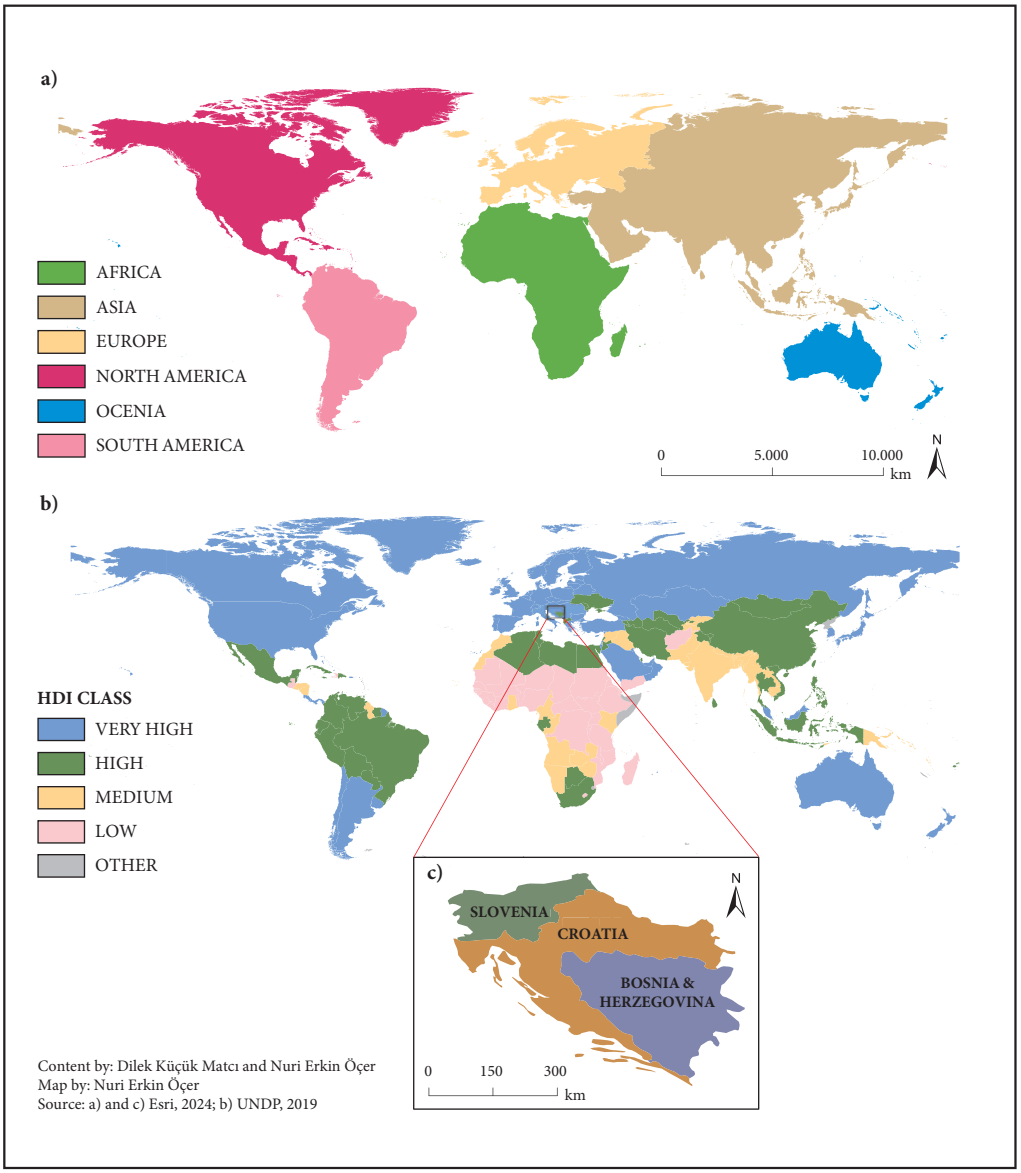


Figure 2: The study areas: a) the geographic continents, b) countries grouped according to HDI, c) the triad of Slovenia, Croatia, Bosnia and Herzegovina.

Table 1: The countries as grouped according to HDI for the year 2019.

Very High	Andorra	Very High	Portugal	High	Palestine, State of	Medium	Papua New Guinea
	Argentina		Qatar		Paraguay		Sao Tome and Principe
	Australia		Romania		Peru		Solomon Islands
	Austria		Russian Federation		Philippines		Syrian Arab Republic
	Bahamas		Saudi Arabia		Saint Kitts and Nevis		Tajikistan
	Bahrain		Serbia		Saint Lucia		Timor-Leste
	Barbados		Singapore		Saint Vincent and the Grenadines		Vanuatu
	Belarus		Slovakia		Samoa		Zambia
	Belgium		Slovenia		Seychelles		Zimbabwe
	Brunei Darussalam		Spain		South Africa	Low	Afghanistan
	Bulgaria		Sweden		Sri Lanka		Benin
	Canada		Switzerland		Suriname		Burkina Faso
	Chile		Turkey		Thailand		Burundi
	Costa Rica		United Arab Emirates		Tonga		Central African Republic
	Croatia		United Kingdom		Trinidad and Tobago		Chad
	Cyprus		United States		Tunisia		Congo (Dem.Rep. of the)
	Czechia		Uruguay		Turkmenistan		Côte d'Ivoire
	Denmark	High	Albania		Ukraine		Djibouti
	Estonia		Algeria		Uzbekistan		Eritrea
	Finland		Antigua and Barbuda		Venezuela (Bolivarian Rep. of)		Ethiopia
	France		Armenia		Viet Nam		Gambia
	Georgia		Azerbaijan	Medium	Angola		Guinea
	Germany		Belize		Bangladesh		Guinea-Bissau
	Greece		Bolivia		Bhutan		Haiti
	Hong Kong, China (SAR)		Bosnia and Herzegovina		Cabo Verde		Lesotho
	Hungary		Botswana		Cambodia		Liberia
	Iceland		Brazil		Cameroon		Madagascar
	Ireland		China		Comoros		Malawi
	Israel		Colombia		Congo		Mali
	Italy		Cuba		El Salvador		Mauritania
	Japan		Dominica		Equatorial Guinea		Mozambique
	Kazakhstan		Dominican Republic		Eswatini (Kingdom of)		Niger
	Korea (Republic of)		Ecuador		Ghana		Nigeria
	Kuwait		Egypt		Guatemala		Rwanda
	Latvia		Fiji		Guyana		Senegal
	Liechtenstein		Gabon		Honduras		Sierra Leone
	Lithuania		Grenada		India		South Sudan
	Luxembourg		Indonesia		Iraq		Sudan
	Malaysia		Iran (Islamic Republic of)		Kenya		Tanzania (United Republic of)
	Malta		Jamaica		Kiribati		Togo
	Mauritius		Jordan		Kyrgyzstan		Uganda
	Montenegro		Lebanon		Lao People's Democratic Rep.		Yemen
	Netherlands		Libya		Micronesia (Federated States of)	Others	Korea (Dem. People's Rep. of)
	New Zealand		Maldives		Morocco		Monaco
	Norway		Marshall Islands		Myanmar		Nauru
	Oman		Mexico		Namibia		San Marino
	Palau		Moldova (Republic of)		Nepal		Somalia
	Panama		Mongolia		Nicaragua		Tuvalu
	Poland		North Macedonia		Pakistan		

3 Results and discussion

The results obtained by the method employed are presented in this section in the form of maps and tables. The maps illustrate the distributions of the annual averages of tropospheric NO_2 column concentrations, while the tables show the annual and the monthly average values over each study area. The results are presented in the following order: the Earth, the geographical continents, the countries grouped according to HDI, and the triad of Slovenia, Croatia, Bosnia and Herzegovina.

3.1 NO_2 emission across the Earth

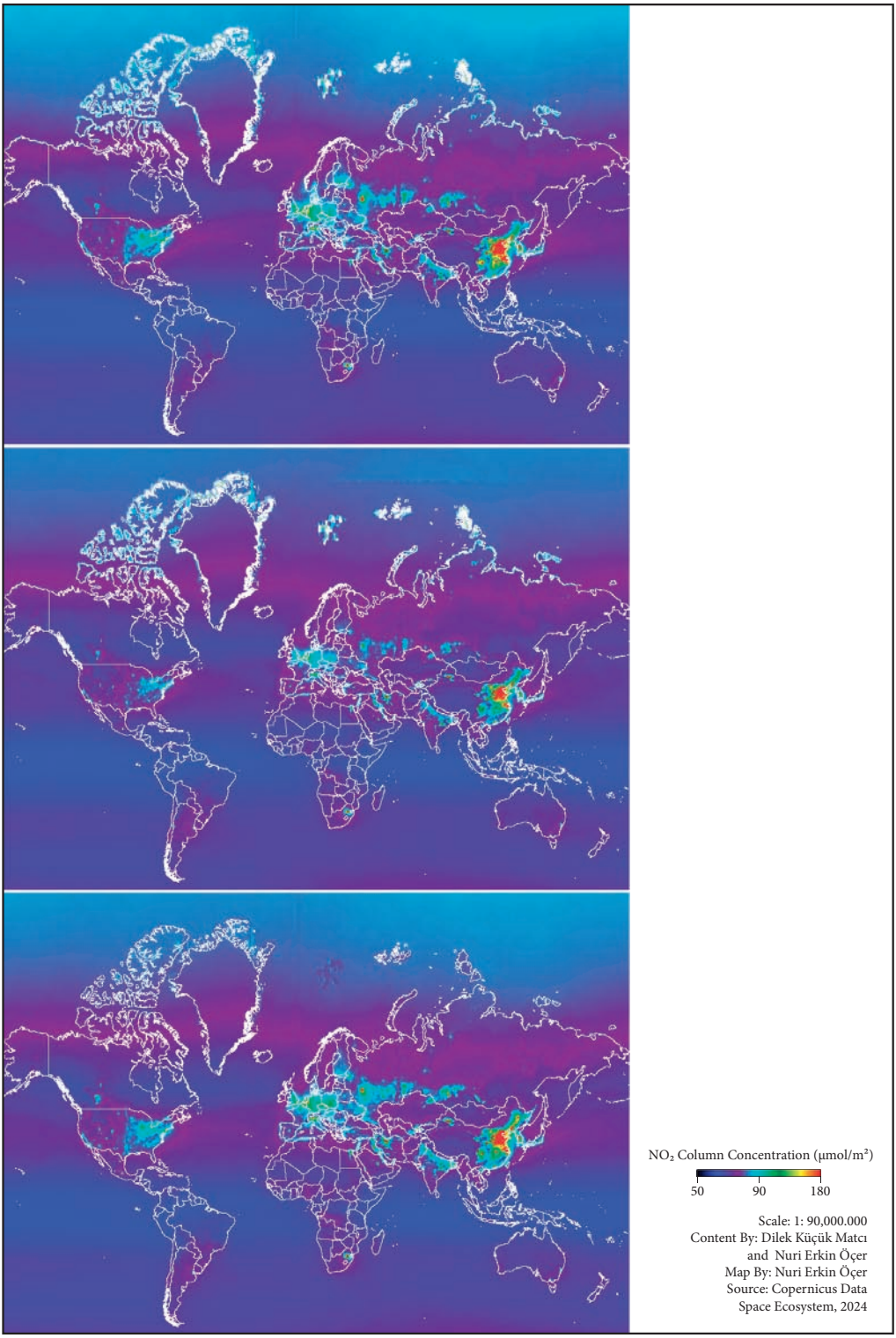
The distribution of the annual averages of the Earth's tropospheric NO_2 column concentrations for the years 2019, 2020 and 2021, are presented in Figure 3. The maps, each of which is an average of more than 64,000 images (occupying more than 30 terabytes of memory) recorded by the satellite throughout the study period, reveal the concentrations and distributions of tropospheric NO_2 worldwide before, during and after the pandemic, respectively. A visual comparison of the data reveals a significant decrease in the average NO_2 emission in the pandemic year (2020). This result is corroborated by Table 2, which presents the annual averages of tropospheric NO_2 concentrations for the study period across all study areas. For the Earth, the total NO_2 concentration decreased by 3.4% in 2020 (51.2 μmol/m²) in comparison to 2019 (53.0 μmol/m²), and then increased by 2.9% in 2021 (52.7 μmol/m²) in comparison to 2020. This represents a net decrease of 0.6% in the average concentration of NO_2 in 2021 in comparison to 2019.

The outcomes are in line with the results of the study of Saha et al. (2022), which compiled worldwide research on air quality parameters. They reported a significant improvement in global air pollution levels during the quarantine period and indicated the extent to which concentrations of major air pollutants, such as NO_2, SO_2, CO and particulate matter, decreased in major countries of the world. Furthermore, Cooper et al. (2022) employed a method that enabled them to quantify changes in NO_2 concentrations across more than 200 cities. Their results demonstrated that countries with stringent lockdown policies exhibited NO_2 concentration levels that were on average approximately 30% lower than in those without. Furthermore, the study revealed that the sensitivity of atmospheric NO_2 to closures exhibited variability across countries and emission sectors.

Table 2: The annual averages of NO_2 column concentrations for the Earth, the continents, the countries grouped according to HDI and the triad of Slovenia, Croatia, Bosnia and Herzegovina for the years of 2019, 2020 and 2021, and the change between years.

		NO_2 Column Density (μmol/m²)			Yearly Change (%)		
	Study Area	2019	2020	2021	2020–2019	2021–2020	2021–2019
	The Earth	53.0	51.2	52.7	–3.4	2.9	–0.6
The Continents	Africa	51.8	51.3	54.0	–1.0	5.3	4.2
	Asia	65.5	61.5	65.8	–6.1	7.0	0.5
	Europe	73.9	67.5	73.7	–8.7	9.2	–0.3
	North America	56.8	54.1	55.8	–4.8	3.1	–1.8
	Oceania	52.7	53.2	51.8	0.9	–2.6	–1.7
	South America	45.2	46.8	47.4	3.5	1.2	4.8
HDI Classes	Very High HDI	61.4	58.3	61.0	–5.1	4.7	–0.6
	High HDI	60.2	58.0	61.3	–3.7	5.7	1.9
	Medium HDI	57.4	56.3	59.8	–2.0	6.2	4.1
	Low HDI	49.6	48.9	52.4	–1.5	7.2	5.6
	Slovenia	80.7	76.0	83.9	–5.9	10.5	4.0
	Croatia	74.4	69.9	76.6	–6.1	9.6	3.0
	Bosnia and Her.	68.9	64.6	71.2	–6.3	10.3	3.4

Figure 3: The global distribution of annual averages of NO_2 column concentration for the years 2019 (top), 2020 (middle), and 2021 (bottom). ► p. 83


NO_2 Column Concentration (µmol/m²)
50
90
180
Scale: 1: 90,000.000
Content By: Dilek Küçük Matcı
and Nuri Erkin Öçer
Map By: Nuri Erkin Öçer
Source: Copernicus Data
Space Ecosystem, 2024

The variation in the monthly averages of NO_2 emissions for the Earth is presented in Table 3 and Figure 4. Accordingly, the mean NO_2 emissions for each month of 2020 were consistently lower than those for each month of 2019. Moreover, the results demonstrate that NO_2 levels were lower than the pre-pandemic values even before the countries adopted the pandemic closures and restriction measures, namely before mid-March. During the course of 2020, which encompassed a series of closures and the implementation of stringent measures, the tropospheric NO_2 concentration exhibited a decrease of 3.4% per month in comparison to the preceding year. In contrast, prior to the implementation of government measures, namely in the first three months of 2020, there was a monthly decrease of 4.0% in comparison to the corresponding period of the previous year. This can be interpreted as a result of individuals voluntarily limiting their movements and spending more time at home in order to protect themselves from the effects of pandemic. In 2021, following the relaxation of restrictions, monthly averages increased in all months except January in comparison to 2020.

Table 3: The monthly averages of tropospheric NO_2 global density for the period from January 2019 to December 2021.

	NO_2 column density ($\mu mol/m^2$)		
Month	2019	2020	2021
January	55.3	53.9	53.7
February	52.3	49.7	50.6
March	49.1	46.8	48.2
April	51.0	48.6	50.2
May	55.3	52.3	54.5
June	58.4	55.4	57.1
July	55.9	54.4	57.0
August	51.6	51.2	53.2
September	48.1	47.4	49.1
October	49.3	48.3	49.6
November	53.8	50.9	52.9
December	55.5	55.3	55.9

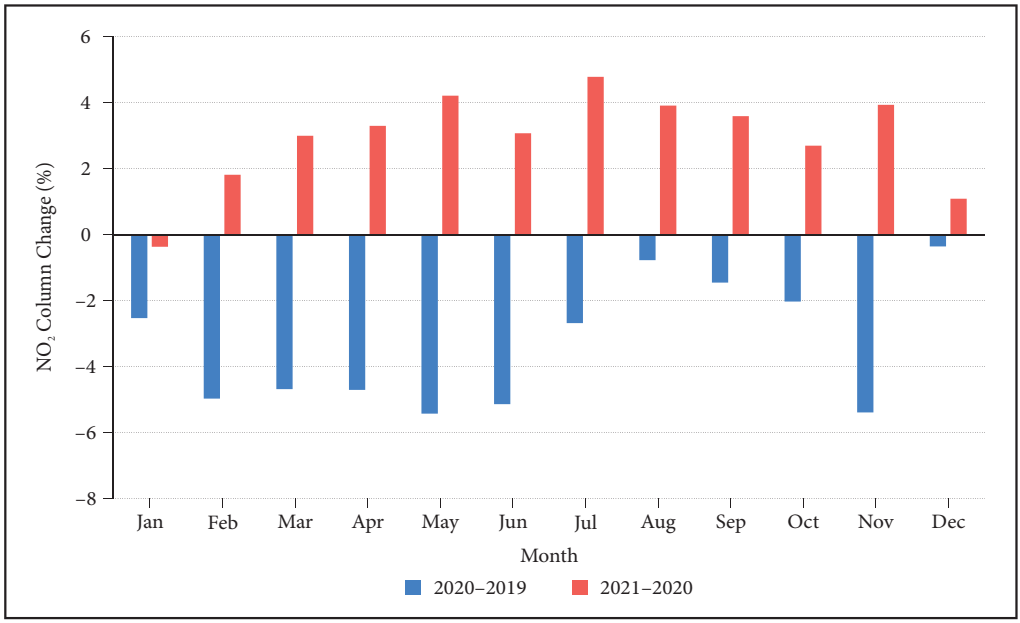


Figure 4: The percentage differences between 2020–2019 and 2021–2020 of global monthly averages of tropospheric NO_2 concentrations for the same month.

3.2 NO_2 emissions on the continents

The annual averages of NO_2 emissions by continent for the years 2019, 2020 and 2021 are presented in Table 2. The ranking in 2019, from the highest to the lowest, is as follows: Europe, Asia, North America, Oceania, Africa and South America. The ranking remains unchanged in 2020, but Oceania regresses one place and Africa rises one in 2021. In comparison to 2019, NO_2 emissions in 2020, the year during which pandemic restrictions were most strictly applied, decreased by 8.7% in Europe, 6.1% in Asia, 4.8% in North America, 1.0% in Africa, while they increased by 0.9% in Oceania and 3.5% in South America. In 2021, NO_2 emissions exhibited an increase of 9.2% in Europe, 7.0% in Asia, 3.1% in North America, 5.3% in Africa, and 1.2% in South America in comparison to 2020. The only decrease was observed in Oceania, where emissions decreased by 2.6%. Between 2021 and 2019, NO_2 emissions decreased by 0.3% in Europe, 1.8% in North America and 1.7% in Oceania, while it increased 0.5% in Asia, 4.2% in Africa, and 4.8% in South America. South America was the only continent whose averages exhibited an increase in both years.

Table 4 presents the monthly averages of NO_2 column densities for the continents from January 2019 to December 2021. With regard to Africa, it can be observed that NO_2 emissions decreased until August 2020 and then increased continuously until the end of the study period (Figure 5a). For Asia, NO_2 emissions exhibited a decrease for all months except December in 2020, followed by an increase for all months except December in 2021 (Figure 5b). In Europe, NO_2 emissions exhibited a decrease until December 2020, followed by a continuous increase (Figure 5c). Among all the continents, the greatest change in NO_2 levels between consecutive years was observed in Europe, with a 40% increase between February 2020 and 2021. For North America, a downward trend is observed across all of 2020, with the exception of November, and an upward trend across 2021, with the exception of January, February and November (Figure 5d). In contrast to the other continents, the tropospheric NO_2 values in Oceania and South America did not decline until May 2020, in comparison to the values observed in 2019. From that point onwards, the values exhibited a variable trend in Oceania and South America (Figure 5e and 5f). Moreover, the magnitudes of change were relatively modest in comparison to those observed in other continents.

The results demonstrate that human-induced NO_2 emissions have undergone corresponding changes across continents during the pandemic process, particularly in relation to the extent of their industrialisation based on fossil fuels. In the study of Cooper et al. (2022), the emission estimates for 2020, which were made by considering the ten-year period prior to the pandemic, were compared with the new situation resulting from the actual pandemic for the continents. Accordingly, the largest discrepancy from the projected values was identified for Europe, corroborating the findings of our investigation.

3.3 NO_2 emissions in countries as grouped according to HDI

The annual changes of NO_2 emissions for countries in categories classified according to the HDI are presented in Table 2. Accordingly, in 2019, the category ranking from high to low is *Very High*, *High*, *Medium* and *Low*. The ranking remains unchanged in 2020, but in 2021 the total emissions of the *High* category exceed those of the *Very High* category. In 2020, when pandemic restrictions were the most stringent, there was a reduction in NO_2 emissions across all categories in comparison to 2019. The decline in the *Very High* category was 5.1%, in the *High* category 3.7%, in the *Medium* category 2.0%, and in the *Low* category 1.5%. In 2021, NO_2 emissions exhibited an increase in all categories when compared to 2020. The increase was 4.7% in the *Very High* category, 5.7% in the *High* category, 6.2% in the *Medium* category, and 7.2% in the *Low* category. A comparison of the 2021 averages with those of 2019 reveals that total NO_2 emissions decreased only in the *Very High* category (0.6%) and increased in all other categories (*High*: 1.9%, *Medium*: 4.1%, *Low*: 5.6%) in 2021. The results of the 2020–2019 period indicate that the reduction in NO_2 emissions is more pronounced in regions with a higher development index. Conversely, the results for the period 2021–2020 indicate a greater rate of increase in emissions in regions with a lower HDI. This suggests that the severity of the closures may be increasing in line with the development level.

Figure 5: The monthly percentage differences of NO_2 column concentrations of a) Africa, b) Asia, c) Europe, d) North America, e) Oceania, f) South America between consecutive years, 2020–2019 and 2021–2020. ► p. 86

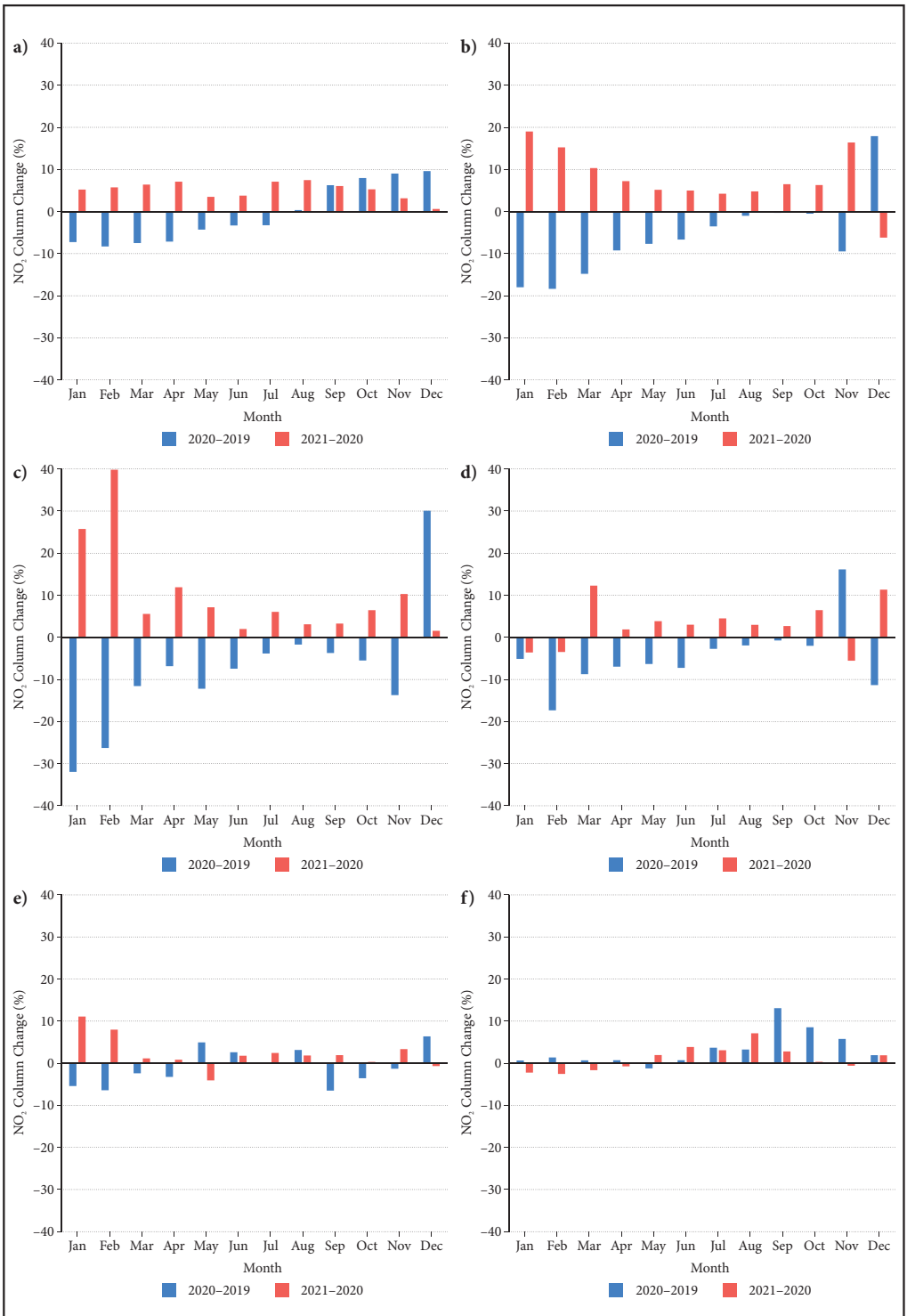

a)
b)
c)
d)
e)
f)
NO2 Column Change (%)
40
30
20
10
0
−10
−20
−30
−40
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Month
2020–2019
2021–2020

Table 4: The monthly averages of NO_2 column densities of the continents for the period from January 2019 to December 2021.

	NO_2 column density (µmol/m^2)																	
	Africa			Asia			Europe			N. America			S. America			Oceania		
Month	2019	2020	2021	2019	2020	2021	2019	2020	2021	2019	2020	2021	2019	2020	2021	2019	2020	2021
Jan.	49.5	45.9	48.3	65.5	53.7	63.9	83.9	57.1	71.8	41.3	39.2	37.8	45.1	45.4	44.4	57.2	60.3	53.6
Feb.	49.4	45.3	47.9	57.1	46.6	53.7	74.6	55.0	76.9	49.1	40.6	39.2	43.1	43.7	42.6	53.0	56.4	51.9
Mar.	50.7	46.9	49.9	62.7	53.4	58.9	70.9	62.7	66.2	48.1	43.9	49.3	42.6	42.9	42.2	50.3	51.5	50.9
Apr.	51.7	48.0	51.4	70.3	63.8	68.4	73.1	68.1	76.2	62.0	57.7	58.8	41.4	41.7	41.4	46.4	47.9	47.5
May	53.7	51.4	53.2	75.5	69.7	73.3	84.4	74.1	79.4	74.6	69.9	72.6	41.1	40.6	41.4	46.4	44.1	45.9
June	57.5	55.6	57.7	79.5	74.2	77.9	87.4	80.9	82.5	81.7	75.8	78.1	40.9	41.2	42.8	45.7	44.5	43.7
July	58.4	56.5	60.5	76.0	73.3	76.4	80.7	77.6	82.3	77.2	75.1	78.5	43.4	45.0	46.4	45.3	45.2	44.1
Aug.	56.0	56.2	60.4	67.7	67.0	70.2	75.4	74.1	76.4	68.0	66.7	68.7	49.0	50.6	54.2	50.5	48.9	48.0
Sep.	52.8	56.1	59.5	58.9	58.7	62.5	70.0	67.4	69.6	55.6	55.2	56.7	50.4	57.0	58.6	53.8	57.3	56.2
Oct.	49.1	53.0	55.8	55.9	55.6	59.1	65.5	61.9	65.9	45.6	44.7	47.6	50.2	54.5	54.7	58.9	61.0	60.8
Nov.	46.6	50.8	52.4	57.9	52.4	61.0	61.9	53.4	58.9	39.0	45.3	42.8	48.5	51.3	51.0	61.8	62.6	60.5
Dec.	45.9	50.3	50.6	58.6	69.1	64.8	59.5	77.4	78.6	39.7	35.2	39.2	46.8	47.7	48.6	62.6	58.6	59.0

Table 5: The monthly averages of NO_2 column densities of the HDI categories for the period from January 2019 to December 2021.

	NO_2 column density (μmol/m^2)											
	Very High HDI			High HDI			Medium HDI			Low HDI		
Month	2019	2020	2021	2019	2020	2021	2019	2020	2021	2019	2020	2021
Jan.	56.9	50.7	53.3	63.0	51.7	59.8	53.7	49.5	52.7	48.8	43.7	48.7
Feb.	55.5	47.6	52.8	59.8	49.3	53.7	53.8	49.9	53.8	48.7	43.6	47.1
Mar.	56.6	51.3	54.7	61.1	54.6	58.2	57.7	52.5	58.5	49.9	45.7	50.0
Apr.	63.6	59.4	62.7	61.0	57.6	60.9	58.8	53.9	58.9	51.3	47.2	50.8
May	70.8	65.1	68.6	62.5	58.9	61.3	61.4	57.4	59.8	52.3	49.5	52.7
June	74.8	70.0	72.2	63.3	60.1	63.1	65.0	61.7	64.6	55.2	52.3	55.7
July	71.8	69.6	72.2	62.0	60.9	64.1	64.8	62.0	66.9	54.6	52.2	56.8
Aug.	66.2	65.5	67.3	61.5	60.4	65.0	61.6	61.4	65.9	51.5	51.4	55.9
Sep.	59.1	59.3	61.3	58.9	61.3	65.1	58.2	61.4	64.9	48.7	51.4	55.3
Oct.	55.3	54.0	57.2	57.6	60.4	62.7	53.8	57.3	60.6	45.8	50.1	53.1
Nov.	53.1	50.2	53.7	56.3	57.3	61.0	50.8	54.0	56.3	44.7	49.4	52.0
Dec.	52.8	56.6	56.3	55.0	63.1	60.6	49.4	54.3	54.1	43.9	49.7	50.5

Table 5 presents the monthly averages of NO_2 column densities for countries belonging to different HDI categories for the period from January 2019 to December 2021. The NO_2 emissions in the *Very High* category exhibited a downward trend for the majority of months in 2020, with the exception of September and December. Conversely, an upward trend was observed for all months in 2021, with the exception of December (Figure 6a). In this category, the greatest reductions and increases in NO_2 emissions for the study period were observed in February 2020 and February 2021, respectively. In the *High* category, NO_2 emissions exhibited a pronounced decline in the initial months of 2020, followed by an upward trend from September of the same year. This upward trend persisted until December 2021, as illustrated in Figure 6b. Among all categories, the greatest reduction and increase in emissions for the entire study period were observed in the *High* category in January 2020 and January 2021, respectively. In the *Medium* and *Low* HDI categories, a reduction in emissions was observed in 2020 until September. Subsequently, emissions exhibited an upward trend until the end of 2021 (Figures 6c and 6d).

Following the implementation of measures to combat the epidemic, there was an uninterrupted decline in emissions over an extended period. However, this trend was reversed in September 2020, with emissions increasing in all categories except the *Very High* category. The reversal of this trend commenced in December 2020 for the *Very High* category, suggesting that the relaxation of lockdowns in countries in this category lagged behind by a few months.

A substantial majority of studies analysing the impacts of the pandemic on pollutant emissions have examined the situation at the scale of cities and countries. In contrast, Li et al. (2022), employing a data-driven approach, analysed regions without limiting them to administrative boundaries. Their findings indicated that these regions can be divided into three distinct clusters according to their pollution levels. The findings of the study indicated that the level of restriction measures in the cluster with the highest emissions was more stringent than in the other clusters, and NO_2 emissions in this cluster declined more than in the others. A comparison of the results of our study with those of this study revealed that a significant number of countries in the *Very High* and *High* HDI categories corresponded to the cluster designated as poor (with the highest emissions) in this study.

3.4 NO_2 emissions in Slovenia, Croatia, and Bosnia and Herzegovina

In the last phase of the study, tropospheric NO_2 levels were monitored in three neighbouring southern European countries: Slovenia, Croatia, Bosnia and Herzegovina (Figure 7a). Slovenia (population approximately 2.1 million) and Croatia (population approximately 3.8 million) are classified as belonging to the

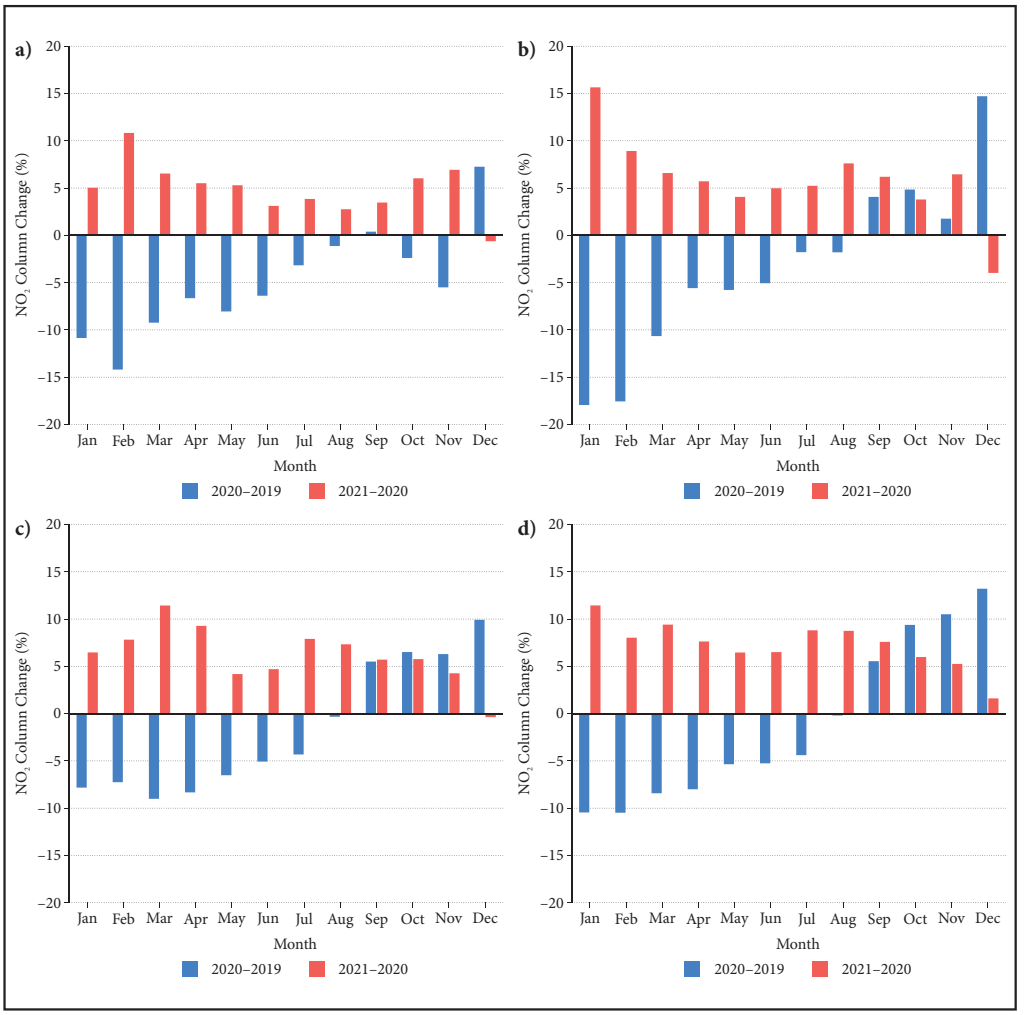
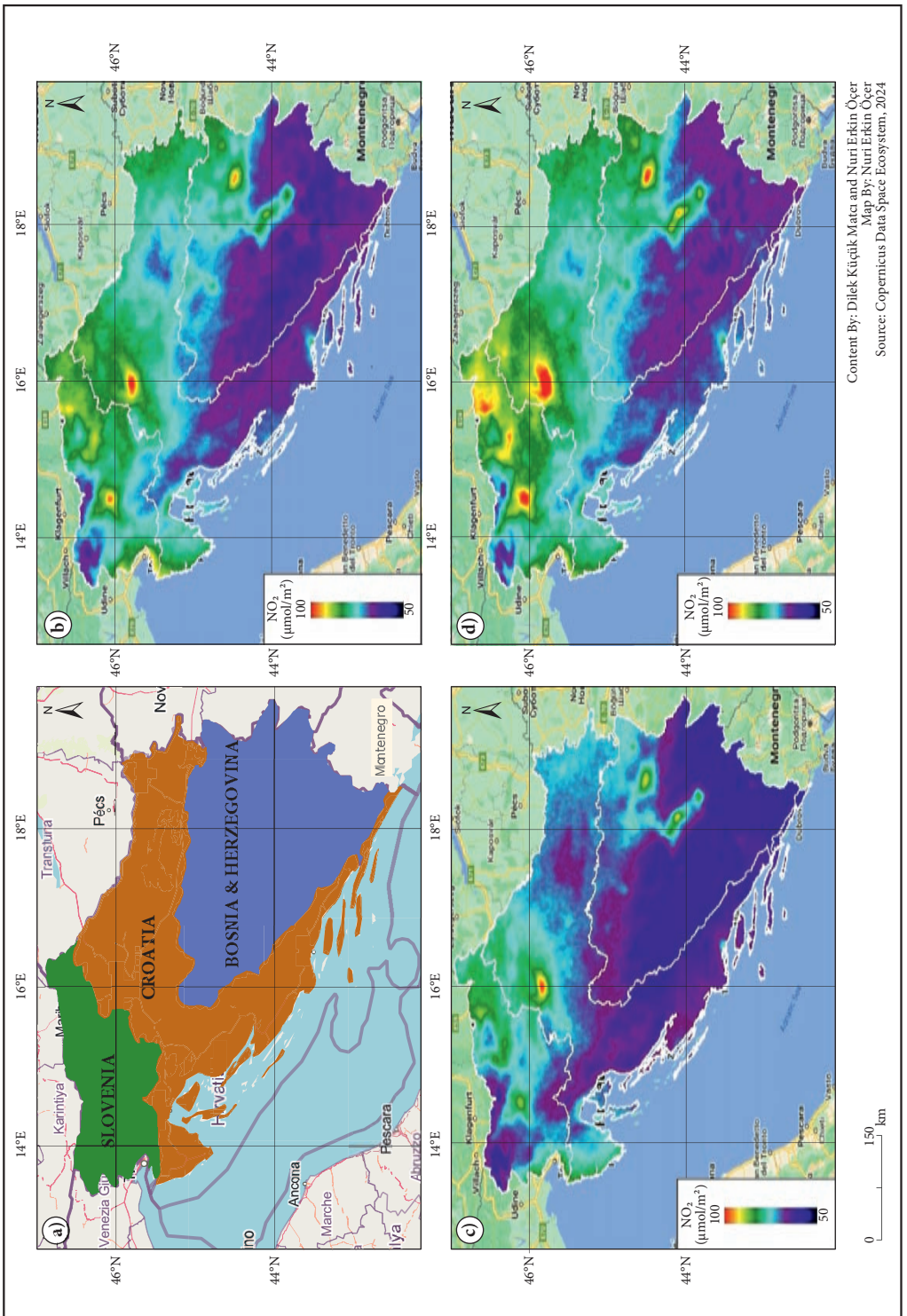


Figure 6: The monthly percentage differences of NO_2 column concentrations of a) *Very High* b) *High* c) *Medium* d) *Low* developed countries between consecutive years, 2020–2019 and 2021–2020.

Very High HDI category, while Bosnia and Herzegovina (population approximately 3.2 million) classified as belonging to the *High* HDI category. The distributions of annual average tropospheric NO_2 levels in these three countries for the pre-pandemic year (2019), pandemic year (2020) and post-pandemic year (2021) are presented in Figures 7b, 7c and 7d, respectively. The annual average of NO_2 over Bosnia and Herzegovina is consistently lower than the other two countries, in line with the values presented in Table 2. The impact of pandemic measures on NO_2 emissions is evident when comparing Figures 7b and 7c for all three countries. Table 2 also indicates that there was a decrease of 5.9% for Slovenia, 6.1% for Croatia and 6.3% for Bosnia and Herzegovina in 2020 compared to 2019. In 2021, the increases in NO_2 emissions following the removal of measures are revealed by comparing Figures 7c and 7d. The annual averages increased by 10.5% for Slovenia, 9.6% for Croatia and 10.3% for Bosnia and Herzegovina in 2021 compared

Figure 7: a) Slovenia-Croatia-Bosnia and Herzegovina triad on the map and their annual average of tropospheric NO_2 column densities for the year b) 2019, c) 2020, d) 2021. ► p. 90


(a)
(b)
(c)
(d)
SLOVENIA
CROATIA
BOSNIA & HERZEGOVINA
Hrvatska
Montenegro
Pécs
Ancona
Marche
Pescara
Abruzzo
Karintiya
Transtura
Venezia Giu
Udine
Villach
Klagenfurt
Pescara
Podgorica
Montenegr
NO2 (µmol/m2) 100 50
14°E
16°E
18°E
46°N
44°N
N
0 150 km
Content By: Dilek Küçük Matcı and Nuri Erkin Öçer
Map By: Nuri Erkin Öçer
Source: Copernicus Data Space Ecosystem, 2024

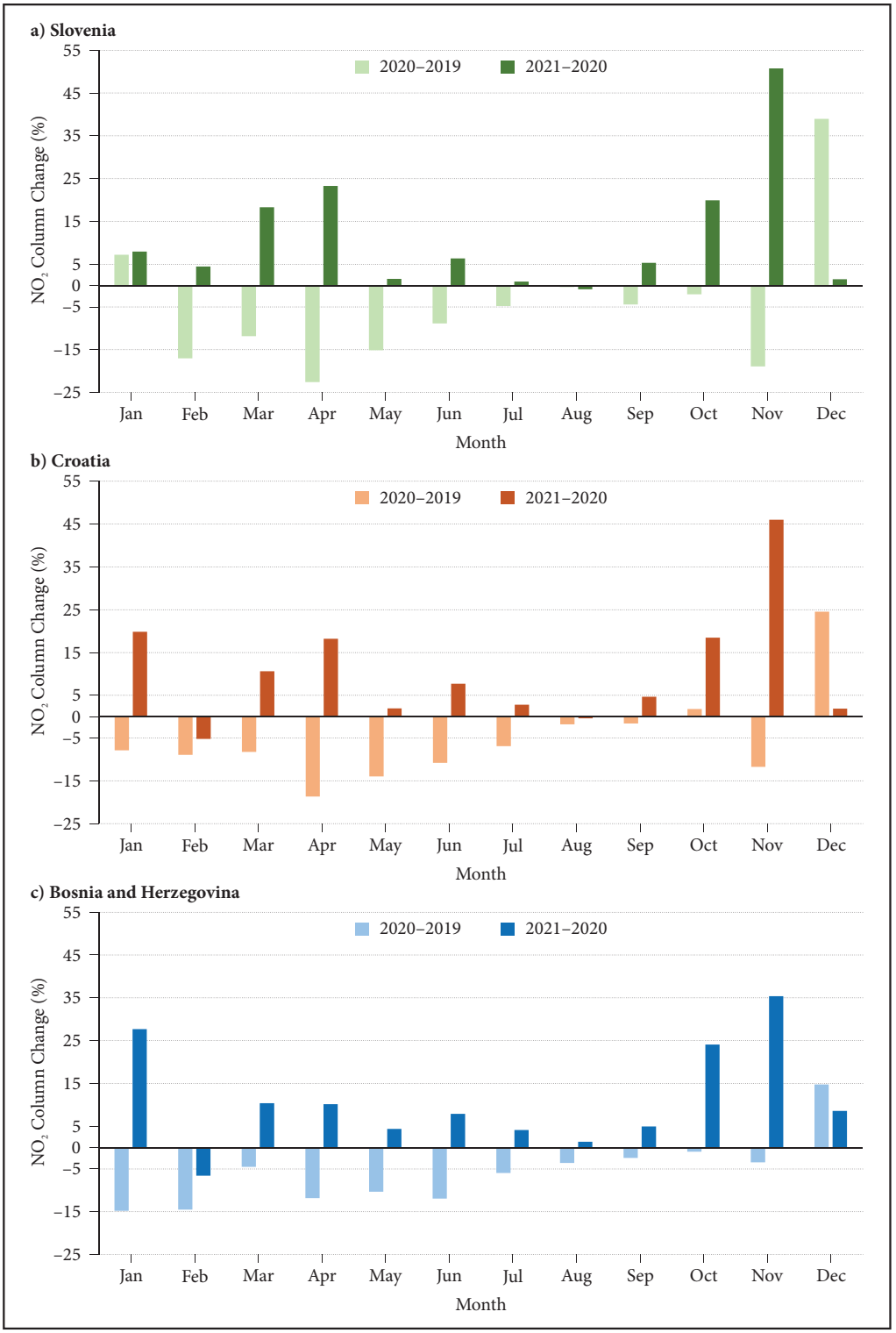
to 2020, as indicated by Table 2. A comparison of the 2021 averages with those of 2019 reveals that there were net increases of 4.0% in Slovenia, 3.0% in Croatia and 3.4% in Bosnia and Herzegovina.

The monthly averages of the NO_2 column densities for these countries for the months from January 2019 to December 2021 are presented in Table 6 and the monthly percentage differences of the NO_2 column concentrations of each country between the consecutive years 2020–2019 and 2021–2020 are presented in Figure 8. According to information reflected in reports by organisations such as the Inter-university Consortium for Political and Social Research (ICPSR) and the Organisation for Economic Cooperation and Development (OECD), in response to the initial cases of coronavirus that emerged in early March 2020 and the subsequent rapid spread of the virus, the governments of all three countries implemented a series of measures with the aim of halting the spread from mid-March onwards. These measures included the closure of educational institutions, limitations on public gatherings, the closure of cafes, restaurants and non-essential shops, and the imposition of travel restrictions. The implementation of these measures, which significantly restrict human mobility (Brezina et al. 2021), has resulted in a downward trend in human-induced NO_2 emissions in the atmosphere during the pandemic year, as illustrated in Figure 8. Following the control of the outbreak, the measures were eased in Bosnia and Herzegovina at the end of April and in Slovenia and Croatia from mid-May. Consequently, the reduction in emissions has slowed down. Nevertheless, following the relaxation of restrictions, the number of infected individuals in Slovenia and Croatia increased exponentially from October, leading to a further tightening of measures in November. Consequently, NO_2 emissions for these two countries fell rapidly again in November. A comparison of 2020 and 2019 November emission values confirms this result. In Bosnia and Herzegovina, the number of infected cases continued to increase linearly, and there was no further tightening of measures. Consequently, the decline in NO_2 emissions in Bosnia and Herzegovina has been considerably less pronounced than in the other two countries. Following the relaxation of restrictions in 2021, there was a notable increase in human mobility across all three countries, which led to a corresponding rise in NO_2 emissions.

Table 6: The monthly averages of NO_2 column densities of Slovenia, Croatia, Bosnia and Herzegovina for the period from January 2019 to December 2021.

	NO_2 column density (μmol/m^2)								
	2019			2020			2021		
	Slovenia	Croatia	Bosnia and Herzegovina	Slovenia	Croatia	Bosnia and Herzegovina	Slovenia	Croatia	Bosnia and Herzegovina
Jan	76.5	67.4	61.0	82.0	62.1	52.0	88.5	74.4	66.4
Feb	89.9	71.8	67.7	74.6	65.4	57.9	77.9	62.0	54.1
Mar	81.9	74.0	66.6	72.2	67.9	63.6	85.4	75.1	70.2
Apr	89.9	85.2	77.1	69.6	69.3	68.0	85.8	81.9	74.9
May	91.1	85.2	76.6	77.3	73.3	68.7	78.5	74.7	71.7
Jun	83.3	83.4	80.6	75.9	74.4	71.0	80.7	80.1	76.6
Jul	81.3	81.3	77.6	77.4	75.7	73.0	78.1	77.8	76.0
Aug	78.3	78.3	75.4	78.0	76.9	72.7	77.3	76.6	73.7
Sep	79.0	74.6	70.5	75.5	73.4	68.8	79.5	76.8	72.2
Oct	72.8	67.2	63.7	71.3	68.4	63.1	85.5	81.0	78.3
Nov	75.1	63.1	55.3	60.9	55.7	53.4	91.8	81.3	72.3
Dec	69.6	60.8	54.8	96.7	75.7	62.9	98.1	77.1	68.3

Figure 8: The monthly percentage differences of NO_2 column concentrations of a) Slovenia b) Croatia c) Bosnia and Herzegovina between consecutive years, 2020–2019 and 2021–2020. ► p. 92


a) Slovenia
2020–2019
2021–2020
NO2 Column Change (%)
55
45
35
25
15
5
0
−5
−15
−25
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month
b) Croatia
2020–2019
2021–2020
NO2 Column Change (%)
55
45
35
25
15
5
0
−5
−15
−25
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month
c) Bosnia and Herzegovina
2020–2019
2021–2020
NO2 Column Change (%)
55
45
35
25
15
5
0
−5
−15
−25
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month

4 Conclusions

In this study, TROPOMI data were accessed and processed through Google Earth Engine (GEE) in order to monitor and evaluate the effects of the COVID-19 pandemic on tropospheric NO_2 concentrations and distributions at various supranational scales. The study examines the levels of NO_2 in countries grouped according to the Human Development Index (HDI), as well as the temporal variation of NO_2 across the globe, continents and the triad of Slovenia, Croatia, and Bosnia and Herzegovina.

The results of the study indicate a notable decline in NO_2 levels across all study areas during the pandemic period in comparison to the pre-pandemic period. The decline commenced even before the implementation of restrictions and closures by governments. In contrast to other studies, the results of our study indicate that the observed reductions in emissions in the period before the implementation of the restrictions, i.e. in the first three months of 2020, cannot be attributed solely to the adoption of the measures. Instead, it appears that individuals are also adopting behaviours to protect themselves from the disease, such as avoiding social contact and limiting their own mobility in the community, and that emissions are starting to fall as a result.

Following a prolonged period of decline, emissions began to increase across all HDI categories and on most continents (with the exception of Oceania and South America) in response to the relaxation and removal of the measures and associated increased human mobility. The increase trend commenced three months earlier in the *High*, *Medium* and *Low* HDI categories than in the *Very High* category, indicating an earlier relaxation of lockdowns in these countries. Another noteworthy finding of the study is that during the period of restrictions, the decline in NO_2 emissions increases as the development index increases. Furthermore, the results for the period following the lifting of restrictions indicate that the rate of increase in emissions is greater in areas with a lower HDI. These two observations were interpreted as the severity of closures increases as the level of development increases.

In the final phase of the study, tropospheric NO_2 levels were monitored in Slovenia, Croatia, and Bosnia and Herzegovina before, during and after the pandemic. Although the pre-pandemic level of emissions in Bosnia and Herzegovina, which is in the *High* HDI category, was significantly lower than in the other two *Very High* HDI countries, it demonstrated similar trends to the pandemic emissions in the other two countries. However, variations in outcomes were also observed in relation to the timing of the implementation of measures.

The results demonstrate that a study requiring the access of thousands of data and the use of terabytes of memory can be successfully conducted through a cloud-based software such as GEE. The processes that would have required considerable resources, time, and labour, and would have been error-prone without GEE, were executed efficiently through this platform in the course of the research.

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ENVIRONMENTAL RESPONSIBILITY AND COMMUNICATION IN SELECTED COMPANIES IN THE PODRAVSKA STATISTICAL REGION

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Drinking fountain at the Faculty of Arts student campus in Maribor.

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Environmental responsibility and communication in selected companies in the Podravska statistical region

ABSTRACT: The paper presents best practices pursued by eight companies from the Podravska statistical region selected because they promote green transition in this society. In the theoretical section, the article presents environmental responsibility as part of corporate social responsibility and deals with the type of communication needed to address and motivate people to implement the EU Green Deal goals. The empirical section analyses eight semi-structured interviews with representatives from selected companies in the Podravska statistical region. The results highlight long-term efforts to raise public awareness about the environmental crisis (without major visible effects), financial aid as the main motivation factor to implement green practices, shortage of specific training courses in communication, and the need for locally focused training.

KEYWORDS: environmental responsibility, sustainability, sustainable organisational practices, green motives, communication, Podravska statistical region.

Okoljska odgovornost in komunikacija v izbranih podjetjih v Podravski statistični regiji

POVZETEK: V prispevku so predstavljene dobre prakse osem podjetij iz podravske statistične regije, ki so bila izbrana zaradi spodbujanja zelenega prehoda v tem okolju. V teoretičnem delu članek predstavlja okoljsko odgovornost kot del družbene odgovornosti podjetij in obravnava vrsto komunikacije, ki je potrebna za nagovarjanje in motiviranje ljudi za izvajanje ciljev zelenega dogovora EU. V empiričnem delu je analiziranih osem polstrukturiranih intervjujev s predstavniki izbranih podjetij v podravski statistični regiji. Rezultati izpostavljajo dolgoročna prizadevanja za ozaveščanje javnosti o okoljski krizi (brez večjih vidnih učinkov), finančno pomoč kot glavni motivacijski dejavnik za izvajanje zelenih praks, pomanjkanje posebnih usposabljanj na področju komuniciranja in potrebo po lokalno usmerjenem usposabljanju.

KLJUČNE BESEDE: okoljska odgovornost, trajnostnost, trajnostne organizacijske prakse, zeleni motivi, komunikacija, Podravska statistična regija

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1 Introduction

In the article »Six decades of human geography and environmental protection in Acta geographica Slovenica,« Urbanc et al. (2014) outline the development of Slovenian and foreign thought in the field of human geography and environmental protection, where globalisation has become a key concept in much of the latest research. Also, Zorn and Komac (2010) discuss how the focus of research has shifted from traditional human geography topics to contemporary issues such as mobility, sustainable development, globalization, creativity and cultural industry (Bole 2008). Since sustainability theory focuses on balancing socio-cultural, economic, and environmental systems, research in this field inherently takes an interdisciplinary approach, going beyond the confines of any single scientific discipline (Nučič 2012).

In this study we focus on corporate social responsibility (CSR), a business model where companies integrate social concerns into their interactions with stakeholders, emphasizing sustainability, accountability, and transparency (European Commission 2001). To date, theories have addressed four core areas of CSR: economic, legislative, ethical and philanthropic (Carroll 1991), and CSR discourse has expanded to several types of CRS: environmental responsibility, digital responsibility etc. (Bednarova and Serpeninova 2023). We also focus on environmental economics and corporate environmental responsibility (CER) (Bansal and Roth 2000), which has become a necessity in times of visible (negative) changes to the environment.

The transition to a resilient society, however, is unthinkable without successful communication of the environmental crisis to various audiences and in cooperation with multiple stakeholders. The Pilot Project for the Renewal of Higher Education for a Green and Resilient Transition has been running from 2022 to 2025 at the Faculty of Arts, University of Maribor, including a module called: Komuniciranje podnebne krize za uspešen prehod v zeleno družbo (Engl. Communicating the climate crisis for a successful transition to a green society; https://zelen.kom.ff.um.si/), within which eight interviews were conducted. These were carried out with various representatives from private and public sectors such as agriculture, public institutions, industry, commercial centres and craftsmanship (hereafter: companies) located in the Podravska statistical region, which is notable for manufacturing, vehicle maintenance, scientific activity, and transport, employing 46.54% of the workforce in this area in 2020 (Pučnik 2022).

The aim of the article is to examine best green practices among these companies in the Podravska statistical region, focusing on their motives for adopting environmentally responsible actions, the communication strategies they use to promote these actions, and their expectations regarding the green transition. All this will serve to raise awareness, create knowledge and to motivate environmentally responsible actions among students, employees, and others, connected to the University of Maribor, because we believe universities are key stakeholders in tackling major societal challenges.

We were particularly interested in what best practices companies are implementing in respect of environmental responsibility, including the context of sustainability and green transition. Furthermore, we were interested in the motives that stimulated them to initiate these best practices, their public communication in this respect, and what challenges they identified as necessary to overcome for a future green transition.

1.1 Corporate social responsibility

Social responsibility has been an integral part of human communities since their inception, evolving with societal values and priorities (Agudelo, Jóhannsdóttir and Davídsdóttir 2019). From ancient Rome to the modern era, awareness of the impact of social behaviour has grown, particularly in response to industrialization, technological advances, and entrepreneurship. This shift has placed CSR at the forefront, emphasizing environmental impact, workers' rights, consumer protection, and anti-corruption measures.

As societal expectations have evolved, so have corporate goals and practices, aligning with public values in economics, law, ethics, and philanthropy (Carroll 1991). This shift is evident in the mid-20th century's theoretical definitions, international commissions, and new legislation focusing on CSR (Agudelo, Jóhannsdóttir and Davídsdóttir 2019). Therefore, multiple European reports define seven inter-related core subjects of CSR: employees, customers, local community, environment, human rights, ethical behaviour, and leadership (European Commission … 2001; International organisation … 2010). Zore, Bastič and Mulej (2016) established that CSR towards employees, human rights and ethical behaviour are united into CSR leadership towards employees. Socially responsible companies engage in ethical behaviour, innovative economic

development, quality work environments, and local community contributions, often exceeding legal requirements (McWilliams and Siegel 2001).

CSR practices enhance corporate reputation and reliability, influencing consumer and stakeholder perceptions (McWilliams and Siegel 2001; Servaes and Tamayo 2014). Feng et al. (2021) found that CSR improves business processes and stakeholder engagement, while Jo and Harjoto (2011) highlighted CSR's importance for shareholders, managers, and regulators. CSR also impacts employee attraction and retention, since individuals prefer companies, whose values align with their own (Gross 2014). A 2016 survey indicated that CSR towards employees is the most prevalent practice in Slovenia, with companies recognizing the value of social responsibility for better relationships and reputation. However, there is a lack of comprehensive implementation of CER, which is crucial for genuine green change (Zore, Bastič and Mulej 2016).

Studies (Sila and Cek 2017; Newman et al. 2020) show a positive correlation between CSR and corporate performance, with tailored CSR activities that address local community needs having the highest impact. CSR enhances profitability, stakeholder relations, reputation, staff retention, efficiency, innovation, and business generation. Recent research by Žabkar et al. (2022) has begun exploring CSR in the Slovenian context.

1.2 Motivation for corporate environmental responsibility

In addition to the general motivation for companies to act in a socially responsible way, as described above, there are also specific motivational factors for environmentally responsible behaviour. These are as follows: a) the competitiveness motive, whereby companies achieve long-term profitability by reducing and optimising environmental costs, which increases their competitiveness in the market and consequently their profits (Uecker-Mercado and Walker 2012; Gonzalez-Benito and Gonzalez-Benito 2004); b) the legitimation motive, whereby companies satisfy official norms and regulations by acting in an environmentally friendly way and consequently avoid sanctions (Sila and Cek 2017); c) the eco-responsibility motive, whereby companies satisfy social expectations and values (Bansal and Roth 2000); and d) the corporate reputational motive, driven by pressure from government, customers, competitors and the media, which is raising the demands for environmentally friendly performance from stakeholders (Berry and Rondinelli 1998; Knanna and Anton 2002). Žabkar et al. (2022) distinguish between instrumental and moral motives for CSR. Public perception of environmentally responsible and irresponsible companies is strongly linked to emotion. Companies that are perceived as environmentally irresponsible trigger feelings of anger and disgust in individuals, leading to the spread of negative opinion, the writing of complaints and potentially even to boycotts. On the other hand, companies that are perceived to be environmentally responsible trigger emotions of gratitude, leading to the spread of positive opinion, greater resistance to negative information about the company, and potentially to identification with the company and new investment (Xie, Bagozzi and Grønhaug 2015).

1.3 Environmental economy

All companies, not just those in the environmental economy sector, must comply with various national and supranational regulations to become more environmentally friendly (Zore, Bastič and Mulej 2016). The environmental economy sector includes activities like producing organic vegetables, renewable energy, and organic waste treatment, and conserving natural resources. Companies in this sector adapt their processes to be environmentally friendly, often implementing zero waste policies and circular economy principles. This has led to an increase in companies within the environmental economy sector across the EU. »The 2014–2021 environmental economy – statistics by EU member state provided by European Commission; Eurostat report 2024«, shows employment in this sector growing by 22.7% from 2014 to 2021, especially in agriculture. In Slovenia, green economy employment grew by 20% from 2014 to 2021, although its growth rate is among the slowest in the EU. Adapting to green policies poses significant challenges for companies. A 2022 survey found that half the organizations are not ready to implement green policies, owing to a lack of awareness and knowledge, though a third have made some environmental changes for profit (European Union … 2022). In Slovenia, the green transition is slow because of low investment and insufficient motivation in companies, as there is not yet an awareness of the benefits of the green transition

for a company's bottom line. Despite this, 75% of companies believe they are adapting their processes to some extent (Kmet Zupančič 2023).

1.4 Communication

Communication is an important part of CSR, and companies themselves are aware of this. Effective CSR communication is based on identifying the expectations of various stakeholder groups and on designing a communication strategy that covers the stakeholders involved (Kitic et al. 2015; Testarmata et al. 2018; Nadanyiova, Majerova and Gajanova 2021). When communicating, it is important to identify effective channels that cover different audiences. Recently, social networks have been gaining in effectiveness (Nadanyiova, Majerova and Gajanova 2021). It is important that communication be transparent, and based on real, verifiable data, and that the content that is communicated be linked to the actual practices of the company.

The content and style of communication must be tailored to the target group, since stakeholder groups have different expectations and needs. At the same time, communication with employees is also important, as a company's employees are a powerful channel for enhancing the company' image and spreading positive opinion (Dawkins 2005). Four common CSR communication practices are as follows: a) reporting on CSR activities; b) running social campaigns; c) publishing sustainability reports; and d) disclosing clear information on the origin of products (Borges et al. 2023). To communicate effectively about the environment, it is important to follow the general guidelines for successful communication, which apply to companies as well as to all other organisations: a two-way communication format; the organisation of competitions and campaigns; adaptation to everyday life; clear, simple explanations; solutions for everyday life; and adaptation of the content to the local environment (Wirth, Prutsch and Grothmann 2014).

2 Methodology

2.1 Research problem

In the survey we were sought to find out how the selected companies from the Podravska statistical region face the CSR situation from an environmental perspective. We were primarily interested in what best practices they are implementing in this respect, including the context of sustainability and green transition. Furthermore, we were interested in the motives for CER. Žabkar et al. (2022) distinguish instrumental from moral motives (also called green extrinsic and green intrinsic motives (Li et al. 2020)) in the factors stimulating companies to imitate these best practices. We were also interested in their public communication in this respect. Successful transition to a green society requires strategic communication of the environmental crisis, which is not yet sufficiently established in Slovenia. Finally, we sought to understand what challenges companies identified as necessary to overcome for a future green transition.

Given the limited research on CER motives, communication, and future expectations, a qualitative study was undertaken in four phases. First, an extensive review of academic literature and press releases on CER practices was undertaken. Second, lectures on conducting interpretative interviews were provided for the researchers. In the third phase, interviews were conducted with broad themes (best practices, perceptions, motives, communication, and expectations), allowing participants to speak freely and minimize biased responses. Lastly, the data was analysed using a provisional code list from the theoretical framework. The interviews were transcribed and entered in a qualitative statistical package. The responses were sorted into coding categories to develop a smaller final set of categories for each theme.

2.2 Instrument and Sample

In the beginning of 2023, best practices in the Eastern Slovenia cohesion region from private and public sectors were analysed, concerning the green transition. Purposive sampling was used: participants in the ZELEN.KOM project created a list of companies and public institutions that are considered examples of best practices according to the personal judgment of individual interviewers. Each department of the Faculty

of Arts at the University of Maribor conducted at least one interview, eleven altogether. Eight were from the Podravska statistical region, and one each from the Pomurska, Savinjska, and Posavska statistical regions, where companies were representing various sectors. Consent was obtained from each interviewee. A compromise between narrative and guided interviews was sought.

Our final sample contains eight interviews from the Podravska statistical region that were conducted with eight company representatives. The interviewees (six men and two women) were experts in their fields – in decision-making positions or a part of the environmental responsibility teams (Table 1).

2.2 Data collection and processing procedure

Interviews were conducted in February and March 2023. Six interviews were conducted in person and two at a distance (one with the help of the Zoom App and one via the MS Teams App). They lasted approximately 70 minutes; the anonymity of interviewees was ensured.

In April 2023, the transcripts were made, and short reports were written by the interviewers. Each transcript was coded separately in QDA Miner Lite14 (free qualitative data analysis software) for the prescribed themes (best practices, perceptions, motives, communication, and expectations), after which codes, categories, and sub-themes were individually identified. Interpretation and extraction of the conclusions and recommendations were completed and were further supported by quotations from individual interviewees (Vogrinc 2008).

Table 1: Sample description of eight interviewees from the private and public sector located in the Podravska statistical region.

interview number	*activity – TSmedia	**activity – SKD	field of activity	organisation status	number of employees
1	catering	I56.210 – occasional preparation and delivery of meals	plant-based food preparation	cooperative	no data
2	tourism	R91.040 – activities of botanical and zoological gardens, protection of natural values	nature conservation	public institution	100–149
3	culture and arts	R90.030 – artistic creativity	wood craft product manufacturer	independent entrepreneur	1
4	agriculture, crop production, fruit growing	A01.610 – crop production services	tourist & eco farm	one holder of supplementary activity on the farm	no data
5	utilities and waste	E38.320 – extraction of secondary raw materials from residues and waste	waste collection and treatment company	limited liability company	250–499
6	tourist farm	I56.105 – tourist farms without rooms	tourist & eco farm	one holder of supplementary activity on the farm	no data
7	maintenance and management of buildings	L68.320 – management of immovable property for remuneration or on a fee or contract basis	management of logistic centre	limited liability company	10-19
8	real estate, trade	G47.110 – retail sale in non-specialised stores, mainly of food products	commercial centre	limited liability company	more than 2000

* TSmedia: A comprehensive private database for accessing data from https://www.bizi.si.

** SKD: Standard classification of activities; version 2008 is currently still in force in Slovenia, but a new SKD 2025 will be in use from 2025. This is an obligatory national standard which is used for the purposes of defining the main activity and for the classification of business entities and their units, to meet the requirements of official and other administrative data collections, as well as national and international statistics and analyses.

3 Results

3.1 Implementation of best practices

Corporate sustainability must include a social and an environmental dimension, in addition to excellent governance (Sila and Cek 2017). Therefore, to comprehensively assess the sustainable performance of companies that we present as examples of best practice, it is necessary to examine them from an environmental, social, and governance (ESG) perspective (Kim and Li 2021), where the latest is a set of standards for how a company operates with respect to the environment and its people. From the social point of view, based on stakeholder theory, we distinguish between activities targeting internal stakeholders, such as employee education, fair pay, and corporate governance, and those targeting external stakeholders, like job creation, public health, and fair business conduct (Hawn and Ioannou 2016; Žabkar et al. 2020). The economic aspect focuses on financial and non-financial performance, including profitability, growth, and employee and customer satisfaction (Žabkar et al. 2020). Environmental practices in companies include reducing resource consumption, greening processes and products, and minimizing waste and emissions, aligning with circular economy objectives like recycle, reuse, replace, renew, and reduce (Murray, Skene and Haynes 2017), and supporting ecosystem services for environmental conservation.

From the eight interviewed companies, regarding CSR, six of the interviewees conduct various forms of educational and awareness-raising activities, mainly related to their narrow field of activity, some of them also working with government bodies responsible for educational activities. For example, the company of interviewee fiveinvests in employee training, and every new employee must undergo »a training programme where the requirements of standards, environmental legislation are also presented, so that basically every employee is already competent in environmental protection.« Four interviewees highlight (interviews 1, 3, 4 and 6), the importance of effective integration of the company into the environment and taking account of local needs and initiatives (interview 2).

Regarding economic concerns, four interviewees talked about the importance of collaboration with multiple stakeholders (interviews 2, 4, 5 and 8), finding it important to build teams in a planned way (4/8), where employee share similar values (at work and in private life), and exposing the need for a changed entrepreneurial model (interviews 1, 3, 8; for example, the interviewee from company 3 said that he values his business as a hobby). No interviewee emphasis profitability.

Regarding ESR three interviewees highlighted measures related to more efficient use of energy in the infrastructure of companies or public institutions. Four interviewees also highlight the use of local ingredients and materials (interviews 1, 3, 4 and 6). Three interviewees link their best practices to their efforts to reduce their carbon footprint or emissions in the environment. Shortening transport routes, or transport routes in general, was the most frequently mentioned concrete example of this. The same proportion of interviewees highlighted zero waste and/or recycling (such as packaging products in reusable packaging) as examples of best practice. Interviewee three said: »My company works like this, let's say I don't really have any leftovers, I don't have anything in a month maybe one bag of rubbish /…/. With the scrap wood, we heat our (work)shop, so we have almost zero-waste production and operation of the company.« A few of the interviewees mentioned environmentally friendly agriculture as the production of food without pesticides, grouping into cooperatives, and ensuring transparency and traceability.

3.2 Motives

The motives can significantly influence the effectiveness and sustainability of the practices implemented. Analysing companies' motives for pursuing CER helps us understand the underlying reasons behind corporate environmental actions – whether driven by regulatory compliance, market competitiveness, ethical considerations, or a combination of these factors.

When analysing motives, all interviewees pointed out that the initiators behind the motives were related to the company itself (the directors, or founders of the company). In some cases, the initiators are national authorities of the Republic of Slovenia, such as responsible ministries with respective legislation, or of the European Union, such as the Nature 2000 commitments. In individual cases, motives are connected to

changes in the expectations, needs and requirements of various stakeholders, including customers and local organizations.

The motives mentioned by interviewees when carrying out environmentally responsible activities are presented in Table 2. Žabkar et al. (2022) divided motives into instrumental and moral (also called green extrinsic and green intrinsic motives (Li et al. 2020)). We divided the motivations for »green behaviour« – behaviour in line with environmental responsibility and sustainability, into (green) intrinsic motives and (green) extrinsic motives. In some places, the reported motives, e. g. why an organisation is doing something, do overlap.

Based on the answers from our interviewees (Table 2), we grouped the codes into six categories for the green intrinsic motivators. In terms of companies' intrinsic motives to implement these best practices in the field of sustainability and environmental responsibility, many interviewees indicated that one of their motives was concern for preserving the environment and nature in various ways. Companies involved in food production and/or processing are motivated to act by an awareness of the importance of consuming healthy local food of high quality and of living in harmony with nature. This is evidenced by the quotation from interviewee 6: »The first thing that made us decide is for sure that you actually offered the best quality food to the children who came« and: »We are indeed responsible to our predecessors and to our successors to leave /.../ nature and this forest ecosystem as it should be«, and to influence people's awareness of issues related to environmental and nature protection and sustainability. Two interviewees stated that the motive for best practices within the companies or public institutions where they work is related to their effective integration into the environment in which they operate. This is reflected, for example, in the recruitment of local people.

We further detected codes for extrinsic motivators and grouped these into six categories. The specific extrinsic motivators highlighted by the interviewees were to enable transparency and traceability of products (in the context of recognition), the desire to become a socially responsible company, the desire to meet green transition standards, to demonstrate the distinctiveness of their product as compared to competitors, the interest of potential customers, the organic farming guidelines, and the desire to be an example of best practice in their own field; however, some also recognise, that »The problem is that green is now the fashionable word and we need to think carefully about which institution uses the word green« (interview 2). Interviewees also cited legislation and the desire to earn money as motivators. »We have a policy in line with the ISO 14.001 environmental standard … which was committed to by the top management … we have rules of procedure, work instructions, organisational regulations, all in accordance with the requirements of this standard … we are fully compliant with the legislation« (interview 5).

Table 2: The motives behind environmentally responsible actions.

theme	sub-theme	category
motives	intrinsic motives	the importance of eating healthy local food of high quality.
		living in harmony with nature.
		being an example of best practice.
		job satisfaction and/or inspiration.
		raising awareness of others.
		caring for the environment and nature (recognised out of context).
	extrinsic motives	achieving the societal objectives of the green transition.
		highlighting differences and/or presenting alternatives.
		following trends.
		promotion.
		earnings.
		legislation

3.3 Communication

Effective communication is key to fostering transparency, accountability, and stakeholder engagement, which are critical for a successful transition to a green society. We were interested in how the companies communicate their exemplary actions. As we can see in Table 3, codes were grouped into categories and further into four sub-themes.

These eight companies adapt their communication to the target group in diverse ways. Almost half the interviewees highlighted communicating their activities or products online as an example of best practice, especially on social networks and by using digital marketing tools; five of them added the importance of direct online sales for their business. Four companies interviewed organise events and activities to communicate their best practices. Other media (television commercials, jumbo posters, word of mouth) were mentioned by up to two of the organisations interviewed. As a result, we find that it is the case for our interviewed organisations that social networks have been gaining in effectiveness for communication.

Five companies monitor the responses of those who use or are interested in their activities or products. The response monitoring is conducted in different ways: through a questionnaire, through the opinions of participants in the events that the organisations carry out, through a book of memories, and by monitoring the responses to posts on the online networks (they adapt their way of working according to the results). On the latter, the interviewee from company 8 said, »We are monitoring these things, we are also monitoring people's reactions, especially in terms of metrics, not how many people see the posts, and then we are trying to tailor these posts as much as possible to make them as easy to understand and simple as possible.« Interviewees pointed to various shortcomings in either the communication of their activities or the communication of the climate change crisis, sustainability, and corporate social (and environmental) responsibility.

Four of the companies interviewed thus cooperate with marketing experts or PR experts to communicate their activities. In addressing the shortcomings, interviewees pointed to the importance of proper communication and awareness-raising on climate change issues from primary education onwards. They believe that more emphasis should be placed on proper communication in public (e. g. in the media environment). One of the shortcomings pointed out by interviewee three is the lack of precision in terminology and that there are »loopholes in the law.

Table 3: Showcasing best practices among the companies.

theme	sub-theme	category
communication	tailoring to the target group	web, online
		social media
		live events and activities
		television commercials
		jumbo posters, flyers, and other promotional material
		spreading the good word
	consumer-oriented selling and marketing campaigns	online selling
		face to face
		major advertising campaigns
	monitoring responses	online analysis
		feedback
		communication with employees
	working with communication experts	working with marketing experts
		communication in education
		communication training
		with public
		eco-terminology

3.4 Future expectations

Next, we were interested in the expectations that companies have about what they would like/need to do in the future to prevent an environmental crisis. Identifying these challenges is a major step in developing strategies and policies that can support companies in their journey toward sustainability. As we can see in Table 4, codes were grouped in categories and further into four sub-themes.

A few interviewees gave their views on where they see opportunities for change in the way people behave towards nature. Some pointed out that issues and topics related to the protection of the environment and nature should be given more attention in primary schools. In this context, some explicitly pointed out that teachers should acquire the relevant competences: »I think it is very important to have this ambition, to give teachers the right basis, also to ensure that appropriate content is included in the curriculum, both nature conservation and environmental protection content.« (interview 2). Interviewee seven stressed the importance of state subsidies in the energy renovation of buildings. In his opinion, the subsidies in Slovenia should be higher. Several other interviewees also thought that the state should allocate more funds for companies to behave in an environmentally and socially responsible way. In addition to these, some interviewees also expressed the expectation that the government would support the removal of administrative barriers and that it would seek to establish cooperation between different sectors that otherwise strive for environmentally friendly actions.

As regards expectations towards people in general, almost half the interviewees pointed out changes in individual values. According to interviewees, people's prejudices against, e.g., organic farming, or plant-based diets need to be eliminated. The achievements of science should not be belittled. Three interviewees pointed to a change in the way communication is done to get relevant and professional information to the public.

Regarding changes being implemented in an environmentally friendly way, about a quarter of interviewees pointed to the establishment of a zero waste/circular economy system and an efficient packaging recycling system. Some of the expectations of companies or public institutions themselves are linked to their specific field of work.

4 Discussion

Our research highlights various best green practices among companies in the Podravska statistical region, their motivations for adopting these practices, and their communication strategies regarding the green transition. Interviewees often expressed pride in their companies' best practices, particularly in project orientation and training. Negative perceptions were rare, and, primarily concerned the slow rate of

Table 4: Expectations of interviewees.

theme	sub-theme (toward . . .)	category
future expectations	the country	obtaining and introducing certificates and statuses.
		removing administrative barriers.
		cooperation.
		government assistance in development and operations, e. g. grants.
	specific professions	changes in the education system.
		development of new technologies.
		establishing an effective way of communicating environmental protection and the green transition.
	people in general	changes in values.
		changes in the way of communication.
		social changes.
	interviewed companies	operating in an environmentally friendly way.
		company benefits.

change in social values, the gap between practice and theory, deficiencies in the recycling system, and inadequate governmental support.

Poljak Istenič (2019) and Godina Golija (2023) provide essential insights into practical sustainability initiatives in Slovenia, such as urban gardening projects and local food production strategies. These studies emphasize the role of community engagement and communication in fostering sustainability, which aligns with our findings that companies actively educate and raise awareness about environmental issues.

Most companies integrate energy efficiency and green energy practices into their operations. For example, three companies reported reducing energy consumption by using only green energy. These efforts are part of a broader commitment to environmental protection and resource optimization, echoing findings by Žabkar et al. (2022) that most Slovenian companies have dedicated personnel for corporate sustainability.

Intrinsic motivations, particularly eco-responsibility, drive these practices. Berry and Rondinelli (1998) and Bansal and Roth (2000) describe this motivation as rooted in a concern for preserving nature and promoting healthy, local food. Similarly, Li et al. (2020) highlight that intrinsic motivations foster green creativity and innovation, essential for developing sustainable products and services.

Our interviewees also discussed the importance of changing attitudes towards plant-based diets and socially responsible behaviour, reflecting a broader trend towards sustainability. Miscommunication and the misuse of eco-terminology for profit-making purposes were identified as significant issues. The emphasis on online communication and collaboration with marketing experts to promote green practices aligns with Dawkins's (2005) findings on the importance of employee-driven communication.

Despite these efforts, challenges remain, such as insufficient governmental support and slow societal change towards environmental responsibility. Many interviewees stressed the need for gradual changes and increased awareness among younger generations, which supports the need for sustained educational efforts.

5 Conclusion

The article examines best green practices among companies in the Podravska statistical region, focusing on their motivations, communication strategies, and expectations regarding the green transition. Most interviewed companies engage in educational activities and efficient energy use, and many use local materials. Intrinsic motives, particularly environmental preservation, drive these practices. Most companies communicate their activities online, with some collaborating with marketing experts. Interviewees view their environmentally responsible actions as standard practice, aligning with universal green transition goals. The survey revealed that all companies demonstrate at least partial social responsibility, with dedicated personnel for this purpose. A significant distinction exists between companies within the environmental economy sector and those outside it. The former are motivated by societal values, whereas the latter prioritize profits and reputation. Interviewees highlighted various national-level issues that hinder environmental initiatives, such as inadequate Zero Waste Economy policies and insufficient subsidies, for example.

To achieve corporate sustainability, it is essential for companies to integrate environmental, social, and governance (ESG) dimensions into their operations to enhance their reputation and build stronger relationships with stakeholders. Our research also reveals those intrinsic motivations, such as a genuine concern for environmental preservation and a commitment to offering high-quality, local products, are powerful drivers of sustainable practices. Companies should cultivate these intrinsic motivations among their leadership and employees to foster a culture of sustainability. This can be achieved by emphasizing the long-term benefits of environmental responsibility, such as enhanced job satisfaction, inspiration, and community recognition. Encouraging a values-driven approach to sustainability can lead to more innovative and resilient practices, as demonstrated by the companies in our study. Effective communication is crucial for raising awareness, engaging stakeholders, and promoting sustainable practices. Companies should tailor their communication strategies to their target audiences, utilizing various channels such as social media, online marketing, live events, and collaboration with marketing experts. Our research shows that companies that actively engage with their audience through transparent and accessible communication are better positioned to influence public perception and drive positive change.

Our research was designed to uncover the motivations for pursuing the environmental economy and the challenges faced by companies in this sector. The findings underscore the need for enhanced governmental support and public awareness to facilitate the green transition, contributing valuable insights to the broader discourse on corporate sustainability in Slovenia. As data provided by the European Commission in the Eurostat report 2024 show the slow growth of environmental economy companies in Slovenia, our findings shed light on these issues and present best practices that can facilitate the green transition.

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MAPPING THE LANDSCAPE OF RECENT RESEARCH ON AGRICULTURAL GEOGRAPHY (2013–2022)

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A rural village in Hualien County, Taiwan.

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Mapping the landscape of recent research on agricultural geography (2013–2022)

ABSTRACT: Agricultural geography has developed for over a century. To review the recent development in this field, 1879 journal articles on agricultural geography published between 2013 and 2022 are analyzed using multi-leveled bibliometric methods and visualized by VOSviewer. Seven research themes are identified: »climate change and food«, »environmental sustainability«, »land and political ecology«, »water resources«, »rural geography«, »economic development«, and »spatial analysis«. Theory and practice are the two research strands, with few authors publishing extensively, indicating a lack of an active long-term research community. Geographical factors significantly influence agricultural geography research, with international collaborations showing regional patterns. China is an emerging player, developing independently from Western peers.

KEYWORDS: bibliographic coupling, citation, co-authorship, co-citation, co-word, landscape of research

Pregled najnovejših raziskav s področja agrarne geografije (2013–2022)

POVZETEK: Agrarna geografija se razvija že več kot stoletje. Da bi pregledala najnovejša dogajanja na tem področju, sta avtorja z večnivojskimi bibliometričnimi metodami analizirala 1879 znanstvenih člankov s področja agrarne geografije, objavljenih med letoma 2013 in 2022, in izsledke vizualizirala v programskem orodju VOSviewer. Določila sta sedem raziskovalnih tem: podnebne spremembe in hrana, okoljska trajnostnost, zemljišča in politična ekologija, vodni viri, geografija podeželja, gospodarski razvoj in prostorska analiza. Teorija in praksa sta glavni smeri raziskav, pri čemer malo avtorjev obsežno objavlja, kar kaže na pomanjkanje aktivne dolgoročne raziskovalne skupnosti. Geografski kazalniki pomembno vplivajo na raziskave na področju agrarne geografije, pri čemer mednarodno sodelovanje kaže regionalne vzorce. Kitajska je nov akter, ki se razvija neodvisno od Zahoda.

KLJUČNE BESEDE: bibliografsko združevanje, citiranost, soavtorstvo, socitiranost, sobesednost, raziskovalna pokrajina

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1 Introduction

Agriculture is one of the prime movers in shaping the trajectory of human civilization. The cultivation of crops and domestication of animals provided a reliable food supply that allowed populations to settle and grow in one place. The surplus production enabled the social specialization and division of labor, furthering the productivity of society and advancing civilization (Fuller and Stevens 2019). However, the conditions that enable and constrain agricultural production vary from place to place, and diverse forms of agriculture have developed and been distributed unevenly across the world. It is in this context that the geography of agriculture emerged (Grigg 1995).

Geographers have always played an important role in agricultural research (Robinson 2018a; Robinson 2018b). Before World War II, agricultural geography was a branch of economic geography under human geography. Agricultural geographers followed the core paradigm of regional geography (Johnston 1997). They collected data and categorized and summarized them according to geographical areas, and they used the concept of »region« as the basis for interpreting and explaining the geographical characteristics of each agricultural region (Liao et al. 2011). General studies have been conducted in the 1920s and 1930s: Jonasson (1925) classified European agricultural regions, Baker (1928) classified North American agricultural regions, Jones (1928) classified South American agricultural regions, and Taylor (1930) classified Australian agricultural regions. Agricultural geographers have also been interested in how natural, economic, social, and cultural factors in different regions affect the structure and distribution of crops (Robinson 2004).

In the 1960s, geography experienced the quantitative revolution. Geographers extensively used mathematical equations to explain and predict spatial phenomena (Kitchin and Tate 2000), e.g., Henshall (1967) used economic modeling to explain agricultural activities and emphasized the importance of economic regulations in controlling agricultural locations. This paradigm shift marked the development of geographic research from regional geography to spatial science (Billinge et al. 1984). Much of the agricultural geography research in the 1970s took quantification as its keynote, with more detailed quantitative analyses of the many phenomena related to agriculture (Coppock 1976a; Coppock 1976b). In addition, agricultural geography was influenced by behavioral geography, which emphasized the relationship between individual decision-making and agricultural space (Liao et al. 2011).

In the 1980s, agricultural geographers shifted their attention from a narrow sense of agricultural production to a broader framework of agricultural economy, and embedded in the complex structure of social, economic, cultural, and political aspects for discussion, which was called »political economy« (Blaikie 1985; Marsden 1988; Marsden et al. 1996). Agricultural geography expanded further in scope and content, and the research was carefully organized to cover the entire production chain of agriculture. From agricultural inputs (such as seeds, fertilizers, and machinery), to the production operations of farms, to downstream food processing, wholesale, retailing, and consumption. This change brought new research challenges and agricultural geography became an interdisciplinary study, encompassing multiple fields of social science (Bowler 1988).

In the 1990s, Morris and Evans (1999; 2004) criticized agricultural geography for focusing too much on objective factors such as production relationships, macroeconomy, and social structures and processes, ignoring the fact that farmers are living individuals; agriculture must be informed by the established culture. Therefore, the extraction of cultural characteristics is one step of research that cannot be omitted. Agricultural geographers theorized how to transform contemporary agriculture and redefine land (Robinson 2004). This shift is known as the »cultural turn in agricultural geography« (Cox 2012).

Since the 2000s, agricultural geography has gradually moved closer to the broader rural geography (Serra et al. 2014; Milbourne 2017). Responding to the challenges to agricultural geography posed by Morris and Evans (1999; 2004), geographers also approach agricultural geography issues from a broader perspective (Pacione 2014). For example: farmer identity (Lobley and Potter 2004), property relations (Ilbery et al. 2010), and civic agriculture (Poulsen 2017). Furthermore, agricultural geographers respond to global issues, such as climate change (Kelley et al. 2015; Ray et al. 2015), biodiversity (Zimmerer et al. 2018), resource depletion (Wardropper et al. 2020), globalization (Robinson 2018c), sustainable food system (McClintock 2013), urban agriculture (Tornaghi 2014), food safety (Schumilas and Scott 2016), food security (O'Connor et al. 2016), etc.

After more than a century of development, agricultural geography has been updated about every ten years, and a huge knowledge system has been established. To summarize and review the latest developments

in agricultural geography research, traditional scholars use qualitative methods to review the existing literature. For example, Marsden (1988) concluded that there are four key issues in agricultural geography: (1) uneven development; (2) geographical and historical specificity; (3) the role of family farms; (4) the role of national policy. Robinson (2018a) argues that agricultural geography has developed its own concepts and concerns over the past few decades, connecting with the broader political economy. The most recent topical concerns are food security, land grabbing, and adaptation to climate change. A similar conclusion was reached by Long et al. (2014), who pointed out that the direction and research focus of agricultural geography is mainly on global issues in the context of globalization, and that the complex impacts of globalization have led to interdisciplinary collaborative research between agricultural and physical geography, rural sociology, and even agricultural economics.

In addition, some authors focused on the development of agricultural geography in individual regions or countries. For example, Liu et al. (2011) pointed out that the recent development of agricultural geography research in China was characterized by five features: (1) close integration with rural geography; (2) rural hollowing and renovation of hollow villages; (3) construction of new rural villages; (4) regional agriculture and rural development; and (5) internationalization of the research findings. Liao et al. (2011) examined the progress of agricultural geography research in Taiwan in the decade 2001–2010. They found that Taiwan's agricultural geography research was different from Western agricultural geography research both in concepts and contents. Taiwanese geographers leaned towards empiricism and were more focused on the issues related to agricultural land use.

Although the above reviews bring readers some insights into the development of agricultural geography research, they are accused of having bias as the selection of literature is mostly based on the subjective judgment of the authors that lacks the scientific standard of replicability (Linnenluecke et al. 2019). Moreover, the number of documents involved is generally relatively small, and a small number of influential authors and works tend to be selected (Byrne 2016).

With this in mind, this study intends to review the research field of agricultural geography by examining relevant literature using multi-level bibliometric analysis, aiming to provide readers with the landscape of recent research on agricultural geography in the last decade. The specific objectives are threefold: (1) to identify the key research themes, topics, and trends in agricultural geography; (2) to map the intellectual structure of the research field; and (3) to provide recommendations for further research.

2 Methods

2.1 Data source and retrieval

Scopus is the largest academic literature database that provides a comprehensive overview of the world's research in the fields of science, technology, medicine, social sciences, arts, and humanities, with smart tools for tracking and analyzing research. The data format is compatible with commonly used visualization softwares, making it a versatile and comprehensive database (Schotten et al. 2017). Baas et al. (2020) considered Scopus the best choice for bibliometric research.

Literature data retrieval for this study was performed on August 23th, 2023. The first query criterion was to search for the English terms »agricultur*« AND »geography« in the »Title, Abstract, and Keywords«. A total of 9043 documents were found. The second criterion was to select journal articles, while other types of literature such as conference papers, reviews, book chapters, and books were excluded, resulting in 7472 journal articles. For the third criterion, only literature from the past 10 years (i.e., 2013 to 2022) was selected, resulting in 2879 papers. Excluding duplicates and irrelevant articles, finally, 1879 articles were obtained for bibliometric analysis.

2.2 Bibliometric methods

The dataset was cleaned and calibrated for bibliometric analysis to address inconsistencies and duplicates in thesaurus terms, such as variations between American and British English usages, singular and plural nouns, full names versus initials of authors, and full titles versus abbreviations of journals. Then the following analyses were conducted to determine various aspects of the research field:

- Temporal and spatial analysis were performed to characterize the publication trends over time and space. Furthermore, international collaboration networks were identified based on co-authorship relationships (Ponomariov and Boardman 2016; Wei et al. 2022).
- Thematic analysis was conducted to identify the themes of the research field based on co-word (also co-occurrence) relationships. Co-word refers to the presence of the same keywords in two documents (Callon et al. 1983). Research themes can be deduced from the clusters, which consist of relevant and related keywords (Chen et al. 2016).
- Textual and authorial analysis were performed to explore the intellectual structure of agricultural geography research. Not only highly cited articles and prolific authors were identified, but also relationships among documents and authors were examined by co-citation analysis. Co-citation refers to the situation where two documents cite another document at the same time (Hausberg and Korreck 2021). Boyack et al. (2013) indicated that co-citation represents similarity between documents or association between authors.
- Source analysis was conducted to identify the important sources of knowledge. Prolific journals were ranked according to the number of articles. Furthermore, bibliographic coupling analysis was performed to investigate the associations among journals. Bibliographic coupling refers to the situation where two documents are cited by the same article, i.e., the reference list includes these two documents (Small and Koenig 1977). Ahlgren and Jarneving (2008) indicated that bibliographic coupling reflects the similarity in the content of the two articles.

2.3 Visualization

Network maps were produced by VOSviewer (version 1.6.18) to visualize the results of co-authorship, co-word, co-citation, and bibliographic coupling relationships. VOSviewer was chosen because of its efficient and convenient data processing and analysis capabilities, excellent and easy-to-read visualization, and user-friendly interface (van Eck and Waltman 2009).

In the network map, dots represent bibliometric items (i.e., keywords, articles, authors, journals, or countries), and their size indicates the number of items. Curved lines represent relationships between items, with the thickness of the line indicating the strength of the relationship. VOSviewer fits the position of the dots on the network map by minimizing the weighted sum of the Euclidean distances between all the dots (Kirby 2023). Items are grouped into clusters based on their degree of similarity and are represented by different colors (van Eck and Waltman 2009).

VOSviewer uses the VOS (Visualization of Similarities) clustering algorithm to partition a network into clusters by optimizing the modularity. The modularity of a partition is given by:

$$Q = \frac{1}{2m}\sum_{i,j}\left[A_{ij} - \frac{K_i K_j}{2m}\right]\delta(c_i, c_j) \quad (1)$$

where A_{ij} is the weight of the edge between nodes i and j; k_i and k_j are the sum of the weights of the edges attached to nodes i and j, respectively; m is the sum of the weights of all edges in the network; $\delta(c_i,c_j)$ is 1 if nodes i and j are in the same cluster, and 0 otherwise.

The clustering procedure involves initializing clusters, iteratively moving nodes to optimize modularity, and aggregating nodes to form higher-level clusters. This process is repeated until the modularity cannot be significantly improved.

To focus on significant associations, a threshold is applied to filter out weak associations. The outputs utilizing various association thresholds for clustering were visually examined and the best clustering result is selected based on three criteria:

- Inter-separation between clusters: Well-separated clusters are believed to reflect the unique and non-overlapping structure of the data (Bertsimas et al. 2021).
- Intra-cohesion within clusters: Dense connections between nodes, which signify significant cohesiveness between data points, indicate high-quality clusters (Bertsimas et al. 2021).
- Interpretability: High-quality clusters should include keywords that lead to meaningful themes or topics (Ohama et al. 2018).

3 Results

3.1 Temporal and spatial analysis of publications

Overall, the number of articles on agricultural geography increased in the past 10 years, but there are two stages of change (Figure 1). From 2013 to 2019, the number of articles remained fairly constant, fluctuating between 148 and 195, with an average of 168. The small fluctuations in the number of articles indicated that agricultural geography drew constant attention from researchers. After 2019, the number of articles on agricultural geography continuously increased from 194 in 2019 to 263 in 2022. Because of COVID's lockdowns, logistical disruptions made it difficult to transport grains from farms to markets, contributing to price fluctuations (Gutierrez et al. 2022). This situation may arouse the interest of researchers in agricultural geography (Nelson 2020).

137 countries published articles on agricultural geography in 2013–2022 (Figure 2). The majority of articles come from either large countries or developed regions where agriculture is well-developed. The three most productive countries the United States (462 articles), China (363 articles), and the United Kingdom (214 articles). Each of the rest countries published fewer than 100 articles.

Co-authorship analysis was performed to identify the international networks of collaboration. Taking the minimum number of eight articles as the threshold for co-authorship analysis, 50 countries were eligible and six clusters were identified (Figure 3). The red cluster consists of 13 countries and is the largest cluster, headed by the United States and the United Kingdom, plus many South American countries.

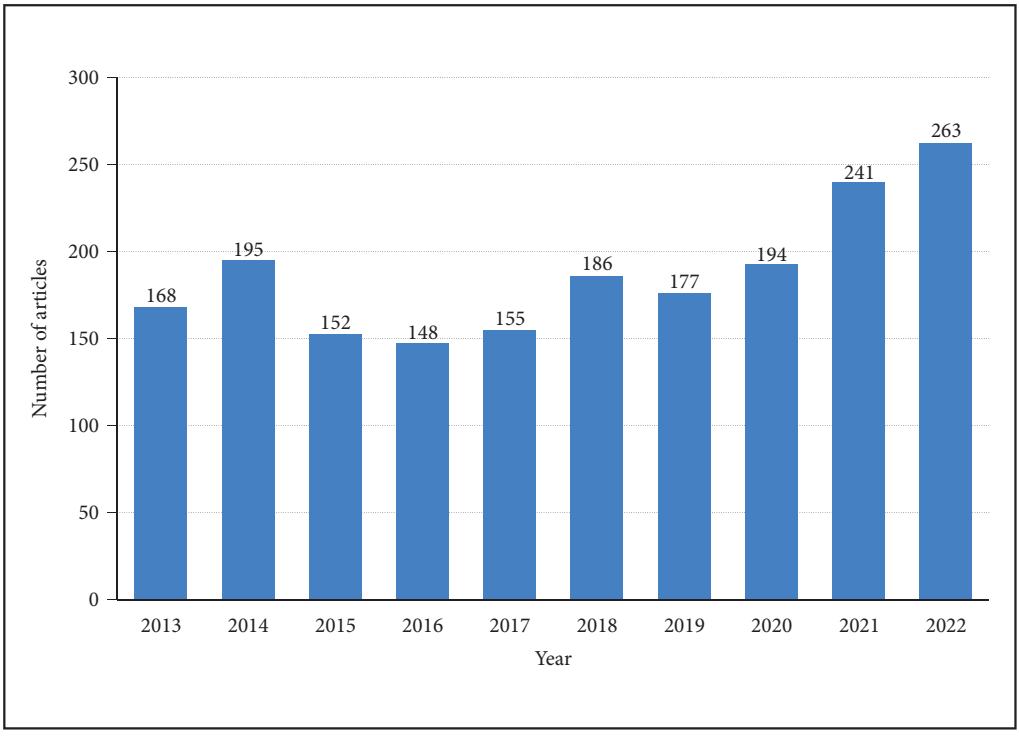
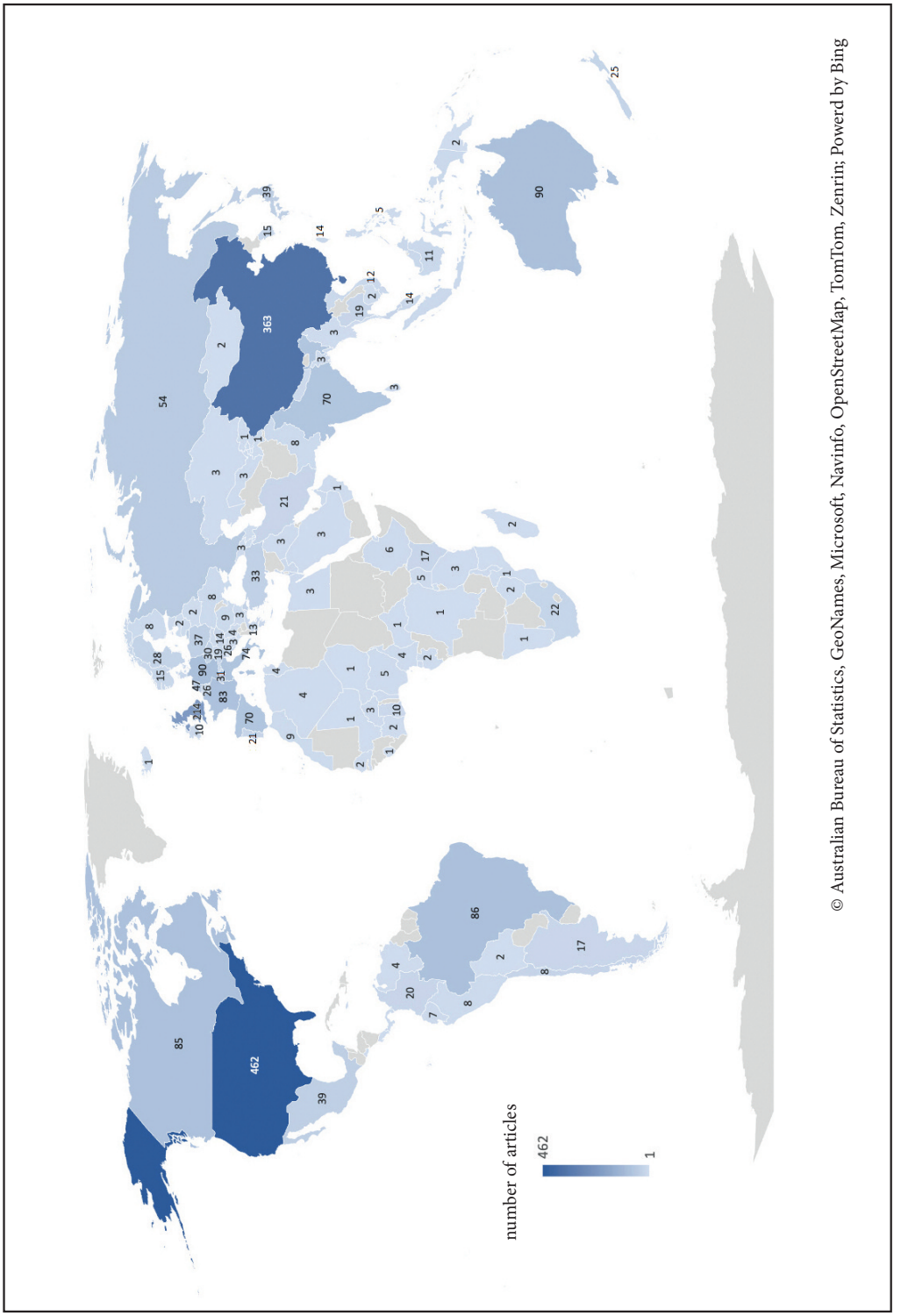
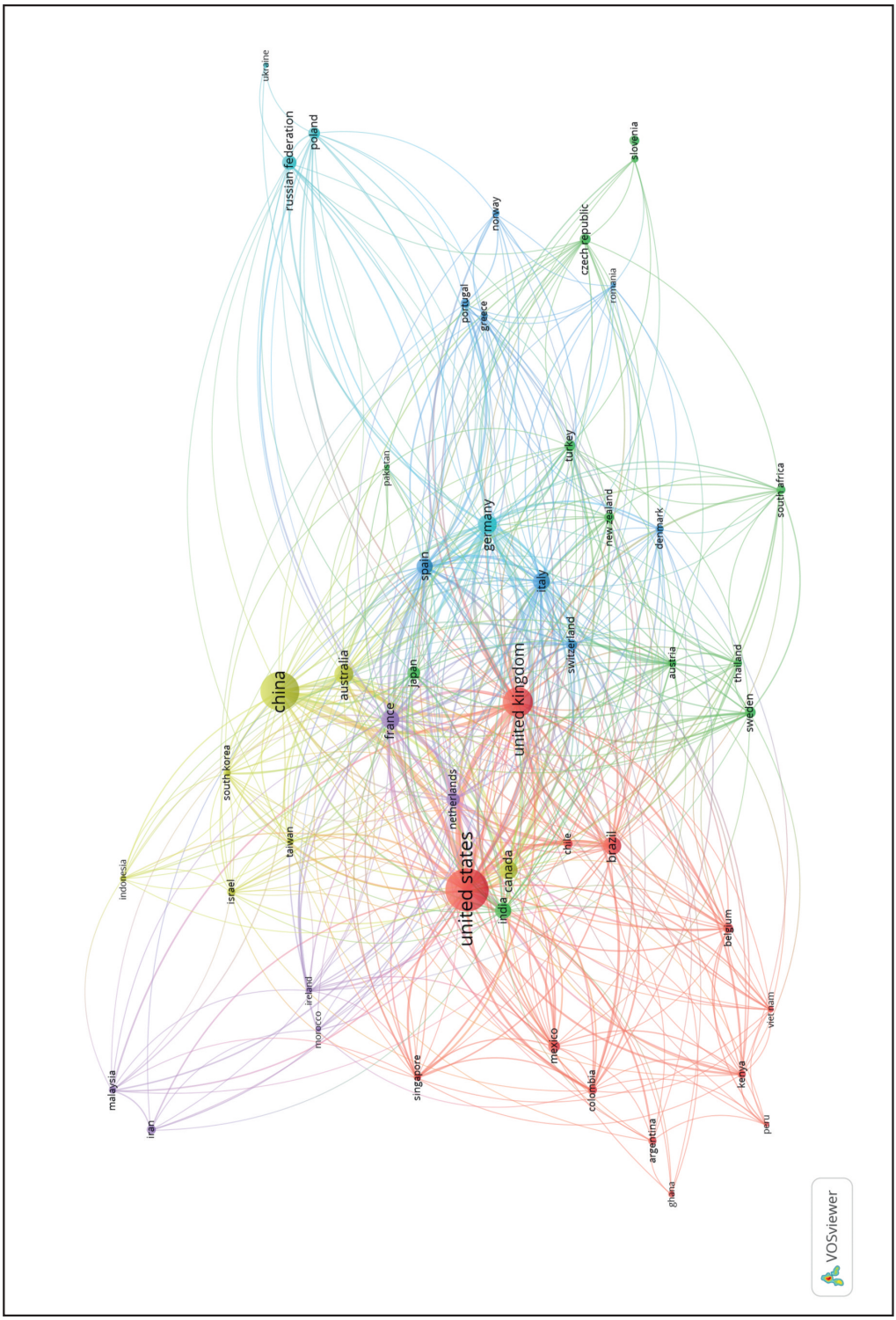


Figure 1: Numbers of articles on agricultural geography (2013–2022).

Figure 2: Global distribution of articles on agricultural geography (2013–2022). ► p. 117
Figure 3: International collaboration of countries on agricultural geography (2013–2022). ► p. 118


number of articles
462
1
© Australian Bureau of Statistics, GeoNames, Microsoft, Navinfo, OpenStreetMap, TomTom, Zenrin; Powerd by Bing


ukraine
russian federation
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norway
czech republic
portugal
greece
romania
pakistan
turkey
south africa
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new zealand
denmark
spain
italy
china
australia
japan
switzerland
austria
thailand
france
united kingdom
sweden
south korea
netherlands
taiwan
chile
brazil
indonesia
united states
india
canada
israel
belgium
ireland
morocco
vietnam
mexico
malaysia
singapore
colombia
kenya
iran
argentina
peru
ghana
VOSviewer

The green cluster, consisting of 12 countries, is led by India and Japan; this cluster also includes many Central European countries. There are eight countries, mainly Western European countries in the blue cluster. The yellow cluster has seven countries; these are mainly Asia-Pacific countries, led by China and Australia. The purple cluster consists of six countries, represented by France and the Netherlands. The cyan cluster consists of four countries, including Germany, Russian Federation, Poland, and Ukraine.

3.2 Keywords and thematic analysis

Among 6476 keywords in the literature on agricultural geography in 2013–2022, 40 keywords have more than 40 occurrences. The number of occurrences represents the popularity of the keyword in a field (Yuan et al. 2022). According to their literal meanings, they are categorized into eight groups (Table 1). Because keywords represent either the key contents of the papers or the interests of the authors (Zhang et al. 2012), Table 1 reflects the breadth of research on agricultural geography.

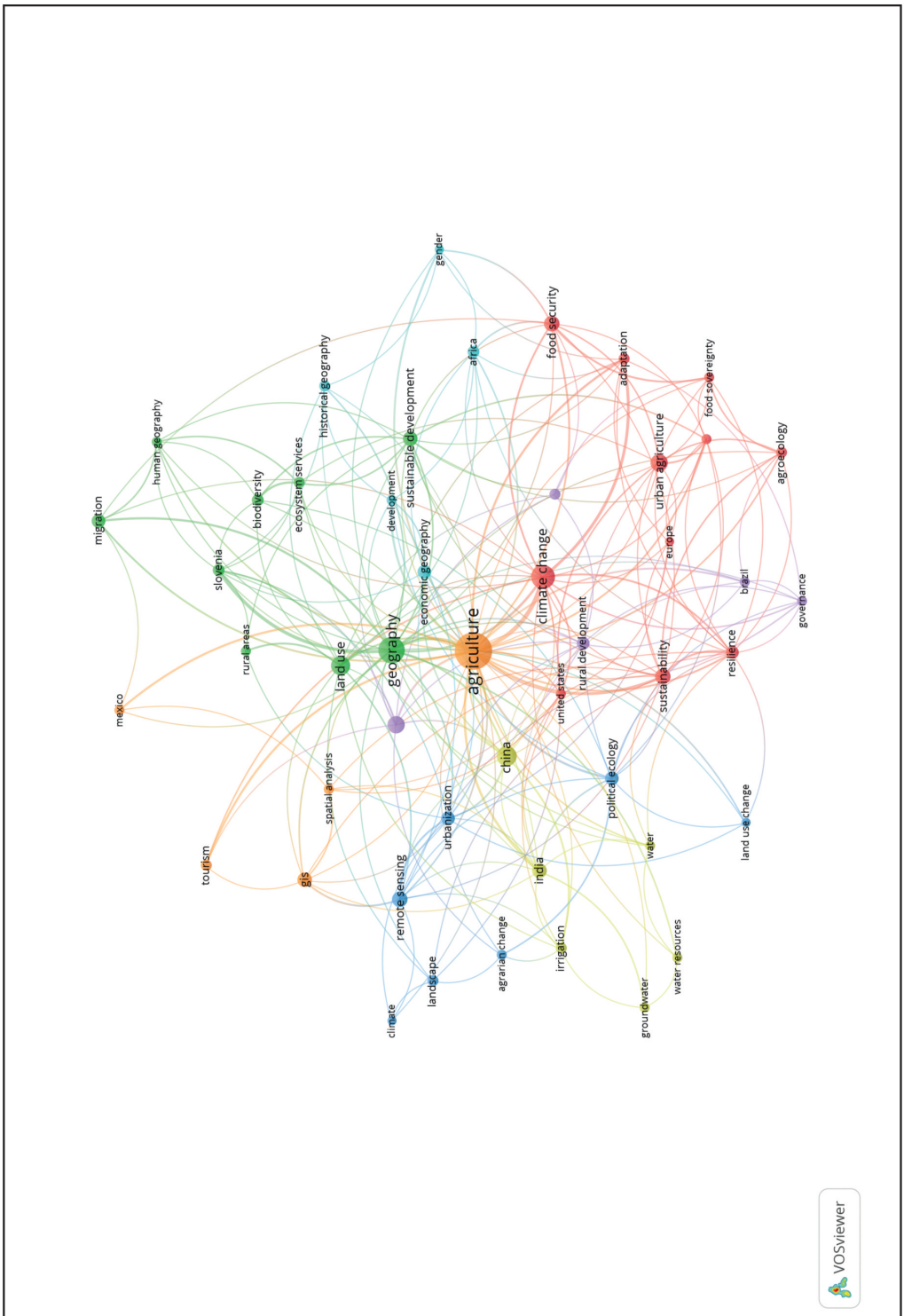
Because the literal meanings do not tell the intellectual associations between them, co-word analysis was performed to determine the relations among 48 keywords that co-occurred not less than 10 times. The results are shown in Figure 4. »Agriculture«, »geography« and »climate change« are the top three largest dots, indicating that they occur most frequently. They are located at the center of the network map, indicating that they play a pivotal role in the intellect network of agricultural geography, and other keywords are related to them to different degrees. The 48 keywords were grouped into seven clusters. Then, the themes of the clusters were identified from the respective keywords. The red cluster consists of 11 keywords. Its theme is »climate change and food«, with Europe and the United States as examples. The theme of the green cluster is »environmental sustainability«. It includes nine keywords, and Slovenia is an example. The blue cluster »land and political ecology« consists of seven keywords. The yellow cluster, consisting of six keywords, has a theme of »water resources«, and India and China are examples. The purple cluster consists of five keywords. Its theme is »rural geography«, with Brazil as an example. The cyan cluster includes five keywords. Its theme is »economic development«, and Africa is an example. Finally, the orange cluster consists of five keywords. Its theme is »spatial analysis«, and Mexico is an example.

Table 1: Grouping of keywords on agricultural geography (2013–2022) based on literal meaning.

Groups (occurrences)	Keywords* (occurrences)
Geography (505)	geography (248), historical geography (156), economic geography (60), economics (41)
Agriculture (664)	agriculture (333), agricultural production (84), agricultural development (62), agricultural history (48), urban agriculture (46), farming system (41), agricultural robots (50)
Food production (288)	food security (48), crops (95), food production (43), crop production (50), cultivation (52)
Rural development (472)	rural area (66), rural development (59), urbanization (56), agricultural land (117), land use (106), land use change (68)
Environment (316)	sustainable development (75), sustainability (68), climate change (130), environmental protection (43)
Biodiversity (368)	Biodiversity (58), animals (135), genetics (82), physiology (52), ecosystem (41)
Spatial analysis (287)	GIS (61), remote sensing (56), spatial distribution (50), spatial analysis (71), spatiotemporal analysis (49)
Country (471)	China (233), United States (140), India (53), Brazil (45)

*Only keywords with more than 40 occurrences are listed.

Figure 4: Co-word clusters of keywords on agricultural geography (2013–2022). ► p. 120


agriculture
geography
climate change
land use
food security
sustainable development
human geography
migration
biodiversity
ecosystem services
historical geography
gender
africa
adaptation
food sovereignty
agroecology
urban agriculture
europe
brazil
governance
resilience
sustainability
rural development
united states
economic geography
development
slovenia
rural areas
mexico
china
india
political ecology
water
land use change
urbanization
spatial analysis
gis
tourism
remote sensing
agrarian change
irrigation
landscape
climate
groundwater
water resources
VOSviewer

3.3 Documents and textual analysis

Among 2879 articles on agricultural geography in 2013–2022, 29 articles have more than 100 citations. The number of citations indicates the document's impact on the body of knowledge (Waltman 2016), although these impacts may not necessarily be limited to the field of agricultural geography. Based on the nature and studied objects, these 29 articles are categorized into six groups (Table 2). The grouping of highly cited articles is similar to the literal grouping of keywords; groups of »biodiversity«, »environment«, »rural development«, »food production«, and »agriculture« can be found in both grouping results.

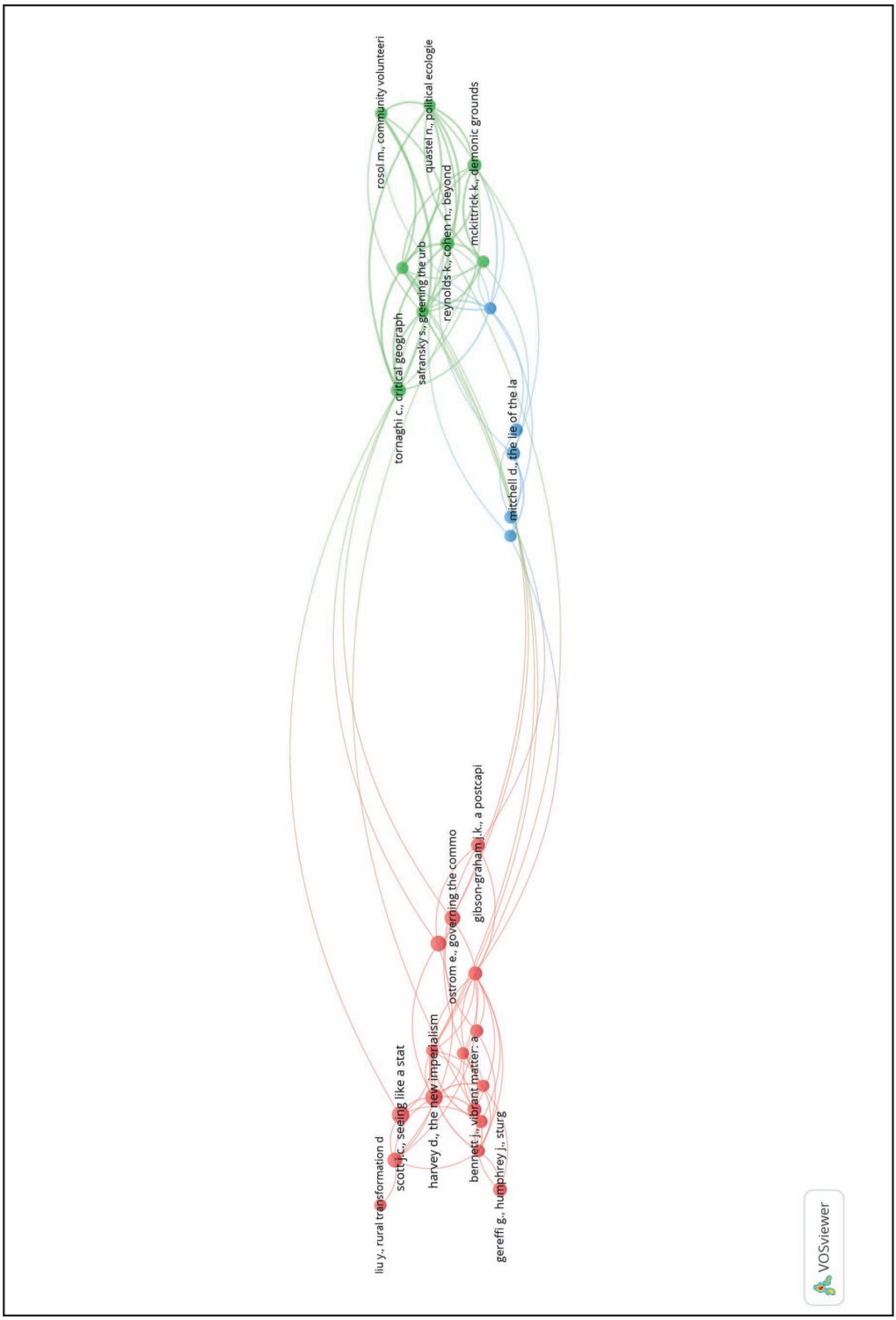
Co-citation analysis was performed to identify the intellectual associations among the articles on agricultural geography. A total of 99,726 references were cited by the 1879 articles. Taking the minimum number of citations of seven times as the threshold for co-citation analysis, 29 papers met the criteria and were categorized into three clusters (Figure 5). The red cluster, consisting of 16 documents, is the largest and is located on the left side of the graph. Documents in this cluster mostly are books on political economy, representative works include Harvey (2003), Scott (1998), Ostrom (1992), and Blaikie and Brookfield (1987). The green cluster consists of eight articles and is located on the right side of the map. The green cluster mostly focuses on global issues related to agriculture, e.g., urban agriculture, represented by McClintock (2013), Safransky (2014), Tornaghi (2014), and Reynolds and Cohen (2016). The blue cluster is an extension of the green cluster with only three papers related to land and farms, e.g., Mitchell (1996) and Guthman (2014).

Table 2: Grouping of highly cited articles (above 100 citations) on agricultural geography (2013–2022).

Groups (citations)	Articles (citations; rank*)
Climate change (2185)	Ray et al. 2015 (1222; 1st), Bassu et al. 2014 (478; 2nd), Chazdon et al. 2016 (372; 3rd), Ma et al. 2015 (113; 27th)
Rural development (1335)	Liu 2018 (317; 5th), Long et al. 2014 (301; 6th), Yang et al. 2016 (198; 13th), Fuchs et al. 2013 (148; 17th), Davis et al. 2017 (142; 19th), Messerli et al. 2014 (116; 26th), Long 2013 (113; 28th)
Food production (783)	Tamang et al. 2020 (223; 11th), Beddow et al. 2015 (182; 14th), O'Hara and Toussaint 2021 (142; 19th), McLain et al. 2013 (135; 21st), Tao et al. 2014 (101; 29th)
Biodiversity (773)	Castañeda-Álvarez et al. 2016 (339; 4th), Rozendaal et al. 2019 (263; 8th), Kwong et al. 2017 (232; 10th), Richman et al. 2015 (200; 12th), Guan et al. 2014 (172; 15th), Maas et al. 2015 (162; 16th)
Environment (674)	Tang et al. 2021 (275; 7th), Song et al. 2014 (144; 18th), Chang and Sheppard 2013 (134; 22nd), Tieskens et al. 2017 (121; 25th)
Agriculture (513)	Tornaghi 2014 (257; 9th), McArthur and McCord 2017 (130; 23rd), Henderson et al. 2018 (126; 24th)

* The ranking represents the order of the articles by number of citations across the groups from 1st to 29th.

Figure 5: Co-citation clusters of documents on agricultural geography (2013–2022). ► p. 122


rosol m., community volunteeri
quastel n., political ecologie
mckittrick k., demonic grounds
reynolds k., cohen n., beyond
safransky s., greening the urb
tornaghi c., critical geograph
mitchell d., the lie of the la
gibson-graham j.k., a postcapi
ostrom e., governing the commo
harvey d., the new imperialism
bennett j., vibrant matter: a
scott j.c., seeing like a stat
liu y., rural transformation d
gereffi g., humphrey j., sturg
VOSviewer

3.4 Authors and authorial analysis

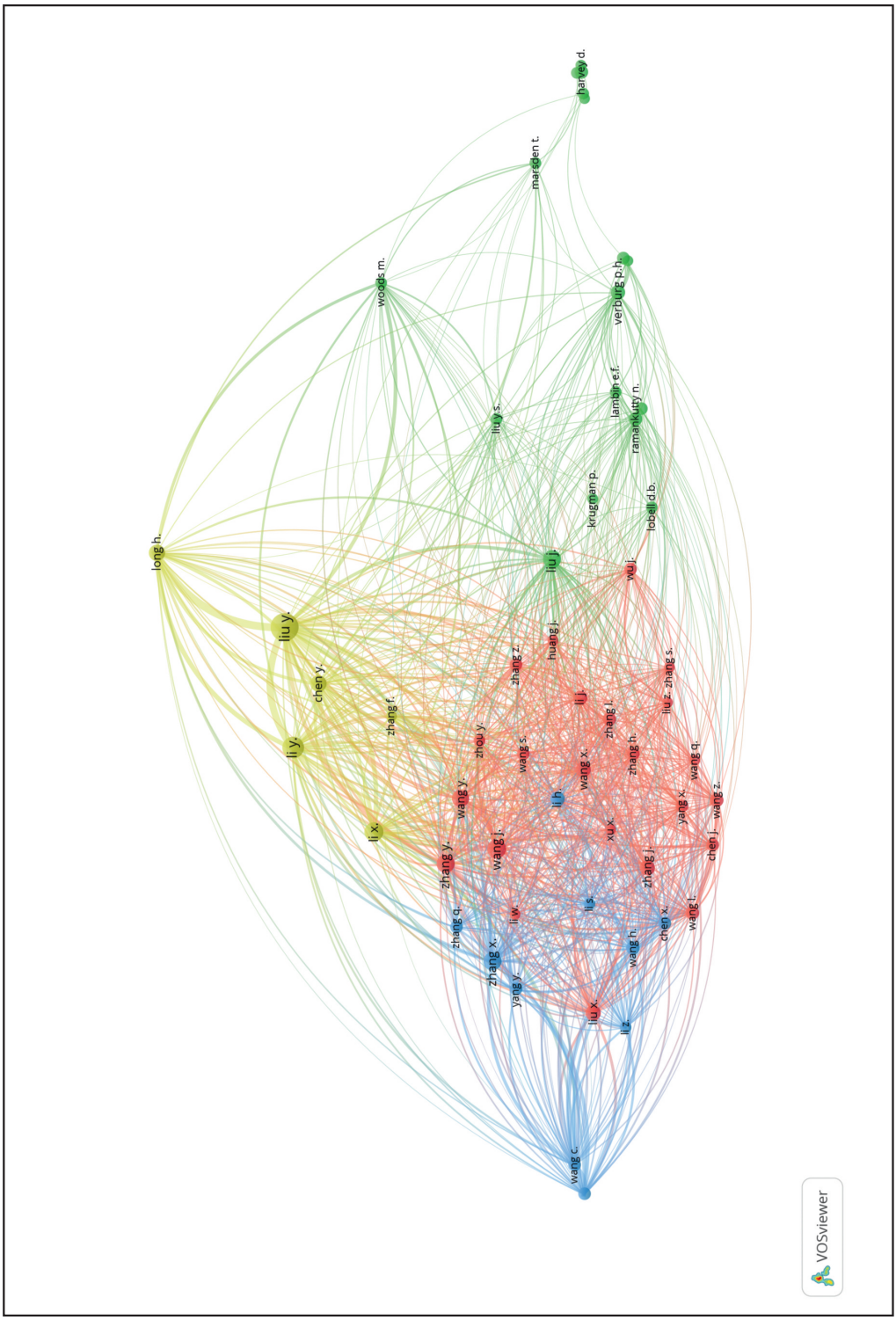
From 2013 to 2022, a total of 1857 authors published articles on agricultural geography. The number of articles contributed to the field was not high, most authors published not more than three articles. Ten authors published at least four articles on agricultural geography (Table 3). Liu Y. and Long H. ranked first and second, respectively. Both published more than 10 articles, standing out from the crowd. Interestingly, the articles on agricultural geography accounted for only a small portion of the total publications of these authors, indicating that agricultural geography is only one of their research interests, perhaps not the major interest as well. Among these ten authors, five work in China, three in Europe, and two in North America.

Taking the minimum number of seven papers as the threshold for co-citation analysis, 56 authors met the criteria and were categorized into four clusters (Figure 6). The red cluster consists of 23 authors, represented by Wang Y., Wang J., and Zhang Y., whose common point is spatial distribution. The blue cluster consists of 10 authors, represented by Wang H. and Zhang H., all of whom were working on environmental or water resources issues. The yellow cluster is small in number, consisting of six authors. It is characterized by a few prolific authors in China (e.g., Liu Y., Long H.). While the clusters red, blue, and yellow are composed of Chinese authors, Western authors are concentrated in the green cluster. There are 17 authors in the green cluster, with some prominent geographers, e.g., Harvey D. and Verburg, P. H., found on the right side. While Harvey D. is famous for critical geography (Harvey 2003), Verburg P. H. makes significant contributions to the study of land use changes (Verburg et al. 2009).

Table 3: Prolific authors who published more than 3 articles on agricultural geography (2013–2022).

Author	Affiliation/country	Number of articles on agricultural geography	Total number of publications	h-index
Liu, Yansui	Chinese Academy of Sciences, China	16	309	82
Long, Hualou	Chinese Academy of Sciences, China	11	139	53
McClintock, Nathan C.	Centre Urbanisation Culture Société, Canada	7	28	17
Li, Yurui	Chinese Academy of Sciences, China	5	114	37
Verburg, Peter H.	Vrije Universiteit Amsterdam, The Netherlands	4	428	106
Fang, Chuangling Lin	Chinese Academy of Sciences, China	4	289	59
Ramirez-Villegas, Julián	Wageningen University & Research, Netherlands	4	89	36
Wang, Jiaoe	Chinese Academy of Sciences, China	4	100	34
Reid-Musson, Emily	St. Francis Xavier University, Canada	4	19	7
Darly, Ségolène	Université Paris 8, France	4	15	6

Figure 6: Co-citation clusters of authors on agricultural geography (2013–2022). ► p. 124


harvey d.
marsden t.
woods m.
verburg p.h.
liu y.s.
lambin e.f.
ramankutty n.
krugman p.
lobell d.b.
long h.
liu j.
yu j.
liu y.
chen y.
li y.
zhang t.
zhang z.
huang j.
li j.
zhang l.
liu z.
zhang s.
zhou y.
wang s.
wang x.
zhang h.
wang q.
li x.
wang y.
li b.
yang x.
wang z.
xu x.
chen j.
zhang y.
wang j.
zhang j.
li w.
li s.
zhang q.
chen x.
wang l.
zhang x.
wang h.
yang y.
liu x.
li z.
wang c.
VOSviewer

3.5 Journals and source analysis

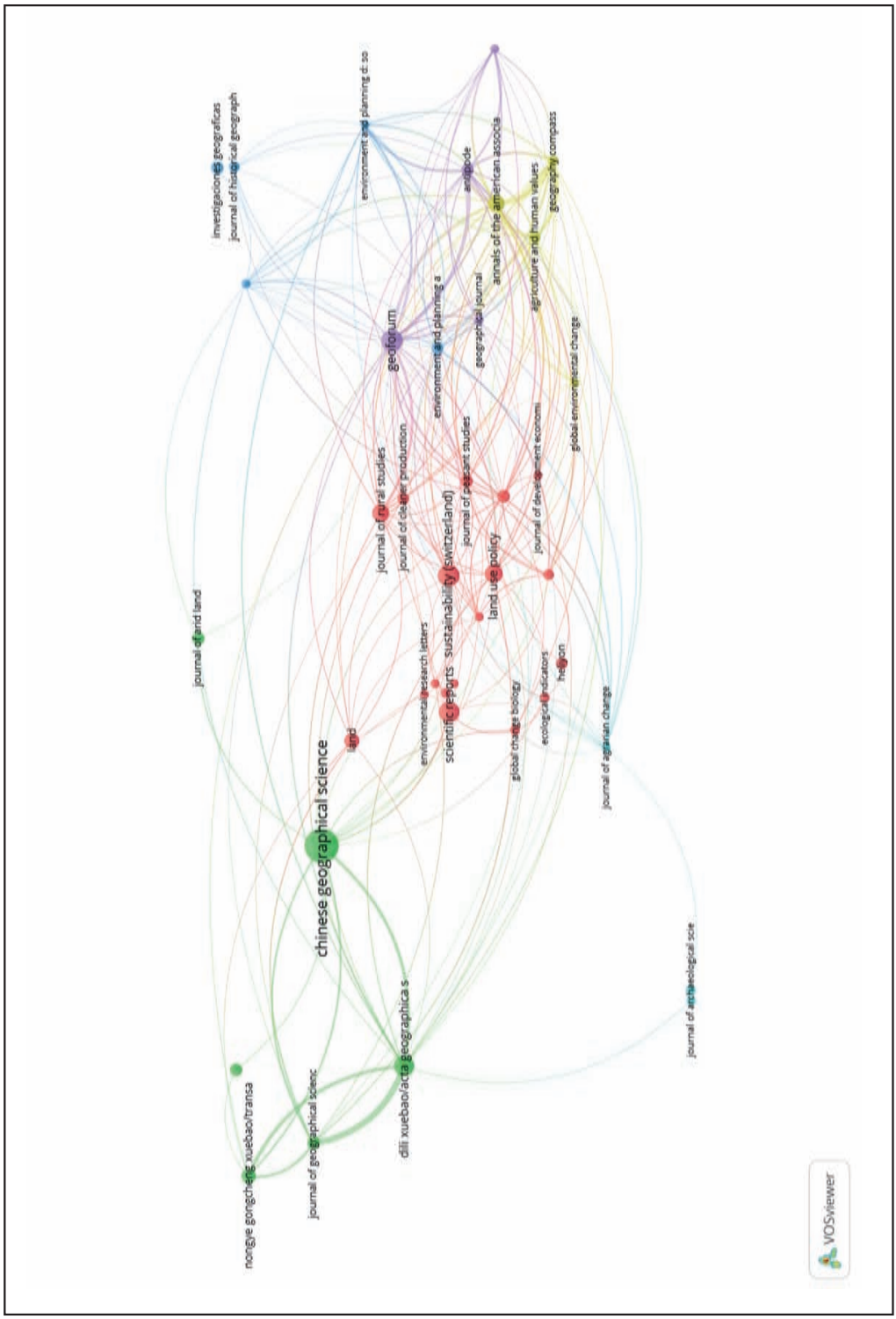
Among 841 journals on agricultural geography in 2013–2022, 21 journals published at least 10 articles on agricultural geography. Based on the aims and scopes, these 21 journals are categorized into six groups (Table 4). Apart from the largest group »geography« which has nine journals, other groups consist of not more than three journals. Interestingly, the most cited articles on agricultural geography (i.e., those listed in Table 2) are not published in these prolific journals.

To examine the intellectual associations among the journals on agricultural geography, bibliographic coupling analysis was performed to analyze 40 journals that published at least seven articles on agricultural geography, and six clusters were identified (Figure 7). The red cluster consists of 18 journals that provide outlets for a wide variety of research topics (e.g., land use, development, rural studies, clean production, etc.) that agricultural geographers can take part. Because of a good mix of journals, the red cluster represents the bulk journals on the agricultural geography. Occupying the center location of the network map, the red cluster extends outwards to form four small clusters (i.e., blue, yellow, purple, and cyan). While these three clusters mainly consist of geographical journals, they may have their own emphasis or perspectives, i.e., the blue cluster focuses on environment, the yellow cluster has a global outlook, the purple cluster encourages dialogues, and the cyan cluster related to certain specific issues related to land, respectively. The green cluster is located on the left side of the network map and is separated from the other clusters. This cluster consists of six journals, all of which are Chinese journals.

Table 4: Grouping of prolific journals with more than 10 articles on agricultural geography (2013–2022).

Groups (articles)	Journals (articles; rank)
Geography (237)	Chinese Geographical Science (86; 1st), Geoforum (35; 2nd), Annals of The American Association of Geographers (21; 7th), Investigaciones Geograficas (13; 11th), World Development (13; 11th), Antipode (13; 11th), Acta Geographica Sinica (31; 5th), Journal of Geographical Sciences (13; 11th), Journal of Arid Land (12; 16th)
Agriculture (25)	Transactions of The Chinese Society of Agricultural Engineering (15; 10th), Agriculture and Human Values (10; 20th)
Land (43)	Land Use Policy (25; 6th), Land (18; 9th)
Environment (34)	Environment and Planning A (11; 18th), Journal of Cleaner Production (10; 20th), Shengtai Xuebao (13; 11th)
Rural studies (33)	Journal of Rural Studies (21; 7th), Journal of Peasant Studies (12; 16th)
Multi-disciplinary (79)	Sustainability (Switzerland) (35; 2nd), Scientific Reports (33; 4th), Heliyon (11; 18th)

Figure 7: Bibliographical coupling clusters of journals on agricultural geography (2013–2022). ► p. 125


investigaciones geograficas
journal of historical geograph
environment and planning d: so
ecology
annals of the american associa
geography compass
agriculture and human values
geoforum
environment and planning a
geographical journal
global environmental change
journal of rural studies
journal of peasant studies
journal of development economi
sustainability (switzerland)
land use policy
journal of arid land
environmental research letters
scientific reports
global change biology
ecological indicators
religion
journal of agrarian change
chinese geographical science
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VOSviewer

4 Discussion

4.1 The geography of agricultural geography

The analysis of publications from 137 countries over the past decade underscores the global interest in agricultural geography. However, the geographical distribution of research efforts is uneven. The »global north« countries, such as the United States and European nations, dominate the field, while the »global south« countries contribute less. This disparity can be attributed to several factors. Developed countries generally have better research infrastructure and more funding available for academic pursuits, including agricultural geography (Mohrman et al. 2008). This enables more extensive and higher-quality research output. Additionally, countries with well-developed agricultural sectors, such as the United States and China, have a vested interest in advancing agricultural research to support their economies (Cantwell and Mathies 2012). Grain-exporting countries require robust agricultural research to maintain and improve their export capabilities, driving more research and publications in agricultural geography (Khosla 2018).

The co-authorship analysis reveals six distinct clusters of international collaboration, which largely align with geographic regions. Generally speaking, countries in the same region share similar climates, livelihoods, and cultures, and may need to work together to face similar agricultural problems, thus leading to research collaboration. In addition, proximity implies low transaction costs for academic exchanges and has a positive effect on academic collaboration (Ng 2022).

4.2 Agricultural geography and legacy of human geography

The evolution of agricultural geography is closely tied to the broader field of human geography. Each significant advancement in human geography has spurred corresponding developments in agricultural geography. Co-word analysis identified seven research themes in agricultural geography in the last 10 years, which are rooted in a certain period in the history of human geography (Figure 8). The themes »climate

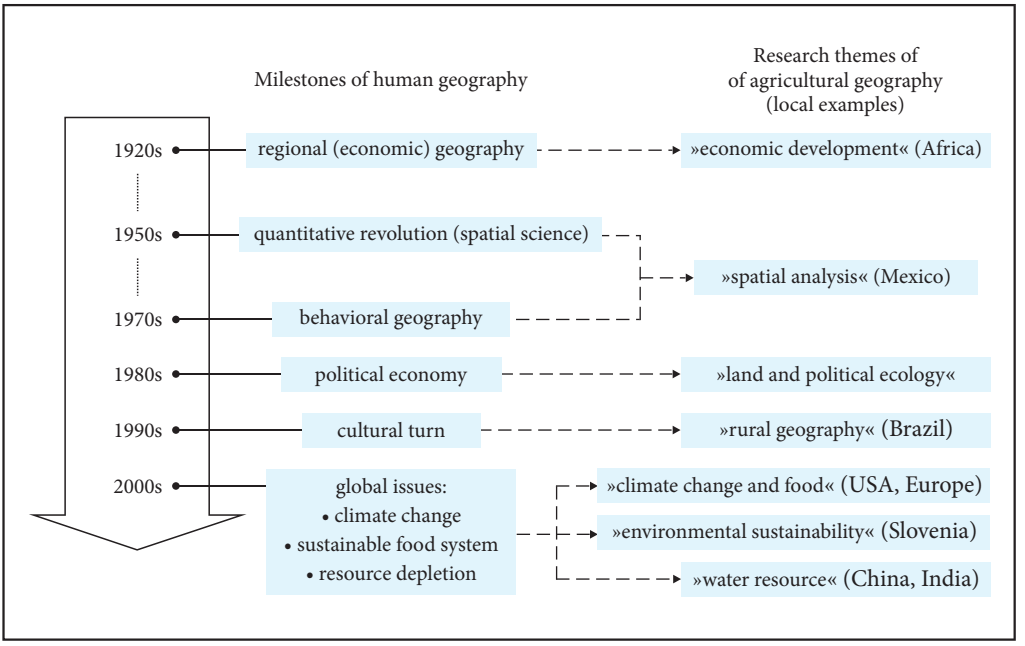

Figure 8: Development of human geography and seven research themes of agricultural geography.

change and food«, »environmental sustainability«, and »water resources« emerge from global issues and are popular topics of interest today. The theme »economic development« originates from regional (economic) geography in the early 20th century. The theme »spatial analysis« originates from the quantitative revolution in the 1960s and behavioral geography in the 1970s. The theme »land and political ecology« has its origins in the political economy in the 1980s, and the theme »rural geography« originates from the cultural turn in the 1990s.

On the other hand, because the natural environment, economy, society, and culture are different across the world, the research focus on agricultural geography may vary in different regions or countries. For example, the United States and the European countries are developed economies, and they are more interested in »climate change and food« (Petersen-Rockney 2022); on the contrary, the economy is generally backward in Africa, hence its agricultural geography focuses on »economic development« (Andrianarimanana and Pu 2021); Slovenia emphasizes the importance of agricultural sustainability (Razpotnik Visković and Komac 2018); China and India have large populations and are large agricultural countries, and »water resource« is an overriding issue (Fang et al. 2020); and »rural geography« is a popular topic in Brazil because of the rapid urbanization of the countryside (Santos et al. 2017).

4.3 Intellectual structure of agricultural geography

The textual analysis of documents reveals two main strands of research within agricultural geography: theoretical and practical. The theoretical strand is heavily influenced by foundational works in human geography, such as Blaikie and Brookfield (1987), Ostrom (1992), Scott (1998), and Harvey (2003). These works provide theoretical and analytical frameworks that are applied to agricultural geography research (Marsden et al. 1996). For instance, Ostrom's (1992) seminal work on common-pool resources has provided a foundation for addressing challenges in land and water management. This approach is increasingly recognized as a potential solution to the dual issues of land abandonment and agricultural intensification (Renes et al. 2023). The growing discourse on commons and collective action in Europe underscores this trend, as evidenced by a recent special issue in Acta geographica Slovenica (Urbanc et al. 2023). The practical strand focuses on empirical issues, addressing real-world challenges in agricultural geography. For example, studies on urban agriculture (McClintock 2013; Tornaghi 2014) and food security (O'Connor 2016) provide practical solutions to pressing global issues. The distinction between these strands highlights the dual nature of agricultural geography as both a theoretical and applied discipline. The integration of theoretical frameworks with empirical research enriches the field and enhances its relevance to contemporary issues.

The authorial analysis indicated that most of the authors published only very few articles on agricultural geography, hence their impact is very limited and piecemeal. The low number of articles per author implies a low level of participation in agricultural geography research, or that there is no active research team carrying out agricultural geography research on a sustained basis.

4.4 Agricultural geography and China

China's prominence in agricultural geography is evident from its high publication output and influential authors. The separation of Chinese research from Western counterparts, as indicated by various bibliometric analyses, can be attributed to several factors. Chinese agricultural geography research often differs from Western approaches in terms of concepts and content (Liao et al. 2011). This divergence reflects the unique socio-economic and cultural context of China (Liu et al. 2011). The predominance of English in academic publishing creates a barrier for Chinese researchers, leading to a more insular research community (Lund et al. 2023).

Chinese researchers primarily collaborate with other Asia-Pacific countries, reflecting regional proximity and shared agricultural challenges. This regional collaboration is partly due to the language issue but also due to the geographical distance between China and other countries that are active in agricultural geography (e.g., the United States and the United Kingdom). Despite these differences, China's contributions to agricultural geography are significant, and its influence is growing. The integration of Chinese perspectives into the global discourse can enrich the field and foster more comprehensive and diverse research.

4.5 Theoretical and practical implications

This study has two theoretical implications. First, this study underscores the importance of contextual factors in the production of geographical knowledge. The uneven distribution of research efforts and the diversity of research focuses highlight the influence of geographical, socio-economic, and cultural contexts on agricultural geography. For example, there has been an increase in both research interest and also publication output on agricultural geography since 2019 due to the pandemic outbreak of COVID-19. The influences of geography on the development of agricultural geography are evident in the uneven distribution of research efforts on agricultural geography globally and the diversity of research focuses in different regions or countries.

Second, this study demonstrates that the research themes of agricultural geography recapitulate the development of human geography. Every advance in human geography can be understood as the development of a new paradigm that subsequently guides the research on agricultural geography, echoing Kuhn's structure of »scientific revolution« that disciplines evolve through paradigms (Livingstone and Withers 2007). This study challenges the traditional view of geography as a unified and objective discipline. As Harvey (2000) indicated, geography is not a monolithic body of knowledge but rather a diverse and evolving field with multiple internal factions and contested perspectives, and this is particularly evident in agricultural geography.

This study also offers a couple of practical insights. First, understanding the development and intellectual structure of the field can help identify gaps and challenges, informing future research agendas. Two critical issues are the lack of a sustainable community of agricultural geographers and the independence of oriental and Western researchers.

Second, exploring the diversity of geographical knowledge can enhance public engagement and geographical literacy. Understanding the research field of agricultural geography can foster a deeper appreciation for the complexities of our world and encourage participation in debates related to agriculture, food, environment, and other geographical issues.

5 Conclusion

Geographers have long participated in the research of agricultural development. Despite the rapid development of agricultural geography in the 21st century, our knowledge about its recent development is very limited. This study analyzes 1879 papers obtained from Scopus to determine the landscape of the recent development in this field. This study identifies 7 research themes: »climate change and food«, »environmental sustainability«, »land and political ecology«, »water resources«, »rural geography«, »economic development«, and »spatial analysis«, and two strands: theory and practice. Geographical factors greatly affect research initiatives and international collaborations among agricultural geographers. The above findings can guide readers to acquaint themselves with the diversity of knowledge in this research field.

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UNVEILING THE CULTURAL ECOSYSTEM SERVICES OF URBAN GREEN SPACES: A CASE STUDY OF LJUBLJANA, SLOVENIA

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BOJAN ERHARTIČ

Tivoli, the largest park in Ljubljana, is a popular place to relax.

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Unveiling the cultural ecosystem services of urban green spaces: A case study of Ljubljana, Slovenia

ABSTRACT: This paper analyses the value of cultural ecosystem services in urban green spaces. A field survey of 900 respondents in Ljubljana, Slovenia, examined cultural ecosystem services in seven types of urban green spaces and compared the results with two types of non-green public spaces (old town, shopping mall). Differences between the types were assessed using one-way variance analysis (ANOVA). Results showed statistically significant differences between the types, with sports facilities standing out as valuable for recreation and education. The old town's cultural heritage and aesthetics were highly valued, while shopping malls ranked lowest. The study emphasises the importance of urban green spaces for quality of life of residents and informs land use planning decision-making.

KEYWORDS: urban green space, recreation, cultural ecosystem services, quality of life, Ljubljana, Slovenia

Odkrivanje kulturnih ekosistemskih storitev na mestnih zelenih površinah: študija primera v Ljubljani, Slovenija

POVZETEK: Članek analizira vrednost kulturnih ekosistemskih storitev na mestnih zelenih površinah. S terensko raziskavo, v kateri je sodelovalo 900 anketirancev iz Ljubljane, smo vrednotili kulturne ekosistemske storitve na sedmih tipih mestnih zelenih površin in rezultate primerjali z dvema tipoma nezelenih javnih površin (staro mestno jedro, nakupovalna središča). Razlike med tipi smo analizirali z enosmerno analizo variance (ANOVA). Rezultati so pokazali statistično pomembne razlike med tipi, pri čemer so športni objekti izstopali kot dragoceni za rekreacijo in izobraževanje. Kulturna dediščina in estetika starega mestnega jedra sta bili visoko ocenjeni, medtem ko so se nakupovalna središča uvrstila na najnižje mesto. Raziskava poudarja pomen mestnih zelenih površin za kakovost življenja prebivalcev, rezultati pa so lahko koristni pri sprejemanju odločitev o prostorskem načrtovanju.

KLJUČNE BESEDE: mestne zelene površine, rekreacija, kulturne ekosistemske storitve, kakovost življenja, Ljubljana, Slovenija

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1 Introduction

Many Europeans are leaving the countryside for urban areas, which has led to a dramatic increase in environmental pressures, particularly in the second half of the 20th century (Antrop 2004; Urbanc et al. 2023). In this context, ecosystem services provided by urban green spaces, such as air purification, temperature regulation, water management, and mental health benefits, are becoming increasingly vital. These services help mitigate the negative environmental impacts of urbanization and play a crucial role in enhancing the quality of life in cities. Recognizing and understanding the importance of these ecosystem services is essential for fostering more sustainable and resilient urban environments (Gómez-Baggethun et al. 2013).

Citizens are exposed to negative environmental pressures, such as pollution, overcrowding, excessive noise, and information overload (Polajnar Horvat and Smrekar 2017; Smrekar et al. 2019; Tzortzi and Ioannou 2022), also called ecosystem disservices (Lyytimäki and Sipilä 2009). Coping with the challenges of everyday urban life puts a strain on people's physical and mental health and, combined with an increasingly sedentary lifestyle, has negative health consequences (Collado et al. 2016). There is a wealth of evidence on the health, social, and psychological benefits of spending time in nature, urban green spaces (Joye and Van den Berg 2013). Such spaces were particularly important during the COVID-19 pandemic when movement was restricted and locally limited (Bakir and Sahar 2021; Grasseni 2022). Studies show that various types of recreational environment possess various restorative quality, which is higher in more natural environments (Tyrväinen et al. 2014). However, some studies show that non-green settings, such as shopping malls, have certain recreational dimensions and are not automatically inferior to more natural surroundings (Craig et al. 2018).

The diversity of Earth ecosystems has an impact on human well-being (Haines-Young and Potschin 2010). The problem is that ecosystems are increasingly being transformed and have become increasingly unrecognizable in recent decades, leading to a loss of biodiversity, disruption of natural processes, and a reduced capacity to provide essential ecosystem services that humans and other species rely on for survival (Ribeiro and Šmid Hribar 2019). These consequences have contributed to a growing awareness of the importance of ecosystems and the need to understand the services they provide to modern society (Millennium Ecosystem Assessment 2005; Pakfetrat et al. 2020; Suhadolc et al. 2022). The urban green spaces of the highest quality include the spectrum of ecosystem services: supporting, regulating and cultural (Wallace 2007; European Environmental Agency 2018). The cultural ecosystem services are directly experienced by people, as their availability depends on the level and type of interactions between people and the natural environment (Plieninger et al. 2013; Gavrilidis et al. 2023).

Cultural ecosystem services play a crucial role in enhancing urban life, contributing to mental well-being, social cohesion, and active lifestyles. Despite their importance, they remain under-researched, particularly in the context of urban green spaces. The concept of cultural ecosystem services has already been introduced and recognized in other operational frameworks, such as environmental and conservation policy (Tengberg et al. 2012), while it is still quite unknown in the fields of health-enhancing physical activity, sport, and recreation (Sielaff et al. 2024).

The aim of this research is to fill the gap in knowledge regarding cultural ecosystem services in urban green spaces. The research focuses on the following key questions:

1) How do users perceive cultural ecosystem services in urban green spaces?
2) Are there significant differences in the valuation of cultural ecosystem services and disservices across different types of urban green spaces?
3) Do old town and shopping malls possess lower value compared to urban green spaces?

The case study for this research is the city of Ljubljana, the capital of Slovenia, which has just under 300,000 residents and more than 125,000 daily commuters. Ljubljana presents an interesting case for analysis due to its diverse range of urban (green) spaces (Smrekar and Tiran 2013; Smrekar et al. 2019). Furthermore, Ljubljana has received numerous awards for its sustainability initiatives, including the title of European Green Capital 2016, in part due to its focus on urban greening projects and the development of new recreational and sports facilities (Kozina et al. 2019; Poljak Istenič 2019).

2 Theoretical background

Human well-being is closely linked to the natural environment (including urban green spaces) and its values (Jabbar et al. 2022). Although this is firmly established, it remains difficult to assess how the

biophysical characteristics of a given space contribute to the well-being of people associated with that space (Bieling et al. 2014).

The concept of natural capital emerged in the early 1970s (Schumacher 1973), emphasising the need for more sustainable utilization of natural resources. This notion sparked a systematic research agenda into ecosystem services. Initially, the primary goal of the ecosystem services concept was to raise awareness of the adverse effects of biodiversity loss on both ecosystem functionality and societal well-being (Gómez-Baggethun et al. 2010). A significant milestone in the development of the ecosystem services concept was the Millennium Ecosystem Assessment (2005, p. V), which underscored society's fundamental reliance on ecosystem services and helped establish them. According to this document, ecosystem services are defined as »the benefits that people obtain from ecosystems« and are divided into four types of direct benefits:

- supporting services: these enable ecosystems to provide services, such as food provisioning, flood regulation, and water purification;
- provisioning services: products derived from ecosystems, such as food and fibre;
- regulating services: benefits derived from regulating ecosystem processes, e.g., climate regulation and water purification;
- cultural services: non-material benefits that people derive from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experience, including, for example, knowledge systems, social relationships, and aesthetic values.

Following the Millennium Ecosystem Assessment (2005), several key initiatives further shaped the field. The Economics of Ecosystems and Biodiversity – TEEB (Sukhdev et al. 2010) was instrumental in integrating biodiversity values into decision-making processes at various levels, emphasising the importance of ecosystem services in policy and economics. Shortly thereafter, the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services – IPBES was formed in 2015 (Brondizio et al. 2019), strengthening the science-policy interface on biodiversity and ecosystem services globally. In parallel, the European Union undertook the systematic mapping of ecosystems (Maes et al. 2020), aiming to standardize the evaluation of ecosystem services across different types of ecosystems. This led to a structured approach for assessing ecosystem states. Building on these foundational works, the Common International Classification of Ecosystem Services – CICES (European Environmental Agency 2018) further refined the classification of ecosystem services into three broad categories – provisioning, regulating, and cultural services – accompanied by detailed subcategories that add precision to the assessment and application of ecosystem services (Šmid Hribar et al. 2021).

Recently, de Groot et al. (2020) published a work analysing 960 studies on the economic valuation of ecosystem services. The highest value estimates are for air quality management, recreation and tourism. For others, there is relatively limited information (e.g., spiritual experiences and ornamental resources). In a similar way, data on ecosystem service studies published in Slovenia were identified, compared and described (Šmid Hribar et al. 2021). The main findings are that the number of scientific and professional articles about ecosystem service in Slovenia is increasing (39 articles in total). The most represented field is forestry, while the most commonly explored individual ecosystem services are cultural, namely recreation and ecotourism.

The term ecosystem disservice is derived from the ecosystem service approach and is thus conceptually related to it. The term is used rarely in papers that were published before Millennium Ecosystem Assessment (2005). One of the first definitions of ecosystem disservice was published by Lyytimäki and Sipilä (2009, p. 311), where ecosystem disservices were defined as »functions of ecosystems that are perceived as negative for human well-being«. Millennium Ecosystem Assessment (2005) uses a general, anthropocentric perspective that builds on a general, universal understanding of human well-being. On a closer look, the general idea of human well-being can be divided into a multitude of categories of human well-being, representing the different values, beliefs and necessities of a multitude of different groups. This subdivision leads to the problem that the identification of ecosystem disservice becomes very dependent on which effects are perceived by individuals and societies as negative in a given context. Very often, noise and waste in the landscape are perceived as ecosystem disservices which are a consequence of human use of ecosystems, not a disservice from the ecosystem itself (Plieninger et al. 2013). For example, a rarely mentioned adverse service that is clearly linked to ecological structures or functions is the perceived fear of wolves roaming in forests (Agbenyega et al. 2009). The concept of ecosystem disservices has its roots in urban ecosystem research (Lyytimäki and Sipilä 2009; Escobedo et al. 2011; Dobbs et al. 2014; Lyytimäki

2014), particularly in the context of complex human-environment systems characteristic of urban spaces (von Döehren and Haase 2015). They have been used to assess the value of green spaces to urban residents (Lyytimäki et al. 2008; Lyytimäki and Sipilä 2009).

Guo et al. (2022) analysed 524 studies of ecosystem disservices. Relevant searches on ecosystem disservices can be found on various ecosystem types. Among them, there are abundant research cases on ecosystem disservices in urban and agricultural ecosystems. Urban ecosystem disservices were associated with changes of biodiversity. Several studies also advocated for better integration of ecosystem services and disservices in stakeholder decision-making on urban green spaces by assessing trade-offs and synergies. Some articles also associated the disservices of urban ecosystems with the public awareness and demand for urban green space.

The concept of cultural ecosystem services is previously defined in this chapter in the context of four types of direct benefits. Cultural ecosystem services can involve the use of natural resources directly (e.g., enjoying walking or viewing the scenery) or indirectly (e.g., the cultural heritage and spiritual value of green spaces) (Sen and Guchhait 2021). Unlike other ecosystem services, such as carbon sequestration and water or air purification that require scientific knowledge to be recorded, cultural ecosystem services are directly experienced and intuitively understood by people who come into contact with nature and the close connection between citizens, and nature offers a valuable opportunity for increasing awareness of the multifunctionality and interconnectedness of different ecosystem services and their significance for quality of life (IUCN 2015, cited in Sen and Guchhait 2021).

In the analysis of valuation of cultural ecosystem services (Matos Márquez et al. 2023), 349 scientific articles were included. The first article was published in 2010. A temporal trend towards an increase in the number of articles has been observed between the years 2010 and 2022. The terrestrial environment and recreational value being the most emphasised among all the analysed articles. The recent themes in the research area are associated with landscape, protected areas, perception, urban green space and social media studies.

Recreation is thus one of the most important cultural ecosystem services in the European context and probably the most tangible, as Kenward and Sharp wrote as early as 2008. The majority of people spend their leisure time outdoors (Sievänen et al. 2009). Recreational activities such as walking, jogging, or playing outdoors provide them the opportunity to directly experience the benefits of a cultural ecosystem. This is especially true for people living in urban environments where contact with natural ecosystems is often limited (Daniel et al. 2012). Natural ecosystems provide many important benefits such as physical exercise, aesthetic experiences, intellectual stimulation, inspiration, and other contributions to physical and psychological well-being (Chan et al. 2011). Numerous studies (Hartig et al. 2003; Karmanov and Hamel 2008; Bowler et al. 2010) have shown that even short stays in green spaces can have positive effects on human health and thus contribute to the economic productivity of society. Urban green spaces can improve environmental conditions and thus the health and quality of life of citizens. They also support green economy, create job opportunities and enhance biodiversity (Tzortzi and Ioannou 2022).

Many studies from different parts of the world report that, compared to urban environments, natural environments improve people's mood. The general conclusion is that being in a built-up urban environment leads to the perception of an incoherent environment. The results also suggest that large urban parks and large urban forests have a positive effect on the well-being of urban inhabitants (Tsunetsugu et al. 2013; Tyrväinen et al. 2014). In contrast to most other studies on nature experiences, which at best compare (for example) a walk through a forest with a walk through an urban centre (Tyrväinen et al. 2014), Craig et al. (2018) looked at comparisons with another everyday experience, in their case shopping. The role of shopping in people's lives goes far beyond the provision of food and other necessary household items and has important symbolic and recreational functions (Falk and Campbell 1997; Miller 1998; Shaw 2010). Although nature experiences have generally been found to be more enjoyable and to evoke more positive memories than shopping experiences, the results are far from clear (Craig et al. 2018). Another form of recreation is so-called recreational shopping, which is usually defined as an activity that consumers enjoy as a leisure activity (Baeckstroem 2006). All these studies indicate that different recreational environments seems to have a significantly different cultural ecosystemic services.

3 Methods

3.1 Selection of cultural ecosystem services and disservices

Our empirical analysis is based on the concept of cultural ecosystem services. The set of services included is mainly based on the highly cited paper by Bieling et al. (2014), but is also supported by the review paper by Yang and Cao (2022). The list of ecosystem services is the following:

- recreation and sports,
- education,
- aesthetics,
- relaxation,
- natural heritage,
- cultural heritage,
- sense of place,
- inspiration and
- spirituality.

A concise list of ecosystem disservices, as identified in various studies, is presented herewith (Lyytimäki et al. 2008; Lyytimäki 2014; von Döhren and Hasse 2015):

- unpleasantness,
- fear and
- noisiness.

In addition to the categories that are typically included, we have also incorporated shopping and hospitality. A comparison of experiences between nature and shopping, which are relatively uncommon (Craig et al. 2018), provides an interesting insight into how people respond to the natural and built environment.

3.2 Selection of urban green spaces

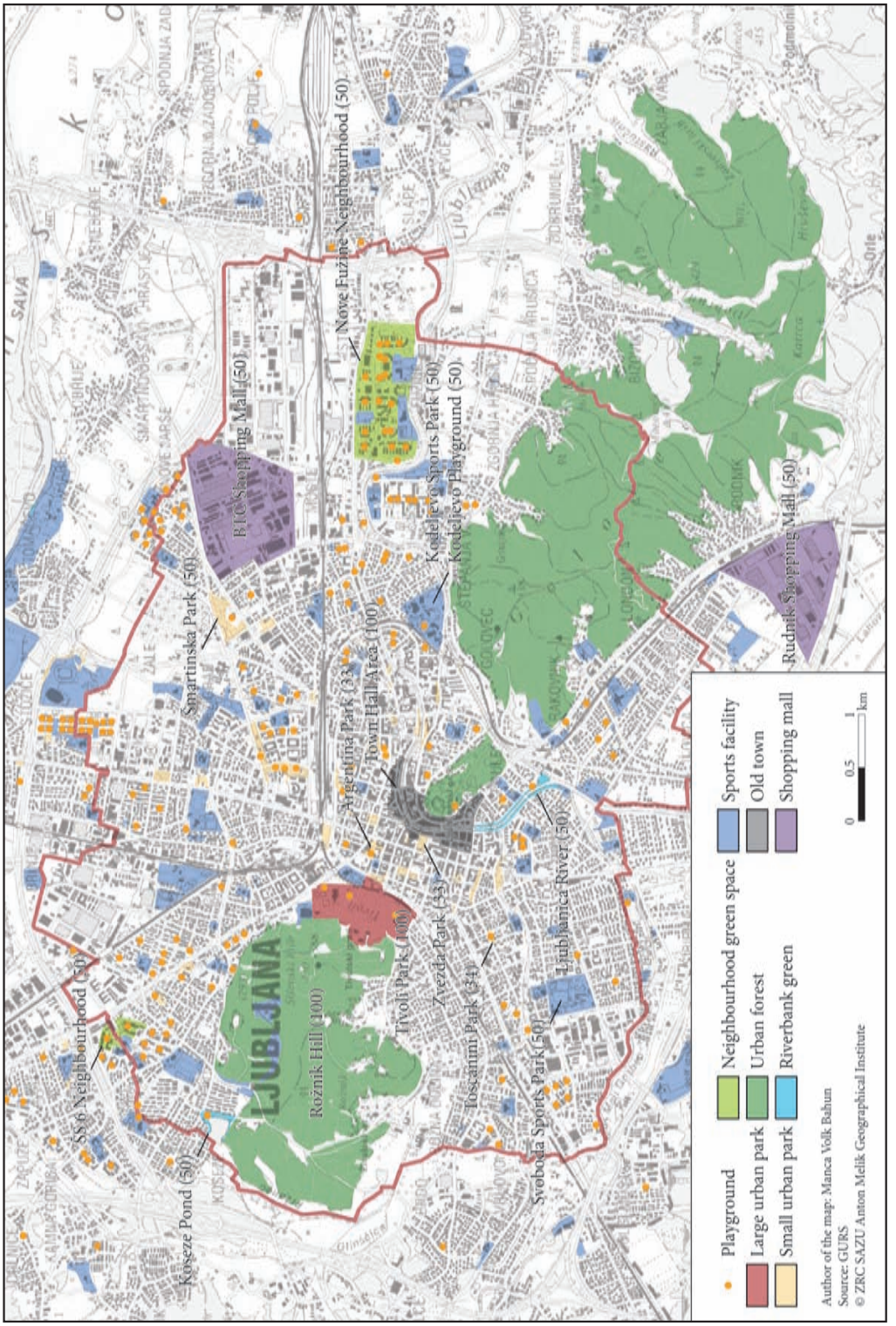
The urban green spaces in the City of Ljubljana were selected based on available public data, our expert opinion, and existing typologies of urban green spaces (e.g., Cvejić et al. 2015; Tiran et al. 2018). Most of these spaces are considered to have cultural ecosystem services. The typology consists of seven types of urban green spaces:

- large urban park,
- small urban park,
- neighbourhood green space,
- urban forest,
- riverbank green,
- open sports facility, and
- open playground.

Table 1: Types and locations of urban green spaces (1–7) and added non-green public spaces (8–9) with numbers of completed surveys.

	type	location (number of completed surveys)
1	large urban park	Tivoli Park (100)
2	small urban park	Zvezda Park (33), Argentina Park (33), Toscanini Park (34)
3	neighbourhood green space	ŠS 6 Neighbourhood (50), Nove Fužine Neighbourhood (50)
4	urban forest	Rožnik Hill (100)
5	riverbank green	Ljubljanica River (50), Koseze Pond (50)
6	sports facility	Kodeljevo Sports park (50), Svoboda Sports park (50)
7	playground	Šmartinska Park (50), Kodeljevo Playground (50)
8	old town	Town Hall Area (100)
9	shopping mall	BTC Shopping Mall (50), Rudnik Shopping Mall (50)

Figure 1: Urban public spaces in Ljubljana with a selection of case studies and number of respondents. ► p. 141


LJUBLJANA
SAVA
Ljubljanica
Rožnik Hill (100)
Tivoli Park (100)
Zvezda Park (33)
Argentina Park (33)
Town Hall Area (100)
Toscanini Park (34)
Smartinska Park (50)
BTC Shopping Mall (50)
Nove Fužine Neighbourhood (50)
Kodeljevo Sports Park (50)
Kodeljevo Playground (50)
Rudnik Shopping Mall (50)
Ljubljanica River (50)
Svoboda Sports Park (50)
Koseze Pond (50)
SS 6 Neighbourhood (50)
Playground
Large urban park
Small urban park
Neighbourhood green space
Urban forest
Riverbank green
Sports facility
Old town
Shopping mall
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Author of the map: Manca Volk Bahun
Source: GURS
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As a contrast to the established forms of recreation on urban green spaces, where we can talk about ecosystem services, recreation, such as walking and recreational shopping, can also take place in non-green public spaces:

- old town,
- shopping mall.

In the next step, we selected 1–2 representative urban green spaces per each type (Jones et al. 2022). They represent spaces where according to our knowledge people spend a lot of their leisure time and recreate (Table 1; Figure 1).

3.3 Field survey

We chose the field survey method as it provides the most efficient way to systematically assess the residents' experience of the use of green spaces and non-green public spaces at numerous locations in the city. The survey was conducted from August 7th to October 19th, 2018. We designed the questionnaire where we asked survey respondents how they value selected cultural ecosystem services and disservices on a 6-point Likert-type scale (1 = Negligible, 2 = Very little, 3 = A little, 4 = Moderately, 5 = Very much, 6 = Exceptionally). In each given unit, we performed quota sampling and tried to find a demographically diverse sample of 100 respondents in each type of space analysed. The requirement for participation was that the respondent had lived in Ljubljana for at least one year before the survey was taken. Each respondent answered to the questions for the specific location, which represents the selected type of space. 100 interviews were carried out in each type of location, resulting in the overall sample of 900 people.

3.4 Statistical analyses

To test the differences in cultural ecosystem services across the urban space types, we performed the one-way variance analysis (ANOVA). Because the group sizes were almost equal, we were able to execute the parametric test regardless violating other two basic assumptions (homogeneity of variance, normal distribution) as the evidence show that these assumptions do not have to be met in case of equal group size (Field 2009). We also ran Tukey's *post hoc* tests to see if there are statistically significant differences between means of every group against every other group. To interpret the results, the Eta squared (η^2) was calculated to measure the effect size. We also calculated the overall score of all cultural ecosystem services and disservices for each type spaces by summing all the scores, with disservices being recoded. All the statistical analyses were done by the IBM SPSS Statistics 22.0 program.

4 Results and discussion

The average and overall scores across space types and cultural ecosystem services and disservices are presented in Figures 2–4. Sport facilities received the highest overall score, indicating that in Ljubljana they are not only sufficiently available and well-designed from a landscape planning perspective, but also function effectively as multifunctional spaces. For all cultural ecosystem services, the differences between the types were small but statistically significant with $p < 0.05$ (Table 2). If we exclude the old town and shopping malls from the analysis, the differences remain significant, except for the sense of place, natural heritage and stimulating inspiration (Table 3). The effect size (η^2) is reduced to small (below 0.06) in most cases (see Table 4).

Regarding both »other«, non-green types of public spaces, the results suggest that shopping malls have a considerably lower value compared to urban green spaces; as expected, the only exception was shopping and hospitality services. The old town even scored the highest in terms of aesthetics and cultural heritage, while it received the second highest overall score among the all types.

Recreation and sports is an exceptionally valuable cultural ecosystem service in sport facilities for 60% of respondents (mean score of 5.4). They are followed by urban forests (5.1) – probably due to their size and variety of recreational options they offer. Surprisingly, people do not consider small urban parks to be very valuable spaces for recreation and sports (3.2), which is just nearly higher than the old town (3.1) with statistically insignificant difference. This can be partly ascribed to limited size of these spaces and

lack of sports infrastructure. Shopping malls (2.2) are considered the least attractive from this point of view. There was a significant effect of the urban green type on values of recreation and sports, $F(8, 896) = 66.31$, $p < .001$. The effect size, eta squared (η^2), was 0.37 (or 0.21 if both non-green types are excluded), indicating a large effect, the largest of all groups of cultural ecosystem services.

Ljubljana residents consider sports facilities also to have the highest **educational value**, with 43% rating them as extremely valuable (mean score of 4.7), similar to old town (4.3), probably due to a rich cultural heritage. The respondents assign surprisingly lower educational value to the large city park (3.7), urban forests (3.6) and riverbank greens (3.4), which can be partly ascribed to the fact that this is not their primary function. The educational value is smaller also in small urban parks (2.9) and, understandably non-green shopping malls (1.9), which more than half of respondents (55%) rate as negligible in this respect.

The highest **aesthetical** value has the old town (5.0) which can be attributed to its rich cultural heritage. This is followed by the admittedly well-maintained green spaces, such as playgrounds (4.9), riverbank green and large urban park (both 4.8), and sport facilities (4.5). The urban forest (4.1) received an unexpectedly low rating; 13% of respondents even considered it a trivial or invaluable space in this regard. This is not consistent with the findings of Bieling et al. (2014) that more natural spaces are more attractive than anthropogenically transformed spaces. This arouses a question if urban dwellers are increasingly alienated from »untamed« nature even in Ljubljana, which is still relatively very green city compared to larger urban agglomerations. Visitors of shopping malls found them the least aesthetically pleasing (3.2).

From the **relaxation** point of view, most types of spaces performed very well, resulting in the highest average value among all the types (4.9) and mostly statistically insignificant differences between individual types. Respondents can relax best in the urban forest, the large city park, riverbank green spaces, and sports facilities (all 5.3) and playground (5.2). Below the average, we can find the old town, but also with

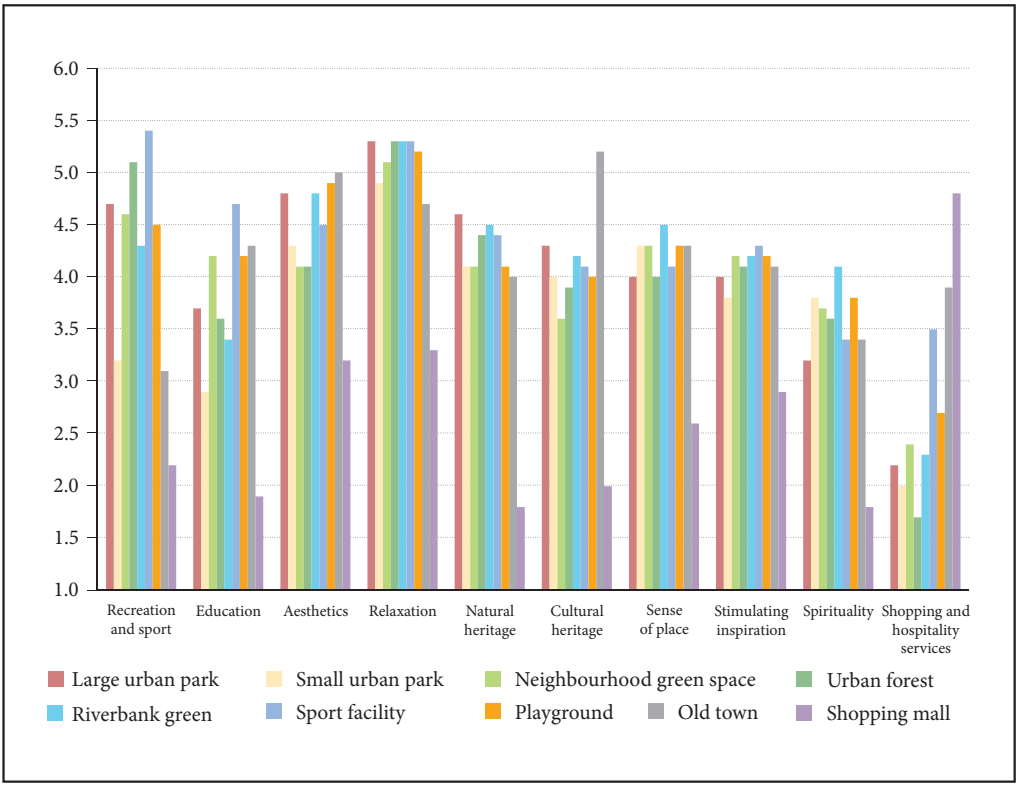

Figure 2: The average value of cultural ecosystem services across types of spaces.

a very decent score (4.7). Once more, the respondents are least able to relax in shopping malls (3.3). The results are in line with existing research showing the importance of open space for relaxation purposes compared to indoor spaces (Ito et al. 2024).

In terms of **natural heritage**, differences between spaces were very small. If we exclude shopping malls (1.8) from the analysis, they even become statistically insignificant. Value of natural heritage was the highest in the large city park (4.6), closely followed by riverbank green spaces (4.5). It is surprising that the urban forest (4.4) was not ranked higher than sports facilities (4.4), which also had the highest share of 32% of »extremely valuable« ratings. We can also interpret this as a result of careful design of sports facilities, which have a lot of greenery. The results are consistent with a study by Plieninger et al. (2015), which found that residents have less and less contact with natural spaces and therefore feel more comfortable in more urbanised environments. Discomfort in nature is becoming more and more evident especially for urban children (McAllister et al. 2012).

Speaking of **cultural heritage**, Ljubljana residents value the old town the most: 87% of respondents consider it very or extremely valuable (5.2), confirming that it is a hotspot of historical sites with a high cultural value (Tiran 2017). The neighbourhood green space (3.6) is found to have the lowest value among the types of urban green, also with statistically significant difference to some other types. The shopping malls (2.0), on the other hand, is rated the least valuable by respondents, with 53% going so far as to call it insignificant.

Table 2: The results of the ANOVA test across types of cultural ecosystem services.

		Sum of Squares	df	Mean Square	F	Significance
Recreation and sport	Between Groups	880.923	8	110.115	66.310	.000
	Within Groups	1487.900	896	1.661		
	Total	2368.822	904			
Education	Between Groups	578.466	8	72.308	38.095	.000
	Within Groups	1691.199	891	1.898		
	Total	2269.666	899			
Aesthetics	Between Groups	257.916	8	32.239	22.842	.000
	Within Groups	1266.040	897	1.411		
	Total	1523.956	905			
Relaxation	Between Groups	358.628	8	44.829	46.425	.000
	Within Groups	866.153	897	.966		
	Total	1224.781	905			
Natural heritage	Between Groups	587.392	8	73.424	42.479	.000
	Within Groups	1543.518	893	1.728		
	Total	2130.910	901			
Cultural heritage	Between Groups	567.881	8	70.985	41.188	.000
	Within Groups	1530.409	888	1.723		
	Total	2098.290	896			
Sense of place	Between Groups	264.135	8	33.017	19.234	.000
	Within Groups	1543.230	899	1.717		
	Total	1807.366	907			
Stimulating inspiration	Between Groups	150.748	8	18.843	9.994	.000
	Within Groups	1689.447	896	1.886		
	Total	1840.194	904			
Spirituality	Between Groups	335.667	8	41.958	20.225	.000
	Within Groups	1856.756	895	2.075		
	Total	2192.424	903			
Shopping and hospitality services	Between Groups	818.237	8	102.280	55.943	.000
	Within Groups	1643.617	899	1.828		
	Total	2461.854	907			

Table 3: The results of the ANOVA test across types of cultural ecosystem services (shopping malls and the old town excluded).

		Sum of Squares	df	Mean Square	F	Significance
Recreation and sport	Between Groups	276.219	6	46.037	29.909	.000
	Within Groups	1071.311	696	1.539		
	Total	1347.531	702			
Education	Between Groups	221.825	6	36.971	18.042	.000
	Within Groups	1420.032	693	2.049		
	Total	1641.857	699			
Aesthetics	Between Groups	62.459	6	10.410	7.747	.000
	Within Groups	935.248	696	1.344		
	Total	997.707	702			
Relaxation	Between Groups	15.462	6	2.577	3.845	.001
	Within Groups	466.532	696	.670		
	Total	481.994	702			
Natural heritage	Between Groups	20.688	6	3.448	1.918	.075
	Within Groups	1243.795	692	1.797		
	Total	1264.484	698			
Cultural heritage	Between Groups	31.958	6	5.326	2.826	.010
	Within Groups	1296.626	688	1.885		
	Total	1328.584	694			
Sense of place	Between Groups	17.275	6	2.879	1.721	.113
	Within Groups	1167.525	698	1.673		
	Total	1184.800	704			
Stimulating inspiration	Between Groups	15.915	6	2.653	1.447	.194
	Within Groups	1274.284	695	1.834		
	Total	1290.199	701			
Spirituality	Between Groups	46.761	6	7.793	3.433	.002
	Within Groups	1577.627	695	2.270		
	Total	1624.387	701			
Shopping and hospitality services	Between Groups	185.804	6	30.967	15.609	.000
	Within Groups	1384.783	698	1.984		
	Total	1570.587	704			

Table 4: The effect size of the space types across cultural ecosystem services.

	Eta Squared (η^2)	
	all types	non-urban green excluded
Recreation and sport	0.372	0.205
Education	0.255	0.135
Aesthetics	0.169	0.063
Relaxation	0.293	0.032
Natural heritage	0.276	0.016
Cultural heritage	0.271	0.024
Sense of place	0.146	0.015
Stimulating inspiration	0.082	0.012
Spirituality	0.153	0.029
Shopping and hospitality services	0.332	0.118

In terms of **sense of place**, indicating to evoke the most emotions (Gottwald 2022), green spaces on the riverbank are rated the highest (4.5). This is in line with several researches so far, as they report a strong sense of place associated with different inland blue space environments (Plieninger et al. 2018; Grace et al. 2023; Grzyb 2024). However, the differences between the types are among the smallest, except for the shopping malls (2.6). If we exclude both non-urban green types from the analysis, the differences are not statistically significant; however, the old town scored very high in this regard.

The results are very similar regarding **stimulating inspiration**. Respondents are most inspired by sports facilities (4.3), where they can practice a variety of sports activities. It is the variety of facilities that attracts visitors in large numbers (Ichsan et al. 2019). Very closely followed by other types, without statistically significant differences; once more, the least inspiration is found in shopping malls (2.9). Once again, with the exclusion of non-urban green types from the analysis, the effect of space type becomes insignificant.

In terms of **spirituality**, the differences are slightly bigger. Respondents are most attracted to the green spaces along the riverbanks (4.1), which is in line with the several researches, for example, urban residents have reported that walking beside rivers and lakes can provide spiritual healing (Dou et al. 2017; Smith et al. 2021). They are followed by small city parks and playgrounds (3.8 each), while shopping malls unsurprisingly receive the lowest rating (1.8). With non-green categories excluded, eta squared only indicates the small effect (0.03).

In terms of **shopping and hospitality**, shopping malls received the highest score (4.8). They are followed also by the old town (3.9). The highest score among the urban green spaces was attributed to sport facilities (3.5), which form a homogenous subset from this point of view and also seem to offer some of this services. The other types of urban green spaces considered scored much lower in this category. Research in recreational shopping typically emphasises the emotional worth of shopping and the pleasure realized from the activity. Such consumers of all ages spend more time in shopping malls than anywhere else except home, work and school (Bäckström 2006). On the contrary, some authors argue that shopping tends to be more stressful for consumers oriented towards traditional outdoor recreation (Albrecht et al. 2017).

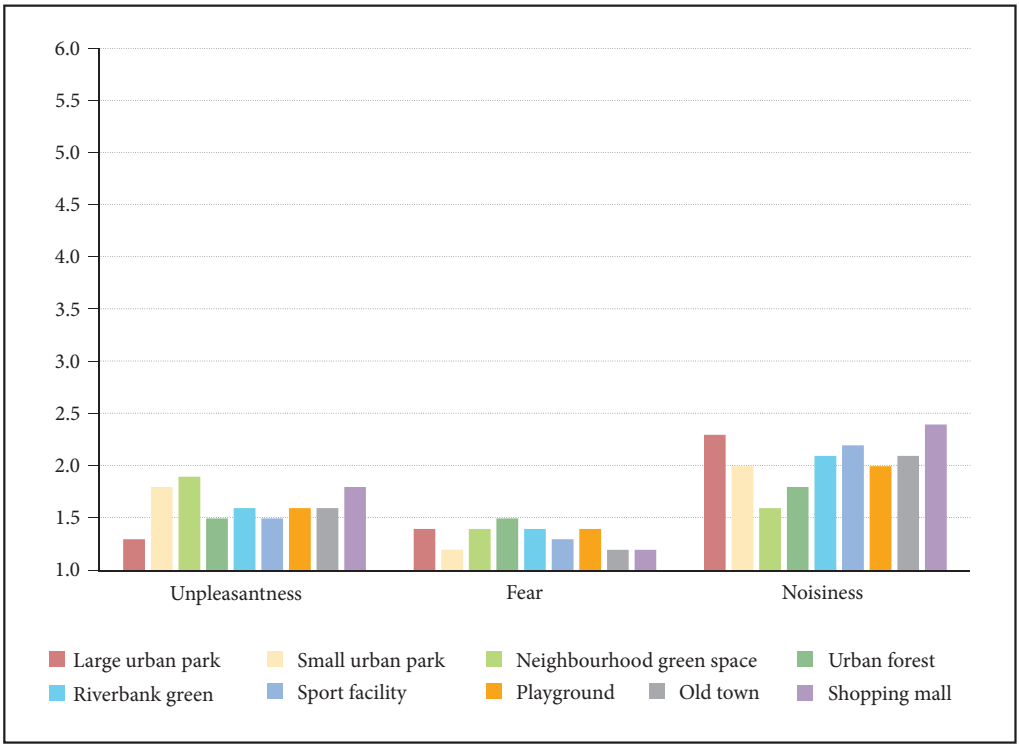

Figure 3: The average cultural ecosystem disservices' values across types of areas.

For all cultural ecosystem disservices (unpleasantness, fear, noisiness), the differences across the types were small (Figure 4) but statistically significant (Table 5). If we limit the analysis to urban green spaces, the differences remain significant and even bigger, except for fear, where they became insignificant (Table 6). In all cases, the effect size is small (Eta Squared below 0.06; Table 7).

Respondents generally do not see any of the studied disservices as problematic. From the viewpoint of **unpleasantness**, the lowest score was given to the large city park (1.3), with as many as 73% rating unpleasantness as negligible, while neighbourhood green spaces (1.9), small urban park and shopping mall (1.8) received the highest score, but still relatively low. However, a deeper insight to the results of the individual survey spaces show bigger differences within certain types (e.g., ranging from 1.3 to 2.2 for neighbourhood green space), suggesting that these results can be very sensitive to a case study selection.

The feeling of **fear** received similar scores across all types with *post hoc* tests showing statistically insignificant differences between individual types, ranging from 1.2 to 1.5. This confirms the image of Ljubljana as a safe city (Meško et al. 2008) and this does not seem to depend on location. Nevertheless, we speculate that the levels of fear in the nighttime could be higher and also with a higher differentiation between types. The highest value (1.5) is achieved by the urban forest, which is consistent with the findings of other studies that urban inhabitants are more afraid of »wild« nature (Tzoulas et al. 2007; Hofmann et al. 2012).

Table 5: The results of the ANOVA test across types of cultural ecosystem disservices.

		Sum of Squares	df	Mean Square	F	Significance
Unpleasantness	Between Groups	27.160	8	3.395	3.856	.000
	Within Groups	789.709	897	.880		
	Total	816.870	905			
Fear	Between Groups	9.664	8	1.208	2.260	.022
	Within Groups	479.510	897	.535		
	Total	489.174	905			
Noisiness	Between Groups	47.607	8	5.951	4.532	.000
	Within Groups	1177.850	897	1.313		
	Total	1225.457	905			

Table 6: The results of the ANOVA test across types of cultural ecosystem disservices (shopping malls and the old town excluded).

		Sum of Squares	df	Mean Square	F	Significance
Unpleasantness	Between Groups	22.130	6	3.688	4.490	.000
	Within Groups	571.724	696	.821		
	Total	593.855	702			
Fear	Between Groups	3.798	6	.633	1.066	.382
	Within Groups	413.408	696	.594		
	Total	417.206	702			
Noisiness	Between Groups	33.322	6	5.554	4.359	.000
	Within Groups	886.672	696	1.274		
	Total	919.994	702			

Table 7: The effect size of the space types across cultural ecosystem disservices.

	Eta Squared (η^2)	
	all types	non-urban green excluded
Unpleasantness	0.033	0.037
Fear	0.020	0.009
Noisiness	0.029	0.036

Noise, however, is somewhat more problematic with bigger differences between the types. Surprisingly, the lowest noise pollution was given for green spaces in the neighbourhood (1.6), while the highest noise pollution was attributed to shopping malls (2.4). However, even there, a large percent of respondents (36%) rated the noise level as negligible. When interpreting these results, we must be aware that the noise has various sources (traffic, people, industry) and can be very »place-sensitive« (Tiran 2017).

Running ANOVA for overall scores (by summing all ecosystem services and disservices; see also Figure 4) show statistically significant differences between the types, also in case of excluding non-green spaces from the analysis (Table 8 and 9). However, in the latter case, the Eta squared indicates that differences are very small (Table 10).

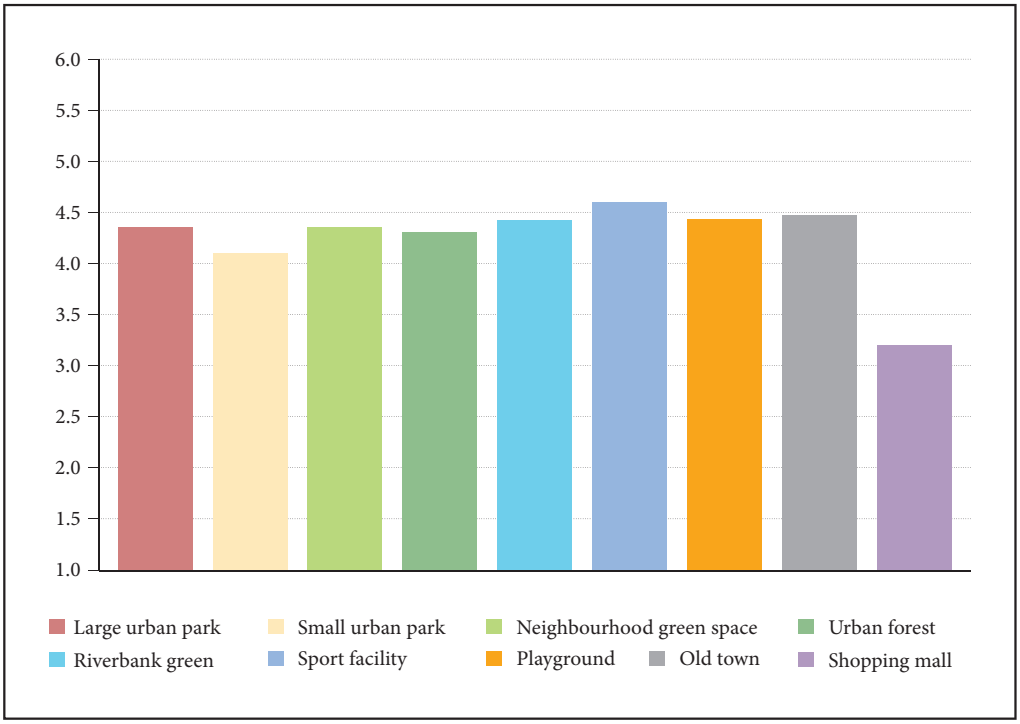

Figure 4: The overall mean scores of cultural ecosystem services and disservices across types of spaces.

Table 8: The results of the ANOVA test for overall scores of cultural ecosystem services and disservices.

	Sum of Squares	df	Mean Square	F	Significance
Between Groups	22649.923	8	2831.240	34.377	.000
Within Groups	71735.184	871	82.360		
Total	94385.108	879			

Table 9: The results of the ANOVA test for overall scores of cultural ecosystem services and disservices (shopping malls and the old town excluded).

	Sum of Squares	df	Mean Square	F	Significance
Between Groups	2248.990	6	374.832	4.488	.000
Within Groups	56375.609	675	83.519		
Total	58624.600	681			

Table 10: The effect size of the space types for overall scores of cultural ecosystem services and disservices.

	Eta Squared (η^2)	
	all types	non-urban green excluded
Overall score	0.240	0.038

5 Conclusion

The purpose of the research, executed in the city of Ljubljana, was to identify how cultural ecosystem services are valued by urban residents and what are the key differences between selected types of spaces.

The results show that the differences between types of urban green spaces in terms of the perceived value of their cultural ecosystem services do exist but they are generally smaller than expected. Overall, sports facilities received the highest mean score (4.6), with majority of respondents rating them exceptionally valuable for recreation and sports (5.4). Two non-urban green types performed very differently: shopping malls had far the lowest overall score (3.2), while the old town had the second highest one (4.5).

Urban forests did not score as well as expected. The results are somewhat surprising because urban forests are a type of space most similar to a natural environment. This fact also contrasts with the findings in the literature, which considers urban forests to be the type with the highest number of ecosystem services. A possible explanation could be that people are being increasingly alienated from »untamed« nature and seem to feel more comfortable in more urbanised environments.

The fact that shopping malls scored quite poorly on most aspects do not support understanding shopping as a recreational activity, even if people sometimes have to walk considerable distances to do so. On the other hand, promoting old towns as spaces for leisure seems to make sense because they possess numerous cultural ecosystem services, especially regarding aesthetics and cultural heritage.

We should also note some limitations of the research. As this questionnaire was used for the first time and respondents did not think of this topic before, the survey results could have certain measurement error, related to coping with the cognitive demands of attitude measures in surveys, also known as »satisficing« (Krosnick 1991). This could also explain somehow small differences between the types. Furthermore, the results could be sensitive to the case study selection and microlocation of field surveying.

The results presented in this study could contribute to the understanding and recognition of the concept of cultural ecosystem services. However, further testing of the methodology is needed, also in other types of cities according to size, population density and quantity and diversity of urban green spaces. As the research was executed before covid-19, it would make sense to repeat the research also in post-pandemic times to test the presumption of increased importance of urban green spaces (Noszczyk et al. 2022). Future studies should also investigate services and disservices in indoor recreational spaces, such as gyms and fitness centres and analyse the impact of services and disservices on subjective well-being. Our findings have important implications for stimulating active and healthy lifestyles and encouraging recreation not only in urban green spaces and natural environments, but also in other urban public spaces.

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1 Focus and scope

The *Acta geographica Slovenica* journal is issued by the ZRC SAZU Anton Melik Geographical Institute, published by the ZRC SAZU Založba ZRC, and co-published by the Slovenian Academy of Sciences and Arts.

Acta geographica Slovenica publishes original research articles 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, Eastern, and Southeastern Europe.

Articles 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, students, and others who are studying or applying geography.

The journal is indexed in the following bibliographic databases: Clarivate Web of Science (SCIE – Science Citation Index Expanded; JCR – Journal Citation Report/Science Edition), Scopus, ERIH PLUS, Directory of Open Access Journals (DOAJ), GEOBASE Journals, Current Geographical Publications, EBSCOhost, Georef, FRANCIS, SJR (SCImago Journal & Country Rank), OCLC WorldCat, Google Scholar, and CrossRef.

2 Types of articles

Unsolicited or invited original research articles and review articles are accepted. Articles and materials or sections of them should not have been previously published or be under consideration for publication elsewhere. The articles 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 articles and present a special topic, with an introduction by the (guest) editors. The introduction briefly presents the topic, summarizes the articles, and provides important implications.

4 Peer-review process

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

5 Publication frequency

Acta geographica Slovenica is published three times a year.

6 Open-access policy

This journal provides immediate open access to the full-text of articles at no cost on the principle of open science, which makes research freely available to the public. There is no article processing fee (Article Processing Charge) charged to authors.

Digital copies of the journal are stored by the repository of ZRC SAZU and the digital department of the Slovenian national library NUK, dLib.

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 an article, please read the details on the journal's focus and scope, publication frequency, privacy statement, history, peer-review process, open-access policy, duties of participants, and publication ethics. See also the latest version of the author guidelines online. All the materials are available at https://ags.zrc-sazu.si.

1 Article structure

Research articles must be prepared using the journal's template (available at https://ags.zrc-sazu.si) and contain the following elements:

- **Title:** this should be clear, short, and simple.
- **Information about author(s):** submit names (without academic titles), affiliations, ORCiDs, and e-mail addresses through the online submission system (available at https://ags.zrc-sazu.si).
- **Highlights**: authors must provide 3–5 highlights in the form of bullets. This section must not exceed 400 characters, including spaces.
- **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.
- **Keywords:** include up to seven informative keywords. Start with the research field and end with the place and country.
- **Main text:** the main text must not exceed 30,000 characters, including spaces (without the title, affiliation, abstract, keywords, highlights, reference list, and tables). Do not use footnotes or endnotes. Divide the article 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 articles 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 articles (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 the statistical methods of meta-analysis.
- **Literature review:** use subheadings to indicate the content of the various subsections. Possible structure: methodological approaches, models or theories, the extent of support for a given thesis, studies that agree with one another versus studies that disagree, chronological order, and geographical location.
- **Conclusions:** provide the implications of the findings and your interpretations (separate from facts), identify unresolved questions, summarize, and draw conclusions.

– **Acknowledgments:** use when relevant. In this section, authors can specify the contribution of each author.
– **Reference list:** see the guidelines below.

2 Article submission

2.1 Open journal system

Author(s) must submit their contributions through the *Acta geographica Slovenica* Open Journal System (OJS; available at https://ags.zrc.sazu.si) using the Word document template (available at https://ags.zrc.sazu.si).

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

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

Do not use contractions or excessive abbreviations. Use plain text, with sparing use of **bold** and *italics* (e.g., for non-English words). 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 proofreading or reject the article. See the section on the peer-review process (available at https//ags.zrc-sazu.si) for details. Author(s) may suggest reviewers when submitting an article.

2.2 Language

Articles are published in English. All articles have English and Slovenian abstracts.

Articles can be submitted in English or Slovenian.

Authors must take care to produce a high-quality English text. In the case of poor language, the article must be proofread/translated. In such a case, the translation or copyediting costs are borne by the author(s) and must be paid before layout editing. If authors are not Slovene native speakers, Slovenian abstracts are prepared by the editorial board.

2.3 Graphic file submission

Graphic files (figures) need to be submitted to the OJS packed in a single zip file not exceeding 50 MB. Multiple zip files can be uploaded if needed. See chapter 6 for details on how to prepare figures.

3 In-text citation

In-text citations should include the last name of the author(s) or the name of the publisher and the year of publication. Arrange citations by year of publication; for example: (Melik 1955; Melik et al. 1963; Gams 1982a; Gams 1982b; United Nations 1987; Royal Australian … 1988; Ford and Williams 2007). For references with more than two authors, cite only the first, followed by et al.: (Melik et al. 1956). Give page numbers only for direct quotations, for example: Perko (2016, p. 25) states: »Hotspots are …« For indirect citations, use this format: (Gunn 2002, cited in Matei et al. 2014).

When presenting publicly archived data, such as statistical and spatial data, describe the name of the dataset, the time frame, and the data provider in the main text only (without citation), for example: »The

2000–2020 population data used in the analysis were provided by Eurostat« If the statistical data were published as a report, cite the document, for example: (European Commission … 2023).

When citing legal sources such as legislative acts, white papers, etc., provide the short formal title and the year, for example: »The European Commission's White paper on transport published in 2011 sets out ten strategic goals for a competitive and resource-efficient transport system.«

4 References

All references in the reference list must be cited in the text. 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., added to the year of publication: (1999a, 1999b). In case there are more than seven authors, list the first seven followed by et al.

Examples of references are given below. The use of »gray literature« is strongly discouraged.

Authors can use the Zotero and Endnote AGS Style templates, which are available in the Article submission section on the https://ags.zrc-sazu.si.

4.1 Articles

Last Name1, A. B., Last Name2, C. D. Year: Title. *Journal Name* Volume-Issue. https://doi.org/…

- Breg Valjavec, M., Janža, M., Smrekar, A. 2018: Environmental risk resulting from historical land degradation in alluvial plains considered for dam planning. *Land Degradation & Development* 29-11. https://doi.org/10.1002/ldr.3168
- Kladnik, D., Kruse, A., Komac, B. 2017a: Terraced landscapes: An increasingly prominent cultural landscape type. *Acta geographica Slovenica* 57-2. https://doi.org/10.3986/AGS.4770
- Kladnik, D., Šmid Hribar, M., Geršič, M. 2017b: Terraced landscapes as protected cultural heritage sites. *Acta geographica Slovenica* 57-2. https://doi.org/10.3986/AGS.4628
- Ni, J., Jin, J., Wang, Y., Li, B., Wu, Q., Chen, Y., Du, S. et al. 2024: Surface ozone in global cities: A synthesis of basic features, exposure risk, and leading meteorological driving factors. *Geography and Sustainability* 5-1. https://doi.org/10.1016/j.geosus.2023.09.008
- Unangst, M. 2023: (De)Colonial historical geography and historical GIS. *Journal of Historical Geography* 79. https://doi.org/10.1016/j.jhg.2022.12.003
- Van de Kerk, G., Manuel, A. R. 2008: A comprehensive index for a sustainable society: The SSI – The Sustainable Society Index. *Ecological Economics* 66-2,3. https://doi.org/10.1016/j.ecolecon.2008.01.029
- Yang, D.-H., Goerge, R., Mullner, R. 2006: Comparing GIS-based methods of measuring spatial accessibility to health services. *Journal of Medical Systems* 30-1. https://doi.org/10.1007/s10916-006-7400-5

4.2 Books

Last Name1, A. B., Last Name2, C. D. Year: Book title. *Book Series Title* with Number. Publisher. https://doi.org/…

If the book is edited by editors, add '(eds.)' before the year of publication.

- Achino, K. F., Velušček, A. 2022: The lake-dwelling phenomenon. *E-Monographiae Instituti Archaeologici Sloveniae* 13. Založba ZRC. https://doi.org/10.3986/9789610506560
- Gams, I. 2004: Kras v Sloveniji v prostoru in času. Založba ZRC.
- Hall, T., Barrett, H. 2018: Urban geography. Routledge. https://doi.org/10.4324/9781315652597
- Knox, P., Marston, S. 2015: Human geography: Places and regions in global context. Pearson.
- Luc, M., Somorowska, U., Szmańda, J. B. (eds.) 2015: Landscape analysis and planning. *Springer Geography*. Springer. https://doi.org/10.1007/978-3-319-13527-4
- Marshall, T. 2016: Prisoners of geography: Ten maps that explain everything about the World. *Politics of Place*. Scribner.
- Mihelič Pulsipher, L., Pulsipher, A., Johansson, O. 2019: World regional geography: Global patterns, local lives. W. H. Freeman.

4.3 Chapters of books or proceedings

Last Name1, A. B., Last Name2, C. D. Year: Chapter title. In: Book Title. *Book Series Title* with Number. Publisher. https://doi.org/…

- Griffin, A. L. 2018: Cartography, visual perception and cognitive psychology. In: The Routledge Handbook of Mapping and Cartography. Routledge. https://doi.org/10.4324/9781315736822
- Solem, M., Boehm, R. 2015: A research coordination network for geography education. In: EUGEO Budapest 2015: Congress Programme and Abstracts. Hungarian Geographical Society.
- Stethem, C. 2013: Avalanches. In: Encyclopedia of Natural Hazards. Springer. https://doi.org/10.1007/978-1-4020-4399-4_7
- Zorn, M., Ferk, M., Lipar, M., Komac, B., Tičar, J., Hrvatin, M. 2020: Landforms of Slovenia. In: The Geography of Slovenia: Small But Diverse. *World Regional Geography Book Series*. Springer. https://doi.org/10.1007/978-3-030-14066-3_3

4.4 Reports, theses, dissertations, and other materials with authors

Last Name1, A. B., Last Name2, C. D. Year: Title. *Type of document*. Publisher. https://doi.org/…

- Davies, G. 2017: The place of data papers: Producing data for geography and the geography of data production. *Blog post*. Geo: Geography and Environment.
- Easterbrook, D. J. 1976: Geologic map of western Whatcom County, Washington (1-854-B). *1:62,500 map*. United States Geological Survey.
- Fležar, U., Hočevar, L., Sindičić, M., Gomerčić, T., Konec, M., Slijepčević, V., Bartol, M. et al. 2022: Surveillance of the reinforcement process of the Dinaric - SE Alpine lynx population in the lynx-monitoring year 2020–2021. *Technical report*. LIFE Lynx.
- Hawking, S. 1966: Properties of expanding universes. *Ph.D. thesis*. University of Cambridge. https://doi.org/10.17863/CAM.11283
- Hrvatin, M. 2016: Morfometrične značilnosti površja na različnih kamninah v Sloveniji. *Ph.D. thesis*. Univerza na Primorskem.
- Šifrer, M. 1997: Površje v Sloveniji. *Technical report*. Geografski inštitut Antona Melika ZRC SAZU.

4.5 Sources without authors

Use in-text citations only (see Chapter 3). If sources need to be listed in the references use the following style: Publisher Year: Title. *Type of document*. https://doi.org/…

- European Commission, Eurostat 2023: Quality report on national and regional accounts. *Report*. https://doi.org/10.2785/825704
- Geodetska uprava Republike Slovenije 1998: Državna topografska karta Republike Slovenije 1 : 25.000 (Brežice). *1:25,000 map*.
- Royal Australian Survey Corps 1988: Australia 1:50 000 topographic survey (Tamborine, Queensland). *1:50,000 map*.
- United Nations 1987: Report of the World Commission on Environment and Development: Our common future. *Report*.
- United States Geological Survey, Earth Resources Observation and Science Center 2018: Shuttle Radar Topography Mission (SRTM) 1 Arc-Second Global. *Dataset*. https://doi.org/10.5066/F7PR7TFT

5 Tables

Number all tables in the article uniformly and provide their own titles. The number and the title text are separated by a colon, and the title ends with a period. A table title is located above the corresponding table. Examples:

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

Tables must be indicated in the main text in parentheses, for example: (Table 1), or as a part of the sentence, for example »… as can be seen in Table 1.« Tables should contain no formatting and must be inserted in the article file.

6 Figures

Figures encompass different graphic presentations used in the article: photography, graphs, illustrations, maps, etc.

Number all figures in the article uniformly and provide their own titles. The number and the title text are separated by a colon, and the title ends with a period. A figure title is located below the corresponding figure. Example:

- Figure 1: Location of measurement points along the glacier.

Figures must be indicated in the main text in parentheses, for example: (Figure 1), or as a part of the sentence, for example »… as can be seen in Figure 1.«

Figures should be exactly 134 mm wide (one page) or 64 mm wide (half page, one column), and up to 200 mm high.

Titles should appear in a caption only. Save colors in CMYK. Use Times New Roman font with a minimum size of 6.

Figures must be submitted as separate files. Multiple graphic files should be uploaded in one zip file. Figures should also be inserted in the main text file in order to ease the review process.

Regardless of the graphic/cartographic software used, save or export figures to the following formats:

- jpg or tiff file for regular photos (use a minimum of 300 dpi),
- xlsx file for graphs made with MS Office Excel,
- pdf or similar common files for maps and illustrations with vector drawings and/or text (embed the font if possible). See chapter 6.3 for details.

If the graphic files cannot be uploaded according to the guidelines, consult the editorial board (ags@zrc-sazu.si) in advance.

To make anonymous peer review possible, the authorship of figures can be added by authors at a later (copyediting) stage, after the review has been completed.

6.1 Photos

Photos must be in raster format with a resolution of at least 300 dpi, preferably in jpg or tiff format.

Figures containing a screenshot should be prepared at the highest possible screen resolution. A figure can be made using Print Screen, and the captured screen is pasted to the selected graphic program (e.g., Paint) and saved as a tiff or jpg file. The size of the image or its resolution must not be changed.

6.2 Graphs

Graphs should be made using MS Excel on separate sheets and accompanied by data.

6.3 Maps and illustrations

Maps should be informative and prepared according to the journal size limitations (see general guidelines defined in chapter 6). Use Times New Roman for the legend (size 8) and colophon (size 6). List scale, source, and copyright in the colophon. List the authors of the content and authors of the maps if needed. Write the colophon in English. Use a graphic scale if possible.

Example of the colophon structure:
Content by: Name Surname
Map by: Name Surname
Source: Institution Year
© Year, Copyright holder

Maps should be submitted in an editable form if possible so that minor errors can be corrected even in the final stages of article production. **The preferred submission file is pdf**. As an exception, maps can be produced in digital raster form with at least 300 dpi resolution, preferably in jpg or tiff format.

Please, pay attention when exporting maps from these software packages:

- if using QGIS, ESRI ArcGIS Pro or similar, maps should be exported as a pdf file,
- if using Gimp, Inkscape, CorelDraw, Adobe Illustrator or similar, two separate files should be prepared: the original software file (e.g. cdr if using CorelDraw) and a pdf file,
- if using ESRI ArcGIS Desktop (ArcMap) with raster layers and vector layers (e.g., a geotiff file for shaded relief and a shp file for roads), three files should be exported and submitted: a pdf or an ai file with all the vector content without transparency (polygons, lines, points, legend, colophon, labels, etc.), a tiff file with a raster background, and a jpg file with all of the content (vector and raster elements) together showing the final version of the map; see an example of the correct file structure (available at https://ojs.zrc-sazu.si/ags/libraryFiles/downloadPublic/14) for submitting a map created with ESRI ArcGIS Desktop.

Illustrations should be prepared according to the journal size limitations (see general guidelines defined in chapter 8). Use Times New Roman font size 8. **The preferred submission file is pdf**. As an exception, illustrations can be produced in digital raster form with at least 300 dpi resolution, preferably in jpg or tiff format.

7 Supplementary materials

Authors are encouraged to make the data (input data, results, maps, spatial data, tabular data, etc.) used or generated in the preparation of the article published in *Acta geographica Slovenica* publicly available in a recognized online repository and to provide the editorial board with a link.

The publication of the data in the repository must indicate that the data are part of the published article. The article must be properly cited when using the data.

SUBMISSION PREPARATION CHECKLIST

As part of the submission process, authors are required to check off their submission's compliance with all of the following items, and submissions may be returned to authors who do not adhere to these guidelines.

- I, the corresponding author, declare that this manuscript is original and is therefore based on original research, done exclusively by the authors. All information and data used in the manuscript were prepared by the authors or the authors have properly acknowledged other sources of ideas, materials, methods, and results.
- Authors confirm that they are the authors of the submitting article, which is under consideration to be published (print and online) in the journal *Acta geographica Slovenica* by Založba ZRC, ZRC SAZU.
- All authors have seen and approved the article being submitted.
- The submission has not been previously published, nor it is under consideration in another journal (or an explanation has been provided in Comments to the Editor). Authors have disclosed any prior posting, publication or distribution of all or part of the manuscript to the Editor.
- Upon publishing an article in the journal, the authors agree to license non-exclusive copyrights to ZRC SAZU (Založba ZRC): they retain the copyright in the scope that enables them to continue to use their work, even by publishing it in one of the personal or institutional repositories before the publication of the article in the journal.
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- Permission has been obtained for the use (in printed and electronic format) of copyrighted material from other sources, including online sources. Restrictions on the transfer of copyright on this material have been clearly indicated.
- All the necessary permits to work with people have been obtained in the research related to the article (in accordance with the applicable laws and institutional guidelines and approved by the relevant institutions).
- The journal policies and guidelines have been reviewed and followed.
- The metadata (title, abstract, keywords, authors, affiliation, ORCiD, etc.) are provided in English (Slovenian authors must also provide the metadata in Slovenian).
- The list of authors is complete. Failure to do so may result in co-authors not being listed on the article at publication.
- 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).
- The article has been checked for spelling and grammar.
- Figures are provided as separate graphic files: editable vector format (e.g., cdr, ai, pdf) for maps and illustrations; jpg or tiff for photographs; xlsx for graphs.
- Tables are placed in the Word file with text in the appropriate place.
- The reference list was prepared following the guidelines.
- All references in the reference list are cited in the text.
- Where available, URLs and DOI numbers for references are provided.
- Graphic files are in one zip file.
- Authors agree that any costs of English proofreading are borne by the author(s). No additional costs are associated with the submission.
- The instructions for ensuring a double-blind review have been followed.

ACTA GEOGRAPHICA SLOVENICA EDITORIAL REVIEW FORM

This is the review form for editorial review (version 15) of an article submitted to the AGS journal.

This is an original scientific article.
(The article is original and the first presentation of research results with the focus on methods, theoretical aspects or a case study.)

- Yes
- No

The article follows the standard IMRAD/ILRAD scheme.

- Yes
- No

The article's content is suitable for reviewing in the AGS journal.
(The article is from the field of geography or related fields of interest, the presented topic is interesting for the readers of *Acta geographica Slovenica* and well presented. In case of a negative answer, add comments below.)

- Yes
- No

Editorial notes regarding the article's content.

The reference list is suitable (the author cites previously published articles with similar topics from other relevant geographic scientific journals).

- Yes, the author cited previously published articles on a similar topic.
- No, the author did not cite previously published articles on a similar topic.

Notes to the editor-in-chief regarding previously published scientific work.

Is the language of the article appropriate and understandable?

RECOMMENDATION OF THE EDITOR

- The article is accepted and can be sent to the review process.
- Reconsider after a major revision (see notes).
- The article is rejected.

ACTA GEOGRAPHICA SLOVENICA REVIEW FORM

This is the *Acta geographica Slovenica* review form (version 8).

1 RELEVANCE

Are the findings original and is the article therefore a significant one?

- yes
- no
- partly

Is the article suitable for the subject focus of the AGS journal?

- yes
- no

2 SIGNIFICANCE

Does the article discuss an important problem in geography or related fields?

- yes
- no
- partly

Does it bring relevant results for contemporary geography?

- yes
- no
- partly

What is the level of the novelty of the research presented in the article?

- high
- middle
- low

3 ORIGINALITY

Has the article already been published or is it too similar to already published work?

- yes
- no

Does the article discuss a new issue?

- yes
- no

Are the presented methods sound and adequate?

- yes
- no
- partly

Do the presented data support the conclusions?

- yes
- no
- partly

4 CLARITY

Is the article clear, logical, and understandable?

- yes
- no

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

5 QUALITY

Is the article technically sound? (If not, the author should discuss with the Editorial Board [ags@zrc-sazu.si] for assistance.)

- yes
- no

Does the article take into account relevant current and past research on the topic?

- yes
- no

Propose amendments if no is selected:

Is the references list at the end of the article adequate?

- yes
- no

Propose amendments if no is selected:

Is the quoting in the text appropriate?

- yes
- no
- partly

Propose amendments if no is selected:

Which tables are not necessary?

Which figures are not necessary?

COMMENTS OF THE REVIEWER

Comments of the reviewer on the contents of the article:
Comments of the reviewer on the methods used in the article:

RECOMMENDATION OF THE REVIEWER TO THE EDITOR-IN-CHIEF

Please rate the article from 1 [low] to 100 [high] (this will NOT be presented to the author):
Personal notes of the reviewer to the editor-in-chief (this will NOT be presented to the authors):

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By submitting their articles or other contributions the authors and reviewers consent to the collection and processing of their personal data (e.g., name, surname and email address) for the purposes of effective communication, editing, and publication of articles or other contributions.

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JOURNAL HISTORY

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* (print ISSN 0373-4498, digital ISSN: 1408-8711). 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*.

Until 1976, the journal was published periodically, then once a year, twice a year from 2003, and three times a year since 2019.

The online version of the journal has been available since 1995. In 2013, all volumes of the magazine were digitized from the beginning of its publication to including 1994.

All articles of the journal are available free of charge in digital form on the journal website http://ags.zrc-sazu.si**.**

Those interested in the history of the journal are invited to read the article »The History of *Acta geographica Slovenica*« in volume 50-1.

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