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LANDSCAPE MACROTYPOLOGIES AND MICROTYPOLOGIES OF SLOVENIA

Drago Perko, Rok Ciglič, Mauro Hrvatin

There are four groups of landscape types in Slovenia: Alpine landscapes (top left), Pannonian landscapes (top right), Dinaric landscapes (bottom right), and Mediterranean landscapes (bottom left). These have a decisive influence on the microtypification of Slovenia and its parts.

V Sloveniji so štiri skupine pokrajinskih tipov: alpske pokrajine (levo zgoraj), panonske pokrajine (desno zgoraj), dinarske pokrajine (desno spodaj) in sredozemske pokrajine (levo spodaj), ki odločilno vplivajo na mikrotipizacijo Slovenije in njenih delov.

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Drago Perko[1], Rok Ciglič[1], Mauro Hrvatin[1]

Landscape macrotypologies and microtypologies of Slovenia

ABSTRACT: This work discusses the historical development of landscape typologies of Slovenia, focusing on methodology, terminology, criteria for the division of territory, and landscape type hierarchy. It presents all five macrotypologies of Slovenia created between 1946 and 2013, Slovenia's classification in nine selected macrotypologies of Europe produced between 1995 and 2016, and eight examples of microtypologies of smaller areas of Slovenia made between 1985 and 2020. It compares and evaluates similar typologies. If, in addition to the landscape typology, a geographical regionalization was also produced, common points are sought between the two. The macrotypologies and microtypologies of Slovenia are accompanied by an original and updated map.

KEY WORDS: regional geography, landscape, landscape type, landscape typification, landscape typology, landscape diversity, Slovenia, Europe

Pokrajinske makrotipologije in mikrotipologije Slovenije

POVZETEK: Obravnavamo zgodovinski razvoj pokrajinskih tipologij Slovenije predvsem glede na metodologijo, terminologijo, kriterije delitev ozemlja in hierarhijo pokrajinskih tipov. Predstavljamo vseh pet obstoječih makrotipologij Slovenije, izdelanih med letoma 1946 in 2013, uvrstitev Slovenije v 9 izbranih makrotipologij Evrope, izdelanih med letoma 1995 in 2016, in 8 primerov mikrotipologij manjših območij Slovenije, izdelanih med letoma 1985 in 2020. Istovrstne tipologije med sabo primerjamo in vrednotimo. Če je avtor hkrati s pokrajinsko tipologijo izdelal tudi geografsko regionalizacijo, iščemo njune skupne točke. Makrotipologije in mikrotipologije Slovenije so opremljene z izvirnim in posodobljenim zemljevidom.

KLJUČNE BESEDE: regionalna geografija, pokrajina, pokrajinski tip, pokrajinska tipizacija, pokrajinska tipologija, pokrajinska raznolikost, Slovenija, Evropa

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[1] Research Centre of the Slovenian Academy of Sciences and Arts, Anton Melik Geographical Institute, Ljubljana, Slovenia
drago.perko@zrc-sazu.si (ORCID: https://orcid.org/0000-0002-2568-9268), rok.ciglic@zrc-sazu.si (ORCID: https://orcid.org/0000-0003-3517-3780), mauro.hrvatin@zrc-sazu.si (ORCID: https://orcid.org/0000-0002-6021-8736)

1 Introduction

The Anton Melik Geographical Institute at the Slovenian Academy of Sciences and Arts Research Center (hereinafter: the institute) has been dealing with Slovenian landscapes, their types, typifications, and typologies ever since its foundation in 1946, largely as part of its Regional Geography Department and with strong support from the Geographic Information Systems and Thematic Cartography departments. It was especially intensively involved in this area after Slovenia's independence in 1991, when it produced seminal geographical volumes on Slovenia with government financial support in the 1990s. Landscapes and their types feature prominently in these works.

This article, which focuses on a systematic overview of landscape typologies of Slovenia, coincides with the seventy-fifth anniversary of the institute, the thirtieth anniversary of Slovenia's independence, and, what is most relevant to this article, the production of the first landscape typology of Slovenia. It was published seventy-five years ago by the academy member Anton Melik (Melik 1946), who also initiated the institute's foundation and was its first director.

The introductory section primarily describes the development of landscape studies in Slovenia and especially at the institute, where focused research in this area has been conducted in Slovenia ever since its establishment. The second section presents and compares all five geographical macrotypologies for all of Slovenia produced by Slovenian geographers between 1946 and 2013. The third section establishes which landscape types of the nine European macrotypologies Slovenia belongs to and how these macrotypologies overlap with Slovenian ones in Slovenian territory. The fourth section presents and compares eight examples of landscape microtypologies (i.e., typologies of small parts of Slovenia), which the institute's researchers produced between 1985 and 2020. The conclusion provides an example showing how current landscape macrotypologies could be improved using state-of-the-art methods.

Certain older findings were updated and expanded, and some are published here for the first time. The reference list at the end is also very important because it provides an extensive overview of publications on geographical landscape typologies in Slovenia and abroad.

In countries as diverse as Slovenia, landscape typifications present a great challenge for researchers. In countries where they form part of official documents that specify financial obligations, they are important for most citizens. This also includes Slovenia.

1.1 Terminology

The main technical terms in landscape classification include *landscape typification*, *landscape typology*, and *landscape type* (from Lat. *typus* 'bas-relief, image, figure', Gr. *týpos* 'example, model'; Snoj 2016). They are combined here into a general definition: landscape typification is the process of classifying landscapes according to their characteristics into landscape types, and its result or final classification is a landscape typology.

Closely related to these are the terms *region* and *regionalization* (from Lat. *regiō* 'region, place, border'; Snoj 2016). They can be combined into the following definition: regionalization is the process of dividing territory into regions and their hierarchical classification.

Increasingly important is also the term *landscape diversity* (Perko, Hrvatin, and Ciglič 2017), which reveals how concentrated the interchange is between landscapes or landscape elements within a given spatial unit. It can also be expressed numerically using a landscape diversity index, which can be defined as the average (arithmetic mean) of the ratios between the number of types found (classes) and all types (classes) of landscape elements considered within a given spatial unit.

Its formula is:

$$\mathrm{LDI} = \frac{1}{S} \sum_{i=1}^{S} \frac{n_i}{N_i} = \frac{1}{S} \left(\frac{n_i}{N_i} + \ldots + \frac{n_s}{N_s} \right)$$

LDI = Landscape Diversity Index
S = number of landscape elements considered
N = number of all types (classes) of a given landscape element
n = number of types found (classes) of the same given landscape element

In Slovenian, the terms *pokrajina* 'region; landscape' and *regija* 'region' are usually synonymous, although sometimes the term *pokrajina* is used to refer to more natural or physical geographical spatial units, and the term *regija* is associated with more social or political geographical spatial units (Perko 1998a; Kladnik and Perko 1998).

The relationship between a landscape or region and a landscape type is as follows: every region belongs to a specific landscape type, and several regions can be part of the same landscape type. Landscape typification and landscape types are characterized by the principle of similarity, and geographical regionalization and regions are characterized by the principle of individuality.

Every landscape type can occur several times and separately, and so it is treated as a common noun phrase and hence not capitalized. In turn, every region occurs only once and is hence capitalized (Perko 1998b; Perko, Hrvatin, and Ciglič 2015). For example, a landscape type can be a *mountain range*, of which there are several in Slovenia and many more elsewhere around the globe, but there is only one mountain region in the world called *Julian Alps* (in Slovenia) and only one called *Andes* (in South America).

When dividing and combining regions and landscape types as part of geographical regionalization and landscape typification, they are hierarchically classified into several levels. Every region can be part of a larger region and divided into smaller regions. Similar applies to landscape types and other geographical units. Hence, a series of terms have developed: *macrounits* (e.g., *macroregion*) and *submacrounits* at the highest levels, *mesounits* (e.g., *landscape mesotype*) and *submesounits* at the middle levels, and *microunits* and *submicrounits* (e.g., *submicroregion*) at the lowest levels. These hierarchical terms are used by most typology authors presented in the second, third, and fourth sections below.

1.2 Landscape typologies around the world

Elsewhere around the world, landscape typologies and other landscape classifications are also related to several levels: global, regional, national, and local. Described in the articles are mainly the classification methods and their usage, and problems associated with data (e.g., Udvardy 1975; Belbin and McDonald 1993; Meeus 1995; Bailey 1996; Burrough et al. 2001; Olson et al. 2001; Bohn et al. 2003; Mücher et al. 2003, 2006, 2010; Leathwick, Overton, and McLeod 2003; Zhou et al. 2003; Wolock et al. 2004; Žiberna, Natek, and Ogrin 2004; Rivas-Marínez, Penas, and Díaz 2004a; 2004b; Hargrove and Hoffman 2005; Metzger et al. 2005; Wascher 2005; Bryan 2006; Jongman et al. 2006; Owen et al. 2006; Renetzeder et al. 2008; Romportl 2009; Van Eetvelde and Antrop 2009; Castillo-Rodríguez et al. 2010; Soto and Pintó 2010; Izakovičová 2014; Grondin et al. 2014; Romportl and Cerny 2014; Cullum et al. 2016; Mezősi 2016; Kozjek, Dolinar, and Skok 2017; see also Drozg et al. 2004; Simensen, Halvorsen, and Erikstad 2018; and Stupariu et al. 2021).

Landscape classifications around the globe are used for research, educational, economic, planning, and other purposes. Europe has adopted several measures for raising residents' awareness about the importance of landscapes (Wascher 2005). As early as 1996, the Council of Europe adopted the Pan-European Biological and Landscape Diversity Strategy (Council of Europe 1996), followed by the European Landscape Convention in 2000, which encourages member states to identify their landscapes (Van Eetvelde 2009; Dempsey and Wilbrand 2017). Based on this, Slovenia updated its 1998 classification of landscape types (Marušič, Ogrin, and Jančič 1998), entitling it *Regionalna razdelitev krajinskih tipov* (Regional Distribution of Landscape Types; Bratina Jurkovič 2008; Council of Europe 2007).

Several countries also use landscape classifications for official purposes at the national level; in addition to Slovenia (Perko, Hrvatin, and Ciglič 2015), this is also done in the UK (Warnock and Griffiths 2015) and Norway (Strand 2011), which also produced a map of landscape types at the local level for Nordland County (Erikstad, Uttakleiv, and Halvorsen 2015). The use of the map of Europe's biogeographical regions for the purposes of the Natura 2000 network is an example of official use of a landscape classification at the European level (Biogeographical regions … 2016).

With regard to landscape classifications that are used for official purposes, it is especially important that they be as accurate and objective as possible and that in producing them subjective definition of criteria and digitization and interpolation errors be avoided as much as possible (McMahon et al. 2004; Ellison 2010). However, many researchers are aware that subjectivity is inevitable (Loveland and Merchant 2004; Leathwick, Overton, and McLeod 2003; Natek and Žiberna 2004; Owen et al. 2006) because landscape classification is an abstraction (Bernert et al. 1997) that never captures all landscape factors (Zonneveld 1994). Sometimes the boundaries in a landscape are clear (Bailey 1996), but often they are defined arbitrarily

(Leathwick, Overton, and McLeod 2003) and subjectively regardless of the quality of the input data (Fňukalová and Romportl 2014). A common weakness of existing landscape classifications is also a poor description of how classification units are defined and classified (Loveland and Merchant 2004), even though a good description is imperative (Mücher et al. 2003; Bailey 2004; Erikstad et al. 2015; Lausch et al. 2015). Another common weakness observed in recent classifications is the omission of field mapping, resulting from the increasingly higher quality of digital data and modern software (Wieczorek and Migoń 2014). Classifications based on landscape stereotypes are considered especially poor (McMahon et al. 2004).

How landscape classifications should be tackled depends on concrete cases (Lu and Weng 2007), and some see the future primarily in enhanced evaluation of current landscape classifications with new quantitative methods that will either fully confirm a landscape typology produced or eliminate any weaknesses and improve it (Congalton 1991; Ciglič and Perko 2015).

We see the future of landscape typologies moving in two directions: toward evaluating, testing, and improving existing landscape typologies using modern tools, and toward producing completely new landscape typologies, while taking into account criteria similar to those for improving the existing typologies. An example of improving an existing landscape typology using modern tools and for a specific purpose is presented in the conclusion.

1.3 Studying Slovenian landscapes at the institute

Professionals outside Slovenia have not dealt with landscape typifications of Slovenia. They have only studied Slovenia at the level of Europe (Ciglič 2009) – that is, in a very generalized manner, which is discussed in the third section. Most studies of Slovenian landscapes and the landscape typologies produced have been concentrated at the geographical institute.

The institute's primary organizational unit specializing in Slovenian landscapes is the Regional Geography Department. It was formally founded on October 14th, 1994, which was relatively late considering that it was already mentioned in the institute's first charter, which its founder, the general assembly of the Slovenian Academy of Sciences and Arts, adopted on November 6th, 1948. According to the charter, the institute was to be divided into departments. Its Articles 5 and 6 specify that it can be divided into physical, human, and regional geography sections, as well as into further sections and subsections if needed. In addition, the charter defines research on Slovenian landscapes as one of the institute's main priorities (Natek and Perko 1999).

The first such section or unit, the Institute of Cartography, was established in 1952 and then renamed the Thematic Cartography Department on October 14th, 1994, when the institute was last reorganized. The Geographic Information Systems Department was also established as part of this reorganization. Without both of these departments, it is practically impossible to imagine contemporary research on landscapes and the publication of findings in this area. The institute currently has seven departments, a physical geography laboratory, a library, and a museum, which adds up to a total of ten units:

- The Physical Geography Department (since October 14th, 1994);
- The Human Geography Department (since October 14th, 1994);
- The Regional Geography Department (since October 14th, 1994);
- The Natural Hazards Department (since October 14th, 1994);
- The Environmental Protection Department (since October 14th, 1994);
- The Geographic Information Systems Department (since October 14th, 1994);
- The Thematic Cartography Department (since February 7th, 1952);
- The Physical Geography Laboratory (since April 18th, 2018);
- The Geographical Museum (since May 7th, 1946); and
- The Geographical Library (since September 1st, 1964).

The institute was named after Anton Melik in 1976, ten years after his death. Since 1981, it has been operating as part of the Slovenian Academy of Sciences and Arts' Research Center.

Its Regional Geography Department studies Slovenia as a whole and as part of Europe or the world and, most importantly, it explores Slovenian regions. The project has also carried out the largest Slovenian geographical project to date: it produced a volume on Slovenia's regional geography, which practically all geographers from Slovenian universities and research institutes contributed to. Work on the volume was completed as part of the first geographical project in Slovenia since 1993, when research in the country began to largely be funded through projects and programs approved by the Slovenian Research Agency. The funding for the project was approved in 1993 and it lasted three years, which even now continues to be the average duration of agency-funded projects. More general and long-term programs normally last six years.

Two research programs that also focused on landscape typifications have been carried out at the institute to date:

- The Regional Geography of Slovenia, which lasted from January 1st, 1999, to December 31st, 2003, and was headed by Drago Perko, focused entirely on studying Slovenian regions and landscapes;
- The Geography of Slovenia, which has been taking place since January 1st, 2004, and is headed by Blaž Komac, dedicates two of its five thematic sections to Slovenian landscapes: one in full and one in part.

Twelve research projects dealing with landscapes have been carried out so far:

- Completion of the Regional Geographical Volume on Slovenia, which was carried out from January 1st, 1993, to December 31st, 1995, and headed by Drago Perko, concluded with the publication of nine scholarly volumes and the book *Slovenija: pokrajine in ljudje* (Slovenia: Landscapes and People; Perko and Orožen Adamič 1998) for general audiences (Figure 1);
- The National Atlas of Slovenia, which was carried out from January 1st, 1993, to December 31st, 1995, and headed by Andrej Černe, concluded with the publication of *Geografski Atlas Slovenije* (Geographical Atlas of Slovenia; Figure 2) and *Nacionalni atlas Slovenije* (National Atlas of Slovenia), in both of which Slovenian landscapes play an important role;
- Cultural Landscapes of Slovenia, which lasted from November 1st, 1994, to December 31st, 1999, and was headed by Drago Perko, focused on cultural landscape elements; the two publications with the greatest impact were the multimedia *KulturAtlas Slowenien* (Culture Atlas of Slovenia) published as part of the German series *KulturAtlas Europa* (Aimée et al. 1996) and the scholarly volume *Kulturne pokrajine v Sloveniji* (Cultural Landscapes in Slovenia; Urbanc 2002);
- Geographical Microregionalization of Slovenia, which took place from January 1st, 1996, to December 31st, 2000, and was headed by Drago Perko, focused on state-of-the-art methods used in geographical regionalizations and typifications of small spatial units;
- Common Lands in Slovenia: Cultural Landscape between the Past and Future was carried out from September 1st, 2005, to August 31st, 2007; it was headed by Drago Perko and it explored common lands as an important landscape element of Slovenian regions;
- Determining Natural Landscape Types of Slovenia Using a Geographic Information System, carried out from May 1st, 2010, to April 30th, 2013, and headed by Drago Perko, established the effectiveness of modern geoinformation methods in landscape typifications;
- Terraced Landscapes in Slovenia as Cultural Values, carried out from July 1st, 2011, to June 30th, 2014, and headed by Drago Kladnik, dealt with the differences between cultural terraces in various Slovenia's landscape types, and it concluded with the book *Terasirane pokrajine* in Slovenian (Terraced Landscapes; Perko, Ciglič, and Geršič 2016), which later also appeared in an abridged English edition (Perko et al. 2017);
- Textbooks as Tools for Shaping the Geographical Imagination of Slovenian Landscapes, carried out from July 1st, 2011, to June 30th, 2014, under the leadership of Mimi Urbanc, determined the role of Slovenian landscapes in textbooks and concluded with the publication of the book *Oblikovanje predstav o slovenskih pokrajinah v izobraževalnem procesu* (Shaping the Geographical Imagination of Slovenian Landscapes in Education; Urbanc et al. 2016);
- Landscape Diversity and Hotspots of Slovenia, carried out from October 1st, 2014, to September 30th, 2017, and headed by Drago Perko, focused on determining landscape diversity as one of the elements shaping Slovenian identity (Perko and Ciglič 2015; Perko, Hrvatin, and Ciglič 2017);
- Cultural Landscapes Caught between Public Good, Private Interests, and Politics, carried from October 1st, 2014, to September 30th, 2017, and headed by Mimi Urbanc, elucidated cultural landscapes from aspects that had been poorly studied in Slovenian geography until then and gave them new dimensions;
- Advancement of Computationally Intensive Methods for Efficient Modern General-Purpose Statistical Analysis and Inference, carried out from March 1st, 2016, to February 28th, 2019, and headed by Erik Štrumbelj, explored the use of artificial intelligence in landscape typifications.

As already mentioned above, the first research project approved was actually the concluding act of more than ten years of efforts to produce a regional geographical volume on Slovenia, which officially began by accepting the volume as part of the institute's program of work in 1981. The volume's thematic concept envisaged a landscape typological presentation of Slovenia in the introduction, which was to form the basis for the geographical regionalization of Slovenia and its presentation by regions (Ilešič 1981). Until funding for the project was approved in 1993, work on the volume had proceeded very slowly but, once the funding was secured, researchers made a commitment to complete their work in three years (i.e., by the end of 1995), which they also did. They divided Slovenian into nine macrounits and sixty-one mesounits, which they described in nine volumes published in 1996:

- The macrounit *alpski svet* 'Alpine region' with four mesounits (Pak and Perko 1996b);
- The macrounit *zahodni predalpski svet* 'western Prealpine region' with four mesounits (Pak and Perko 1996c);
- The macrounit *Ljubljanska kotlina* 'Ljubljana Basin' with six mesounits (Pak and Perko 1996a);
- The macrounit *submediteranski svet* 'sub-Mediterranean region' with seven mesounits (Kladnik and Perko 1996a);
- The macrounit *visoki kraški svet* 'high karst region' with eight mesounits (Kladnik and Perko 1996b);
- The macrounit *nizki kraški svet* 'low karst region' with seven mesounits (Perko 1996a);
- The macrounit *srednji in južni subpanonski svet* 'central and southern sub-Pannonian region' with seven mesounits (Perko 1996b);
- The macrounit *vzhodni in severovzhodni predalpski svet* 'eastern and northeastern Prealpine region' with eight mesounits (Drozg and Perko 1996a); and
- The macrounit *severni subpanonski svet* 'northern sub-Pannonian region' with twelve mesounits (Drozg and Perko 1996b).

In 1997, the institute also produced a more popular version of the regional geographical volume of Slovenia with a simplified division of the country into four macrounits and forty-six mesounits. It was published a year later in a single volume (Perko and Orožen Adamič 1998), together with a popular-science film about Slovenian landscapes released on a videotape. The film was special because it presented Slovenian landscapes for the first time together with their natural sounds (Perko and Križnar 1998). The volume (Figure 1) was the result of work contributed by thirty-two authors, six cartographers, forty photographers, and thirty-four other professionals. It contains 736 pages, 455 photos, 118 maps, and 426 graphs (Natek and Perko 1999).

Before the projects listed above, which were funded by the agency, the institute also carried out another large project associated with Slovenian landscapes: *Krajevni leksikon Slovenije* (Gazetteer of Slovenia; Figure 3). The institute managed to have most Slovenian geographers employed as researchers at universities and institutes work on the project, alongside many geography teachers. They all performed fieldwork, wrote texts, and took photos, and most processed the settlements within one municipality. Work began in 1993 and was completed in two years. The book was published in 1995, presenting all 5,981 settlements (i.e., villages and towns) of that time with descriptions, photos, and tables (Orožen Adamič, Perko, and Kladnik 1995). It contains 640 pages, 492 color photos, thirty-nine 1:100,000 color thematic maps with settlements, which were an outstanding technological achievement of the institute's digital cartography at that time, and several other thematic maps (Natek and Perko 1999). Among them is also a geographical regionalization of Slovenia with six macrounits and sixty-two mesounits, which in places are divided into further subunits. An interactive CD, the first of its kind in Slovenia, was released together with the book, and *Priročni krajevni leksikon Slovenije* (Pocket Gazetteer of Slovenia; Orožen Adamič, Perko, and Kladnik 1996), about half the size of the original gazetteer in terms of both its format and content, was published a year later.

The last major project associated with landscapes was carried out at the institute between 2017 and 2019 as part of the program *Geografija Slovenije* (Geography of Slovenia). Its final outcome was *The Geography of Slovenia* (Perko, Ciglič, and Zorn 2020a), a book published in 2020 as part of Springer's *World Regional Geography Book Series*, which was the first extensive and detailed geographical presentation of Slovenia in English (Figure 4). The 360-page work begins with a chapter about Slovenia's exceptional landscape diversity, followed by five thematic sections comprised of twenty-two chapters, including one on the landscape typification of Slovenia and one on its geographical regionalization. The text is complemented by 222 color photos, including many thematic maps. The book contributes greatly to promoting Slovenian research and enhancing Slovenia's international profile, and its subtitle *Small but Diverse* highlights the fact that, despite being a small country, Slovenia is characterized by above-average geographical diversity and hence it also offers numerous research challenges in studying landscapes (Ciglič and Perko 2013a).

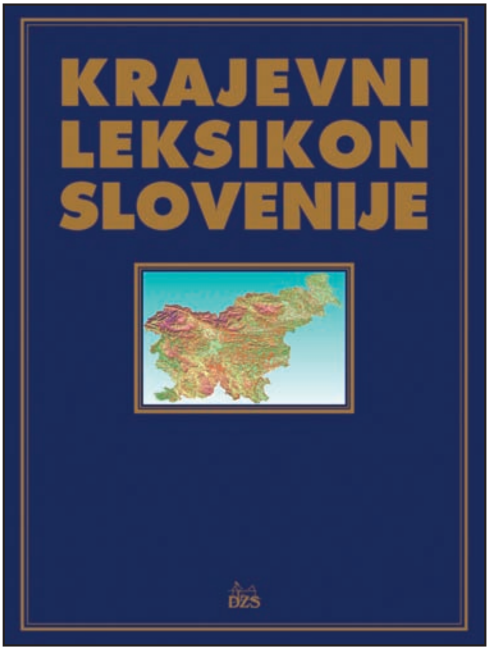


Figure 1: Cover of *Krajevni leksikon Slovenije*, which also introduced a new geographical regionalization of Slovenia (Orožen Adamič, Perko, and Kladnik 1995).

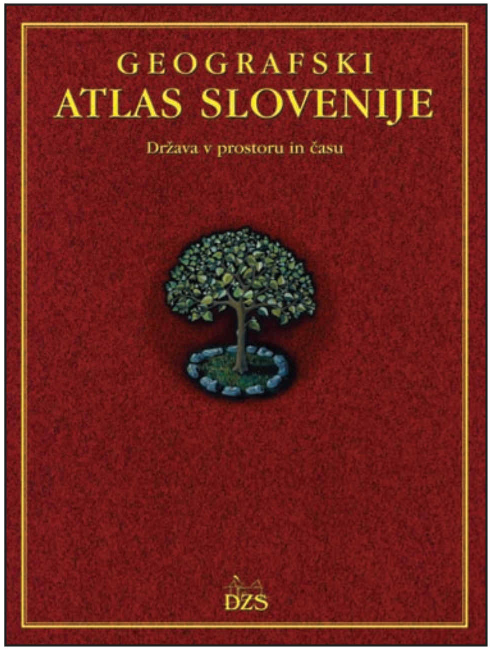


Figure 2: Cover of *Geografski atlas Slovenije*, which also contains a chapter on the geographical regionalization and landscape typology of Slovenia (Fridl et al. 1998a).

Figure 3: Cover of *Slovenija: pokrajine in ljudje*, which also presented maps of the most important geographical regionalizations and a new landscape typology of Slovenia (Perko and Orožen Adamič 1998).

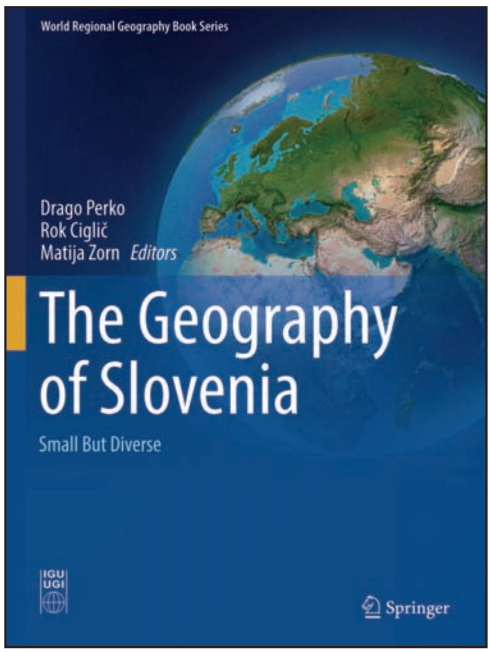


Figure 4: Cover of *The Geography of Slovenia: Small but Diverse*, which dedicated two chapters to landscape typologies and geographical regionalizations in English (Perko, Ciglič, and Zorn 2020a).

Because a quarter of a century has already passed since the publication of the gazetteer, national atlas, and regional geographical volume on Slovenia, and because the country has experienced great changes in practically all areas, updating all these seminal geographical works on Slovenia should be an important priority in the future. This will demand cooperation between all geographical research institutions in Slovenia (the geographical institute and the three geography departments at the universities of Ljubljana, Maribor, and Primorska) and substantial funding, which is needed to carry out all the projects, from research to book publication.

As already mentioned, all these major geographical works on Slovenia include landscape typologies and geographical regionalizations, but they are largely limited to one typification and regionalization only. The following section provides, for the first time in Slovenian geography, a systematic overview of all landscape macrotypologies by Slovenian authors and compares them. Added to this is a section on landscape microtypifications because some macrotypologies had an important influence on the production of microtypologies.

2 Macrotypologies of Slovenia

Slovenian geographers and similar professionals have produced various classifications of Slovenia (Kladnik 1996; Kladnik and Perko 1998; Perko and Ciglič 2020a, 2020b). Most divisions are based on one landscape element or only a few elements. They include several regionalizations, but only five classifications can be defined as landscape typologies. Three were produced by the geographical institute's directors, and two were also co-created by other institute employees. Nearly seventy years passed between the first one produced in 1946 and the last one produced in 2013, and during this period people's attitude toward nature and landscape changed significantly. However, with the development of modern technology, geographical methodology changed even more. This also influenced the design and characteristics of these five landscape typologies of Slovenia, which are presented below. They were produced for the territory of all of Slovenia at the highest spatial levels and can therefore be defined as macrotypologies.

2.1 Melik's typology (1946)

The first landscape typology to cover all of Slovenia was produced by Anton Melik (1890–1966), the greatest Slovenian geographer, who also initiated the establishment of the geographical institute in 1946 (Figure 7). He received a bachelor's degree in geography and history in Vienna in 1916 and a doctorate in Ljubljana in 1927. That same year, he began teaching at the University of Ljubljana. In 1940, he became a member of the Slovenian Academy of Sciences and Arts, and in 1946 he was appointed director of the geographical institute, which was named after him in 1976, ten years after his death. His most important works include the first general geographical work on Slovenia in two volumes (Melik 1935–1936) and the first regional geographical work on Slovenia in four volumes (Melik 1954, 1957, 1959, and 1960).

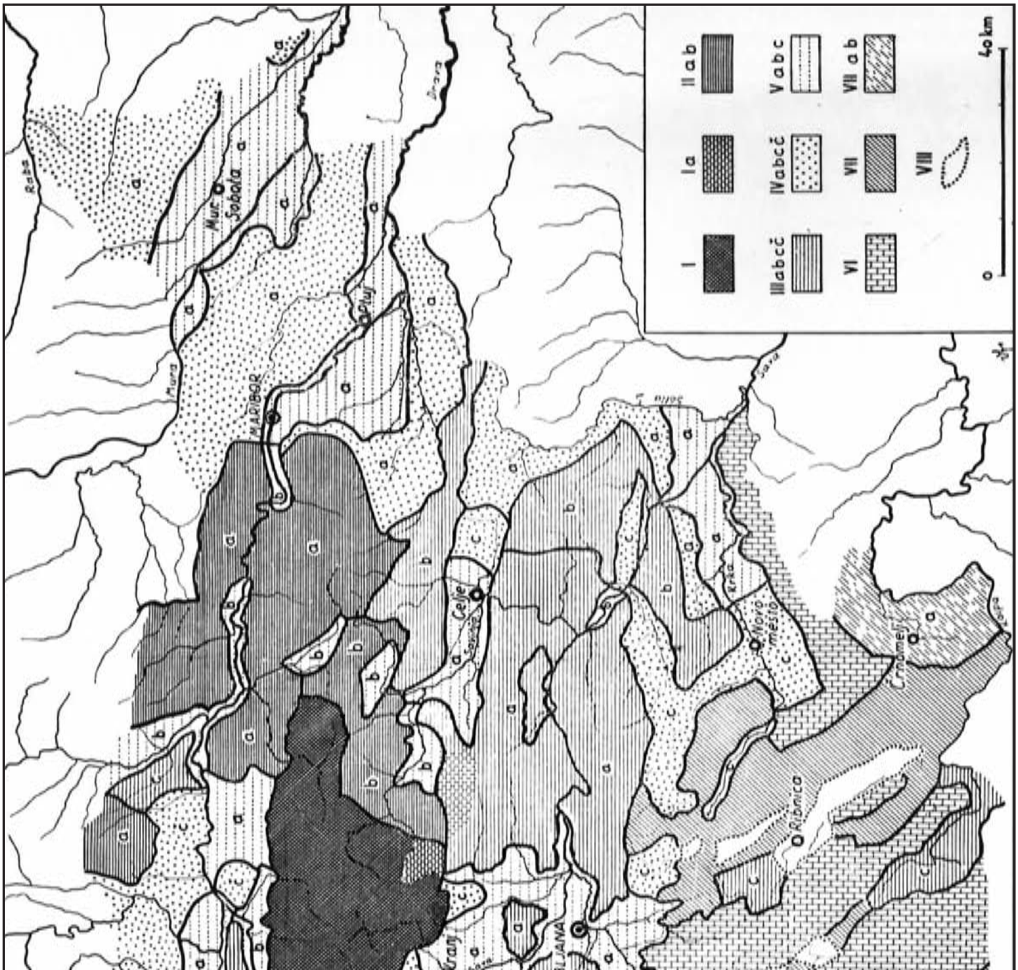
The first major work that he tackled as the institute's director was a landscape typology of Slovenia (Melik 1946), which covered Slovenia and ethnic Slovenian areas outside Slovenia. Without using any special methodology and relying primarily on his expertise and fieldwork experience, he divided the territory in terms of geomorphology, rocks, and climate. According to Melik (1946), the purpose of his typology was not to divide Slovenia only into natural landscape units, but primarily into such homogenous units that offered similar opportunities for the economy and its development for people and society in general.

He published a map with boundaries between the types and described their natural and social characteristics in the main text, also listing the most important (micro)regions within each type.

He entitled the map presenting this typology *Prirodnogospodarska sestava Slovenije* (Natural Economic Structure of Slovenia) and referred to its units as *prirodni sestavni deli* 'natural component parts'.

Figure 5: Original map of Melik's landscape typology of Slovenia (Melik 1946) with legend: I High Alpine mountains, II Low Alpine mountains, III Hills, IV Low hills, V Plains and wide valleys, VI Dinaric high plateaus, VII Karst hills with low plateaus and lowlands, and VIII Karst poljes. ➤ p. 16

Figure 6: Updated map of Melik's landscape typology of Slovenia. ➤ p. 17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TRST
J-A-D-R-A-N-S-K-O
M-O-R-J-E

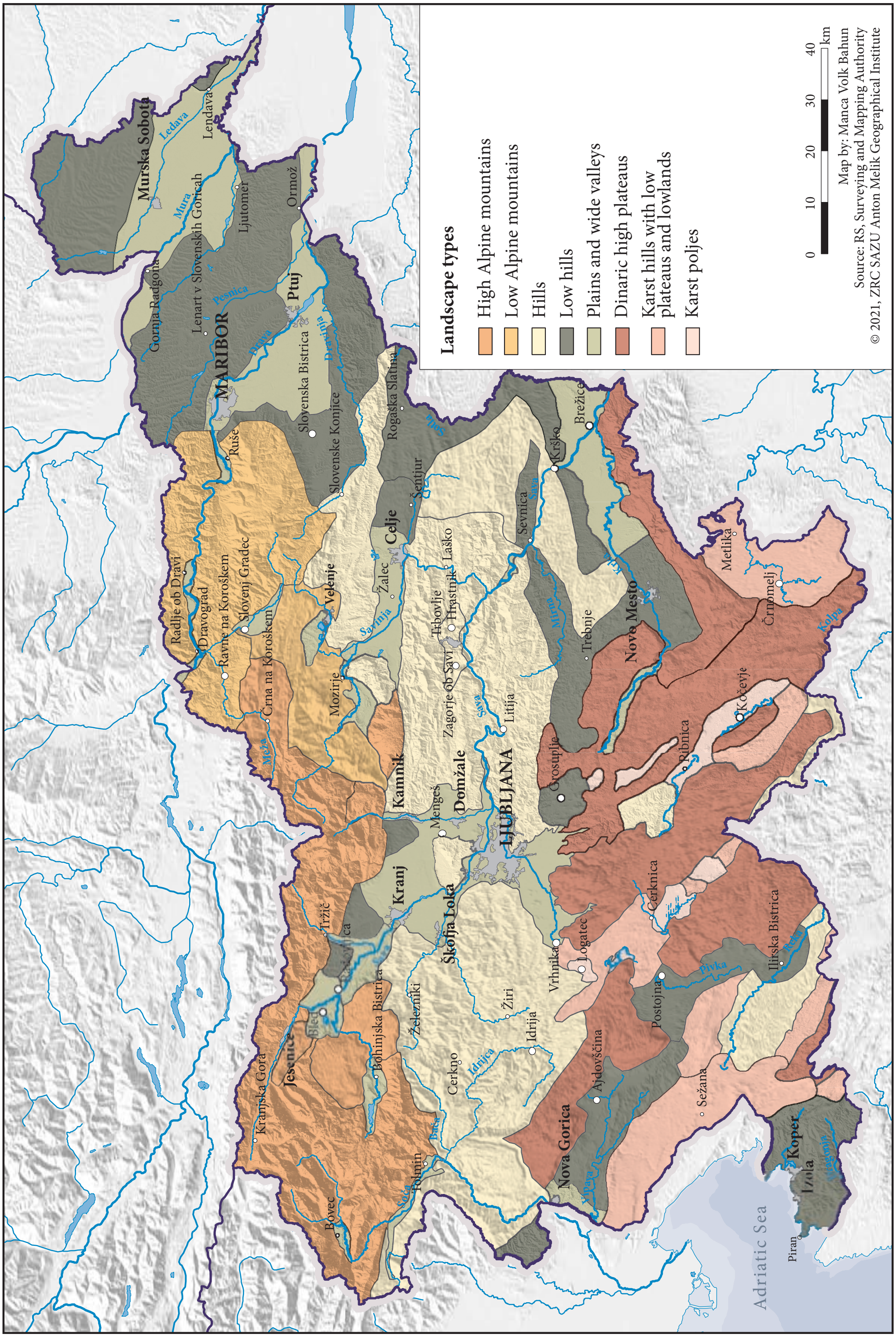

Landscape types
High Alpine mountains
Low Alpine mountains
Hills
Low hills
Plains and wide valleys
Dinaric high plateaus
Karst hills with low plateaus and lowlands
Karst poljes
0 10 20 30 40 km
Map by: Manca Volk Bahun
Source: RS, Surveying and Mapping Authority
© 2021, ZRC SAZU Anton Melik Geographical Institute
Murska Sobota
Lendava
Ledava
Mura
Ormož
Ljutomer
Gornja Radgona
Lenart v Slovenskih Goricah
Pesnica
Ptuj
MARIBOR
Drava
Dravinja
Slovenska Bistrica
Slovenske Konjice
Rogaška Slatina
Sotla
Ruše
Šentjur
Celje
Krško
Brežice
Sevnica
Sava
Laško
Žalec
Velenje
Savinja
Slovenj Gradec
Radlje ob Dravi
Dravograd
Ravne na Koroškem
Črna na Koroškem
Mežica
Mozirje
Trbovlje
Hrastnik
Zagorje ob Savi
Litija
Trebnje
Mirna
Krka
Novo Mesto
Metlika
Črnomelj
Kolpa
Kočevje
Ribnica
Grosuplje
Kamnik
Domžale
Mengeš
LJUBLJANA
Kranj
Škofja Loka
Tržič
Bled
Jesenice
Kranjska Gora
Bohinjska Bistrica
Železniki
Žiri
Idrija
Idrijca
Cerkno
Vrhnika
Logatec
Cerknica
Postojna
Pivka
Ilirska Bistrica
Reka
Ajdovščina
Nova Gorica
Vipava
Sežana
Tolmin
Bača
Soča
Bovec
Koper
Izola
Piran
Adriatic Sea

Figure 7: Anton Melik (1890–1966), author of the first landscape typology of Slovenia.

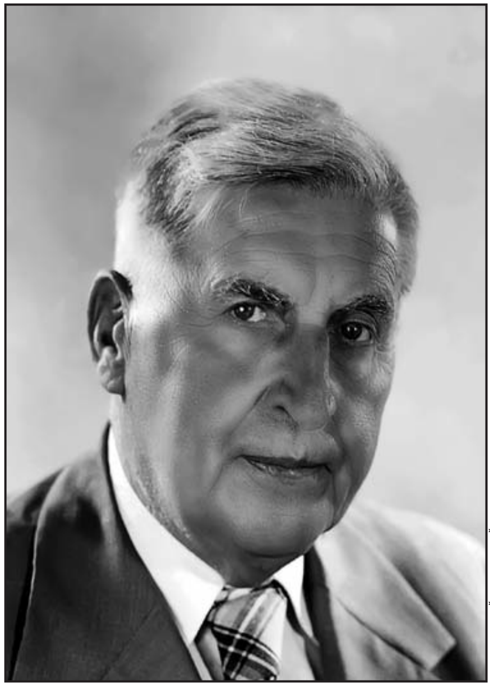


Figure 8: Svetozar Ilešič (1907–1985), author of the second landscape typology of Slovenia.

He divided the territory into eight macrounits, whose names represented typical landscape types (e.g., *hribovje* 'hills'). He then divided these further into three submacrounits and thirteen mesounits, which he partly named as a landscape type (e.g., the mesounit *širše doline* 'wide valleys'), a region (e.g., the submacrounit *Bela krajina* 'White Carniola'), or something in between (e.g., the mesoregion *dolina ob zgornji Krki* 'valley along the upper Krka River').

The basic types in Melik's division of Slovenia were as follows (Figures 5 and 6):

- *visokogorski alpski predel* 'high Alpine mountains';
- *predel alpskega sredogorja* 'low Alpine mountains';
- *hribovje* 'hills' as the largest type, covering 23.8% of Slovenia;
- *predel goric* 'low hills';
- *ravnine in večje doline* 'plains and wide valleys';
- *dinarske visoke planote* 'Dinaric high plateaus';
- *kraško hribovje z nižjimi planotami in podolji* 'karst hills with low plateaus and lowlands'; and
- *kraška polja* 'karst poljes' as the smallest type, covering only 1.3% of Slovenia.

It is interesting that, compared to Melik's regionalization (Melik 1954, 1957, 1959, and 1960), which was slightly deficient in certain aspects, his typology (Melik 1946) met with significantly less response in the Slovenian professional community, even though it was based on more thorough research (Perko 1998a).

2.2 Ilešič's typology (1958)

The second landscape typology of all of Slovenia was produced by Svetozar Ilešič (1907–1985), who received a bachelor's degree in geography and history in Ljubljana in 1930, followed by a doctorate in 1933. In 1967, he became a member of the Slovenian Academy of Sciences and Arts, and he served as the second director of the geographical institute from 1967 to 1981 (Figure 8).

Various classifications of Slovenian territory formed an important part of his work as a researcher. Even though he advocated a uniform and complex geography, he believed that nature and society differ from one another to the extent that two basic types of territorial geographical division are necessary: a landscape-physiognomic one, which falls into the realm of physical geography, and an economic-functional one, which is the subject of human geography (Ilešič 1958).

Among the divisions he produced, his landscape typology of Slovenia stands out. He published it three times with minor modifications. First, he only published the names and more non-technical descriptions of individual units (Ilešič 1956), which he called *pokrajine* 'landscapes'. Two years later (Ilešič 1958), he published the typology again as part of a theoretical discussion on issues connected with the geographical division of Slovenia. He entitled it *Pokrajinsko-fiziognomične regije Slovenije* (Landscape-Physiognomic Regions of Slovenia) in Slovenian and simply *Régions physionomiques de la Slovénie* (Physiognomic Regions of Slovenia) in French. The typology was the same as the previous one, but he added a map with unit boundaries and improved the units' hierarchy. He replaced the term *pokrajina* 'landscape' with *regija* 'region' (e.g., *makroregija* 'macroregion'), but he retained it with concrete names (e.g., the macroregion *Alpske pokrajine* 'Alpine landscapes'). He referred to the typology using two names: a landscape-type division and an ecological division. The units of the former were *pokrajinski tipi* 'landscape types' and those of the latter were *ekološka območja* 'ecological areas'. On the 1972 map (Ilešič 1972), he then combined both names into the title *Pokrajinsko-ekološka razčlenjenost Slovenije* (Landscape-Ecological Division of Slovenia), which he himself translated into English as *Landscape Types and Ecological Areas of Slovenia*.

Just like with Melik, his typology covered Slovenia and its nearby surroundings, and with regard to methodology he only presented the criterion of division – that is, a uniform, homogenous landscape physiognomy or external landscape image, which is largely affected by natural landscape elements and the anthropogenic elements strongly associated with them, such as land use, settlement type, and agriculture.

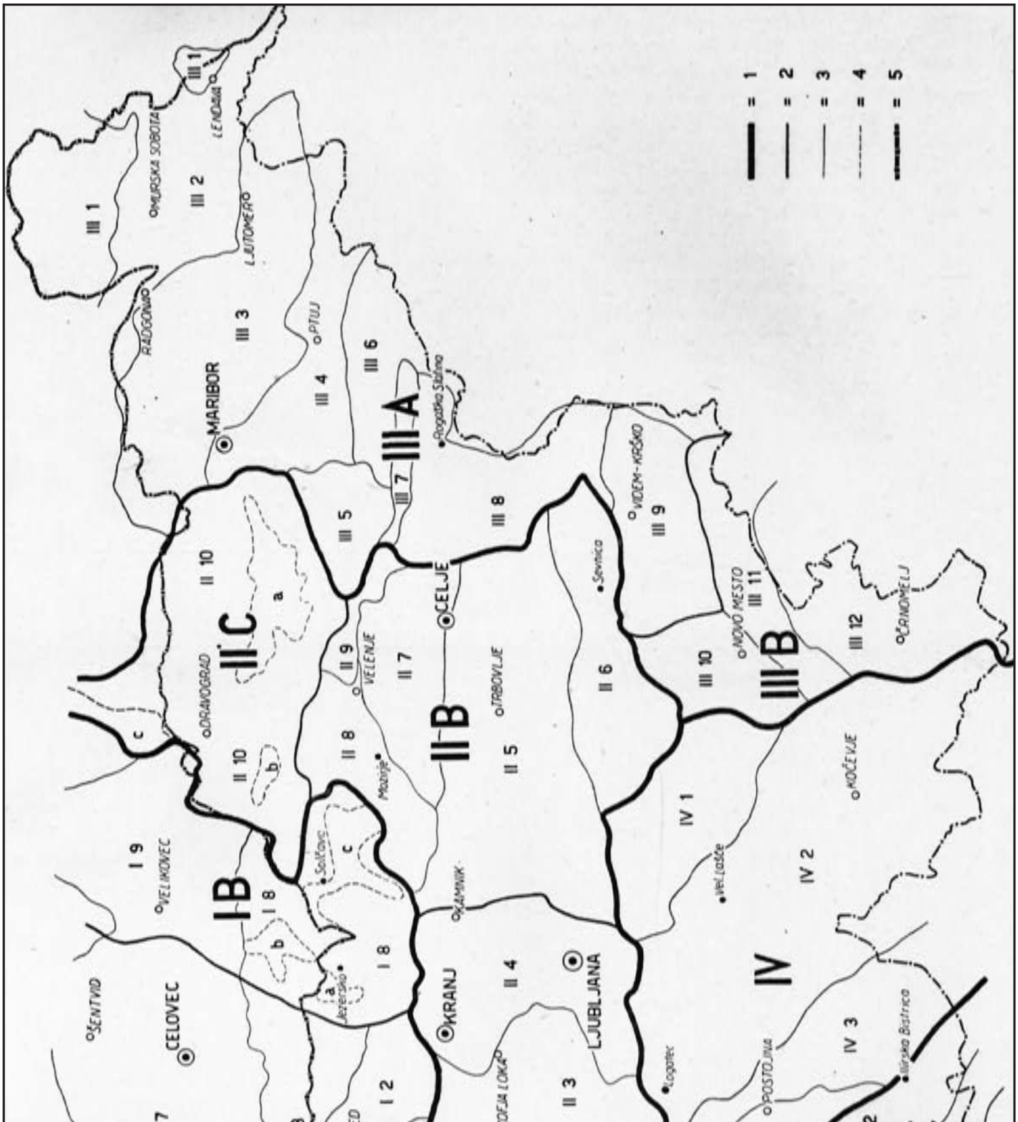
Ilešič divided the territory into five macroregions and ten mesoregions (two macroregions had three mesoregions, two macroregions had two mesoregions, and one macroregion had no mesoregions), which represented typical landscape types (e.g., the macroregion *predalpske pokrajine* 'sub-Alpine landscapes' or the mesoregion *submediteransko-subalpske pokrajine* 'sub-Mediterranean–sub-Alpine landscapes'). He then divided these further into thirty-seven submesoregions and ten microregions, nearly all of which were actually regions and not types (e.g., the submesoregion *Julijske Alpe* 'Julian Alps' or its microregion *Zgornja Soška dolina* 'Upper Soča Valley').

The basic types (ten mesoregions within the macroregions and one macroregion with no mesoregions) in Ilešič's division of Slovenia were as follows (Figures 9 and 10):
- *zahodne alpske pokrajine* 'western Alpine landscapes';
- *vzhodne alpske pokrajine* 'eastern Alpine landscapes';
- *zahodne predalpske pokrajine* 'western sub-Alpine landscapes';
- *vzhodne predalpske pokrajine* 'eastern sub-Alpine landscapes';
- *severovzhodne predalpske pokrajine* 'northeastern sub-Alpine landscapes';
- *prave subpanonske pokrajine* 'sub-Pannonian landscapes' as the largest type, covering 22.0% of Slovenia;
- *subpanonsko-subdinarske pokrajine* 'sub-Pannonian–sub-Dinaric landscapes';
- *kraške pokrajine notranje Slovenije* 'karst landscapes of inner Slovenia';
- *submediteransko-subalpske pokrajine* 'sub-Mediterranean–sub-Alpine landscapes' as the smallest type, covering 0.5% of Slovenia;
- *submediteranske pokrajine* 'sub-Mediterranean landscapes'; and
- *submediteransko-dinarske pokrajine* 'sub-Mediterranean–Dinaric landscapes'.

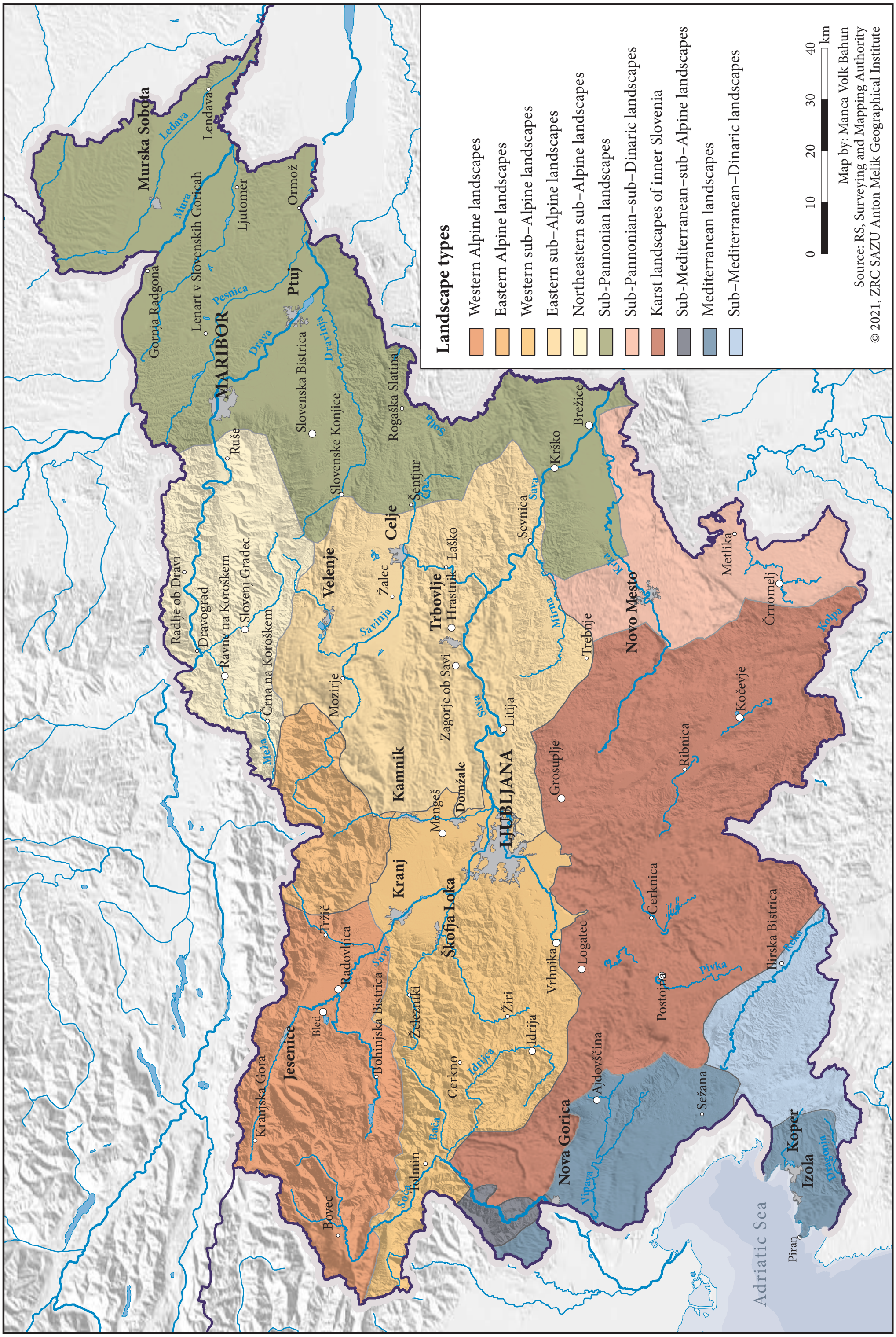
Ilešič's typology was met with a wider public response than that of Melik. This was partly because Ilešič promoted his typology with several publications and partly because his division of Slovenia combined typology at the higher levels with regionalization at the lower levels.

Figure 9: Original map of Ilešič's landscape typology of Slovenia (Ilešič 1958) with legend: IA Western Alpine landscapes, IB Eastern Alpine landscapes, IIA Western sub-Alpine landscapes, IIB Eastern sub-Alpine landscapes, IIC Northeastern sub-Alpine landscapes, IIIA Sub-Pannonian landscapes, IIIB Sub-Pannonian–sub-Dinaric landscapes, IV Karst landscapes of inner Slovenia, VA Sub-Mediterranean–sub-Alpine landscapes, VB Sub-Mediterranean landscapes, and VC Sub-Mediterranean–Dinaric landscapes. ➤ p. 20

Figure 10: Updated map of Ilešič's landscape typology of Slovenia. ➤ p. 21



I A
I B
II A
II B
II C
III A
III B
IV
V A
V B
V C
MARIBOR
CELJE
KRANJ
LJUBLJANA
CELOVEC
BELJAK
GORICA
TRST
KOPER
PTUJ
VELENJE
TRBOVLJE
DRAVOGRAD
KAMNIK
ŠKOFJA LOKA
IDRIJA
TOLMIN
BLED
JESENICE
POSTOJNA
NOVO MESTO
ČRNOMELJ
KOČEVJE
AJDOVŠČINA
MURSKA SOBOTA
LENDAVA
LJUTOMER
RADGONA
VIDEM-KRŠKO
Sevnica
Logatec
Ilirska Bistrica
Rogaška Slatina
ČEDAD
TRBIŽ
ŠENTVID
VELIKOVEC
= 1
= 2
= 3
= 4
= 5


Landscape types
Western Alpine landscapes
Eastern Alpine landscapes
Western sub-Alpine landscapes
Eastern sub-Alpine landscapes
Northeastern sub-Alpine landscapes
Sub-Pannonian landscapes
Sub-Pannonian–sub-Dinaric landscapes
Karst landscapes of inner Slovenia
Sub-Mediterranean–sub-Alpine landscapes
Mediterranean landscapes
Sub-Mediterranean–Dinaric landscapes
0 10 20 30 40 km
Map by: Manca Volk Bahun
Source: RS, Surveying and Mapping Authority
© 2021, ZRC SAZU Anton Melik Geographical Institute
Adriatic Sea
LJUBLJANA
MARIBOR
Murska Sobota
Ptuj
Celje
Velenje
Kranj
Kamnik
Novo Mesto
Nova Gorica
Koper
Izola
Jesenice
Škofja Loka
Trbovlje

2.3 Perko's typology (1996)

The third landscape typology of all of Slovenian territory was produced half a century after Melik by Drago Perko while preparing a volume on Slovenia's regional geography (Perko and Orožen Adamič 1998) and the national atlas of Slovenia (Fridl et al. 1998a, 2001). This was the first partly computer-based landscape typology of Slovenia. Its research bases were first published in 1998, together with the natural geographical regionalization of Slovenia (Perko 1998a).

Perko started the process of typification in 1995 using a geographic information system (Idrisi, now Terrset). He entered four data layers: the surface elevation and inclination, and lithology and vegetation types. The inclination and elevation data were based on a 100-meter digital elevation model, and the lithology and vegetation data were obtained through digitization of a 1:250,000 lithological map with thirty-seven basic units and a vegetation map with sixty-two basic units, which were both rasterized to a 100-meter grid. All four layers were then generalized and simplified into seven classes. Perko covered and joined all four layers. Altogether 2,401 different combinations were theoretically possible (Perko and Ciglič 2020a).

To reduce the number of combinations, he filtered all four layers and the combined layer three times using the modus inside of a moving 11 × 11 cell square window, obtaining forty-eight larger and spatially separate homogenous cores with the same combination of elevation, inclination, lithology, and vegetation. He printed these cores on a 1:250,000 scale map and, with the help of experts for individual parts of Slovenia, manually plotted the boundaries, mostly in morphological boundaries and larger watercourses. In the end, he combined these forty-eight manually delineated landscape units into nine landscape types, which he combined further into four landscape type groups (Perko and Ciglič 2020a).

The nine landscape types were (Figures 11 and 12):

- *alpska gorovja* 'Alpine mountains';
- *alpska hribovja* 'Alpine hills' as the largest type, covering 23.0% of Slovenia:
- *alpske ravnine* 'Alpine plains';
- *panonska gričevja* 'Pannonian low hills';
- *panonske ravnine* 'Pannonian plains';
- *dinarske planote* 'Dinaric plateaus';
- *dinarska podolja in ravniki* 'Dinaric lowlands';
- *sredozemska gričevja* 'Mediterranean low hills'; and
- *sredozemske planote* 'Mediterranean plateaus' as the smallest part, covering 3.3% of Slovenia.

The four landscape type groups were:

- *alpske pokrajine* 'Alpine landscapes';
- *panonske pokrajine* 'Pannonian landscapes';
- *dinarske pokrajine* 'Dinaric landscapes'; and
- *sredozemske pokrajine* 'Mediterranean landscapes'.

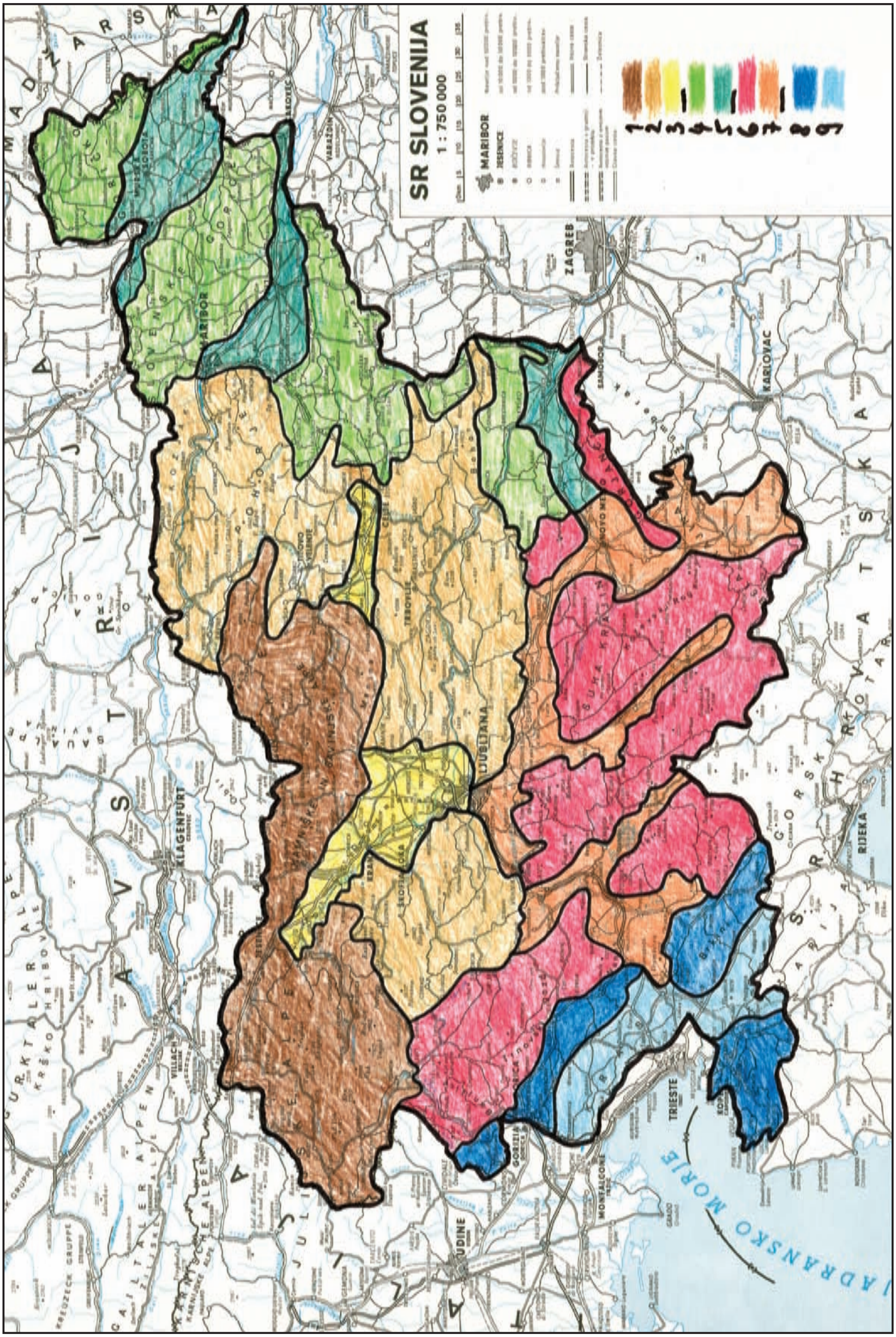
Based on this landscape typology, Perko et al. also produced a natural geographical regionalization of Slovenia, which was first published in 1996 (Kladnik 1996). The four groups of landscape types presented in the typology were replaced by macroregions, and the forty-eight landscape cores turned into mesoregions (Kladnik 1996; Perko 1998a; Perko 2001; Perko 2007a; Perko, Hrvatin, and Ciglič 2015; Perko, Hrvatin, and Ciglič 2017). In addition, the Bay of Trieste, which the Slovenian territorial waters extend to, was defined as a special region (Perko and Kladnik 1998).

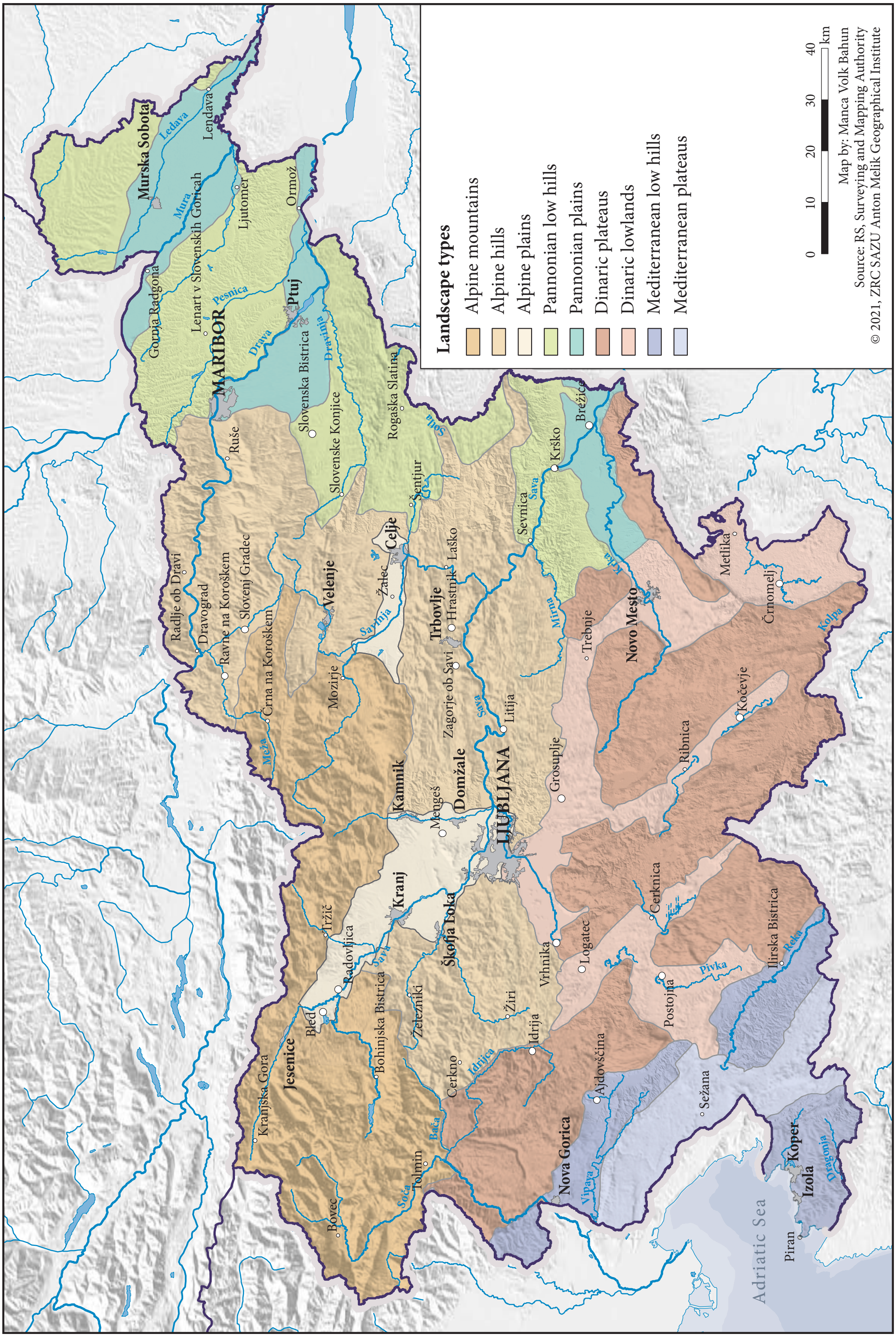
This is the combined or connecting scheme of the landscape typology and regionalization described above:

- The macroregion *Alpe* 'Alps' (corresponding to the landscape type group Alpine landscapes in terms of boundaries and areas covered) includes eleven mesoregions, four of which (e.g., the Julian Alps) fall under the landscape type Alpine mountains, five (e.g., the Sava Hills) belong to the landscape type Alpine hills, and two (e.g., the Sava Plain) fall under the landscape type Alpine plains;

Figure 11: Original map of Perko's landscape typology of Slovenia from 1996 with legend: 1 Alpine mountains, 2 Alpine hills, 3 Alpine plains, 4 Pannonian low hills, 5 Pannonian plains, 6 Dinaric plateaus, 7 Dinaric lowlands, 8 Mediterranean low hills, and 9 Mediterranean plateaus. ➤ p. 23

Figure 12: Updated map of Perko's landscape typology of Slovenia. ➤ p. 24


SR SLOVENIJA
1 : 750 000
MARIBOR
LJUBLJANA
ZAGREB
KARLOVAC
RIJEKA
TRIESTE
GORIZIA
UDINE
KLAGENFURT
VILLACH
JADRANSKO MORJE


Landscape types
Alpine mountains
Alpine hills
Alpine plains
Pannonian low hills
Pannonian plains
Dinaric plateaus
Dinaric lowlands
Mediterranean low hills
Mediterranean plateaus
0 10 20 30 40 km
Map by: Manca Volk Bahun
Source: RS, Surveying and Mapping Authority
© 2021, ZRC SAZU Anton Melik Geographical Institute
Murska Sobota
Lendava
Ledava
Mura
Ljutomer
Ormož
Gornja Radgona
Lenart v Slovenskih Goricah
Pesnica
Ptuj
MARIBOR
Drava
Dravinja
Slovenska Bistrica
Slovenske Konjice
Rogaška Slatina
Sotla
Ruše
Šentjur
Celje
Žalec
Savinja
Velenje
Radlje ob Dravi
Dravograd
Ravne na Koroškem
Slovenj Gradec
Črna na Koroškem
Mežica
Mozirje
Laško
Hrastnik
Trbovlje
Zagorje ob Savi
Sevnica
Sava
Krško
Brežice
Krka
Mirna
Trebnje
Novo Mesto
Metlika
Črnomelj
Kolpa
Kočevje
Ribnica
Litija
LJUBLJANA
Domžale
Kamnik
Mengeš
Grosuplje
Kranj
Tržič
Radovljica
Škofja Loka
Bled
Jesenice
Kranjska Gora
Bohinjska Bistrica
Železniki
Žiri
Vrhnika
Logatec
Cerknica
Idrija
Idrijca
Cerkno
Postojna
Pivka
Ilirska Bistrica
Reka
Ajdovščina
Sežana
Nova Gorica
Vipava
Tolmin
Bača
Soča
Bovec
Koper
Izola
Dragonja
Piran
Adriatic Sea

- The macroregion *Panonska kotlina* 'Pannonian Basin' (corresponding to the landscape type group Pannonian landscapes) has twelve mesoregions, nine of which (e.g., the Lendava Hills) fall under the landscape type Pannonian low hills and three (e.g., the Drava Plain) under the type Pannonian plains;
- The macroregion *Dinarsko gorovje* 'Dinaric Alps' (corresponding to the landscape type group Dinaric landscapes) includes nineteen mesoregions, eleven of which (e.g., the Idrija Hills) fall under the landscape type Dinaric plateaus and eight (e.g., the Ljubljana Marsh) under the landscape type Dinaric lowlands);
- The macroregion *Sredozemlje* 'Mediterranean' (corresponding to the landscape type group Mediterranean landscapes) includes six mesoregions, four of which (e.g., the Koper Hills) fall under the landscape type Mediterranean low hills and two (e.g., the Karst Plateau) under the landscape type Mediterranean plateaus).

Among all five typologies presented, the one produced by Perko has become the most established. It has been incorporated in all major geographical works on Slovenia published after Slovenia's independence: the eleventh volume of *Enciklopedija Slovenije* (Encyclopedia of Slovenia, 1997), *Geografski atlas Slovenije* (Geographical Atlas of Slovenia; Fridl et al. 1998a), the book on Slovenia's regional geography titled *Slovenija: Pokrajine in ljudje* (Slovenia: Regions and People; Perko and Orožen Adamič 1998), *Nacionalni atlas Slovenije* (National Atlas of Slovenia; Fridl et al. 2001), *Popisni atlas Slovenije 2002* (Census Atlas of Slovenia, 2002; Dolenc et al. 2007), the atlas *Slovenia in Focus* (Fridl et al 2008), *Terasirane pokrajine* (Terraced Landscapes; Perko, Ciglič, and Geršič 2016; Perko et al. 2017), and *The Geography of Slovenia: Small but Diverse* (Perko, Ciglič, and Zorn 2020a). It has been introduced to primary school students via *Šolska karta Slovenije v merilu 1 : 500.000* (1:500,000 School Map of Slovenia; Perko 1997), *Geografski atlas za osnovno šolo* (Geographical Atlas for Primary Schools; Fridl et al. 1998b), and the popular science magazine *Geografski obzornik* (Geographical Horizon; Perko 1998c). In 2008, it was also incorporated into Slovenian legislation, being used as the basis for assessing land quality (Perko, Hrvatin, and Ciglič 2015).

2.4 Špes et al.'s typology (2002)

This typology was created as part of producing the methodology for studying environmental vulnerability at the national and local levels as stipulated by the 2003 Slovenian environmental protection legislation to ensure a more quality sustainable development of Slovenia. A detailed description of the methodology and data sources used is provided in Špes et al. (2002).

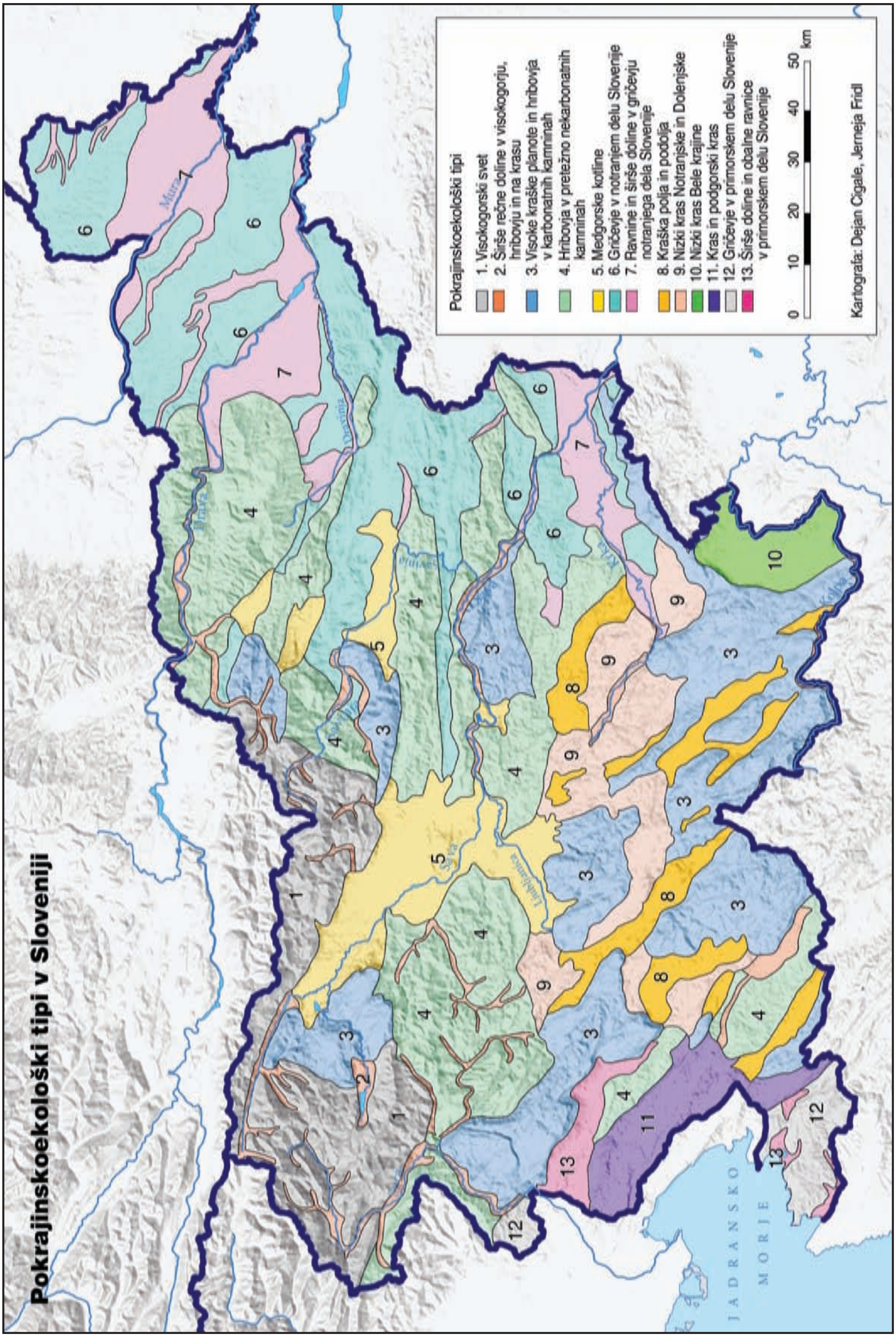
The researchers first produced a three-level landscape ecological regionalization based on the dominant landscape elements. The criteria of division at the highest level were primarily elevation differences, the share of carbonate rock, and average annual temperatures and precipitation, and the main criterion at the second level was the alternation of major concave and convex landforms (e.g., hills and valleys or plateaus and lowlands). At the first level, they defined five macroregions (Alpine Slovenia, Prealpine Slovenia, Pannonian Slovenia, Dinaric–Karst Slovenia, and Mediterranean Slovenia), referring to them as *pokrajinskoekološke makroenote* 'landscape ecological macrounits'. At the second level, they defined sixty mesoregions called *pokrajinskoekološke mezoenote* 'landscape ecological mesounits', and at the third level they defined 223 microregions called *pokrajinskoekološke podenote* 'landscape ecological subunits'.

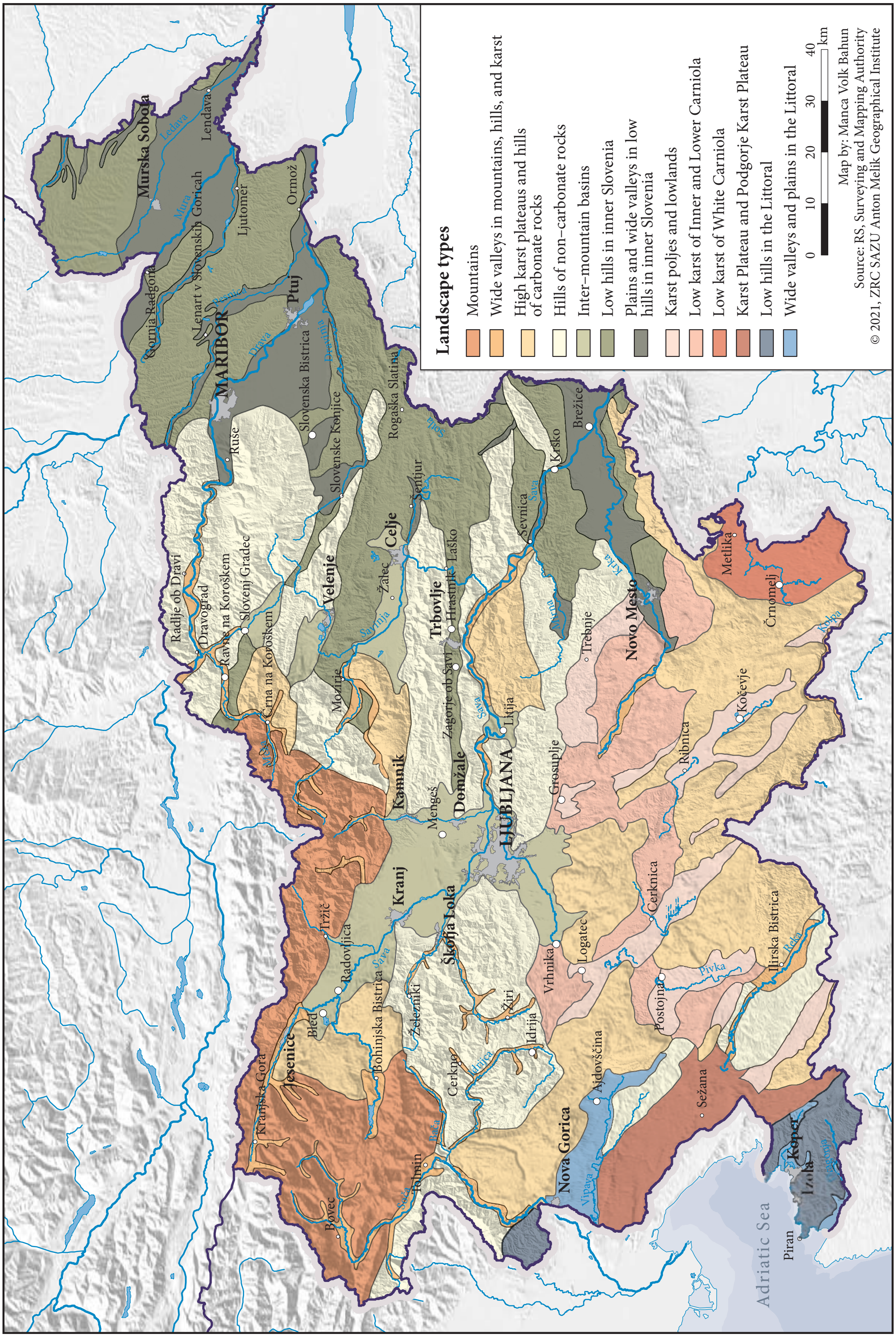
Then the researchers combined similar landscape ecological units to produce a landscape typology with fourteen landscape ecological types: thirteen for land and one for sea. Their land types included the following (Figures 13 and 14):

- *visokogorski svet* 'mountains';
- *širše rečne doline v visokogorju, hribovju in na krasu* 'wide valleys in mountains, hills, and karst';
- *visoke kraške planote in hribovja v karbonatnih kamninah* 'high karst plateaus and hills of carbonate rocks';
- *hribovja v pretežno nekarbonatnih kamninah* 'hills of non-carbonate rocks' as the largest type, covering 22.4% of Slovenia;

Figure 13: Original map of the Špes et al. landscape typology of Slovenia (Špes et al. 2002) with legend: 1 Mountains, 2 Wide valleys in mountains, hills, and karst, 3 High karst plateaus and hills of carbonate rocks, 4 Hills of non-carbonate rocks, 5 Inter-mountain basins, 6 Low hills in inner Slovenia, 7 Plains and wide valleys in low hills in inner Slovenia, 8 Karst poljes and lowlands, 9 Low karst of Inner Carniola and Lower Carniola, 10 Low karst of White Carniola, 11 Karst and Podgorje Karst plateaus, 12 Low hills in the Littoral, and 13 Wide valleys and plains in the Littoral. ➤ p. 26

Figure 14: Updated map of the Špes et al. landscape typology of Slovenia. ➤ p. 27


Pokrajinskoekološki tipi v Sloveniji
Pokrajinskoekološki tipi
1. Visokogorski svet
2. Širše rečne doline v visokogorju, hribovju in na krasu
3. Visoke kraške planote in hribovja v karbonatnih kamninah
4. Hribovja v pretežno nekarbonatnih kamninah
5. Medgorske kotline
6. Gričevje v notranjem delu Slovenije
7. Ravnine in širše doline v gričevju notranjega dela Slovenije
8. Kraška polja in podolja
9. Nizki kras Notranjske in Dolenjske
10. Nizki kras Bele krajine
11. Kras in podgorski kras
12. Gričevje v primorskem delu Slovenije
13. Širše doline in obalne ravnice v primorskem delu Slovenije
0 10 20 30 40 50 km
Kartografa: Dejan Cigale, Jerneja Fridl
JADRANSKO MORJE


Landscape types
Mountains
Wide valleys in mountains, hills, and karst
High karst plateaus and hills of carbonate rocks
Hills of non–carbonate rocks
Inter–mountain basins
Low hills in inner Slovenia
Plains and wide valleys in low hills in inner Slovenia
Karst poljes and lowlands
Low karst of Inner and Lower Carniola
Low karst of White Carniola
Karst Plateau and Podgorje Karst Plateau
Low hills in the Littoral
Wide valleys and plains in the Littoral
0 10 20 30 40 km
Map by: Manca Volk Bahun
Source: RS, Surveying and Mapping Authority
© 2021, ZRC SAZU Anton Melik Geographical Institute
Murska Sobota
Lendava
Ledava
Mura
Gornja Radgona
Lenart v Slovenskih Goricah
Ljutomer
Ormož
MARIBOR
Ptuj
Drava
Dravinja
Slovenska Bistrica
Slovenske Konjice
Rogaška Slatina
Ruše
Radlje ob Dravi
Dravograd
Ravne na Koroškem
Slovenj Gradec
Črna na Koroškem
Velenje
Žalec
Celje
Šentjur
Sotla
Mozirje
Savinja
Trbovlje
Hrastnik
Laško
Zagorje ob Savi
Sevnica
Krško
Brežice
Sava
Krka
Kamnik
Domžale
Mengeš
Litija
LJUBLJANA
Grosuplje
Trebnje
Novo Mesto
Metlika
Črnomelj
Kolpa
Kočevje
Ribnica
Kranj
Tržič
Radovljica
Škofja Loka
Jesenice
Bled
Bohinjska Bistrica
Železniki
Žiri
Idrija
Idrijca
Cerkno
Kranjska Gora
Bovec
Tolmin
Soča
Vrhnika
Logatec
Cerknica
Postojna
Pivka
Ilirska Bistrica
Reka
Ajdovščina
Nova Gorica
Vipava
Sežana
Koper
Izola
Piran
Adriatic Sea

- *medgorske kotline* 'inter-mountain basins';
- *gričevje v notranjem delu Slovenije* 'low hills in inner Slovenia';
- *ravnine in širše doline v gričevju notranjega dela Slovenije* 'plains and wide valleys in low hills in inner Slovenia';
- *kraška polja in podolja* 'karst poljes and lowlands';
- *nizki kras Notranjske in Dolenjske* 'low karst of Inner Carniola and Lower Carniola';
- *nizki kras Bele krajine* 'low karst of White Carniola';
- *Kras in Podgorski kras* 'Karst and Podgorje Karst plateaus';
- *gričevje v primorskem delu Slovenije* 'low hills in the Littoral'; and
- *širše doline in obalne ravnice v primorskem delu Slovenije* 'wide valleys and plains in the Littoral' as the smallest type, covering 1.2% of Slovenia.

They added a geographical definition to some of the types (e.g., *inner Slovenia* or *Lower Carniola*), and with one type they simply combined the names of two microregions or subunits (i.e., Karst and Podgorje Karst).

Both Ilešič and Špes et al. combined the types and regions to some extent. Ilešič divided the landscape types into smaller regions, and Špes et al. combined smaller regions into landscape ecological types, treating them as relatively homogenous areas that respond similarly to anthropogenic impacts and, as such, are extremely important for environmental vulnerability analyses.

2.5 Perko, Hrvatin, and Ciglič's typology (2013)

The landscape types of all four typologies presented so far represented contiguous and more or less rounded-off polygons on the map. An individual landscape type may have represented only one polygon in one place or it may have appeared in several places, in the form of several spatially separated polygons. However, in the landscape typology produced by Drago Perko, Mauro Hrvatin, and Rok Ciglič in 2013, the landscape types were represented by cells that either touched one another, forming a polygon (i.e., they were contiguous), or were located far from one another (i.e., they were independent).

Based on the spatial overlap of 195 landform units, 938 lithological units, and sixty-five vegetation units, the researchers used the geographical information system to produce a typification at multiple levels with a different number of types, which makes it applicable to various areas and for various purposes. At the most detailed level, as many as 11,889,150 unit combinations were theoretically possible and at the most general level, which relied on the spatial overlap of four landform units, seven lithological units, and seven vegetation units, the number of possible combinations was 196, which was manageable. The combinations formed the basis for defining landscape types. A detailed description of the method and data sources used is provided in the article where this typology was first published (Perko, Hrvatin, and Ciglič 2015). Here, only the most generalized typology, which includes twenty-four landscape types, is provided for illustration.

The researchers used a 25-meter digital elevation model with 32,436,693 cells as the basic GIS layer. At this resolution, all three vector layers were then converted into raster format. This way, each square cell with a 25 m baseline and an area of 6.25 ares was furnished with information on the landform unit, lithological unit, and vegetation unit it belonged to.

Through generalization, the researchers gradually reduced and logically combined the number of smaller units. They produced intermediate typologies of various precision, only retaining four landform units, seven lithological units, and seven vegetation units for the simplest typology at the last level.

The final landform units included:

- Plains;
- Low hills;
- High hills; and
- Mountains.

The combined lithological units included:

- Non-carbonate sediments (clay, silt, sand, silicate gravel);
- Carbonate sediments (carbonate gravel, rubble, till);
- Fine-grained clastic rocks (claystone, siltstone, marl);
- Flysch (sandstone, marl);

- Coarse-grained clastic rocks (carbonate conglomerate, silicate sandstone, conglomerate);
- Carbonate rocks (limestone, dolomite, carbonate clastic rocks); and
- Metamorphic and igneous rocks with tuffs (metamorphic rocks, igneous rock, tuffs, tuffites).

The outcome of the final stage of generalizing vegetation units was as follows:

- Downy oak and sessile oak (occasional European hophornbeam);
- European hornbeam, oak, and red pine (occasional black alder, elm, and fir);
- Beech;
- Beech and fir;
- Beech and European hophornbeam;
- Beech, chestnut, and various oaks; and
- Fir, spruce, and highland vegetation.

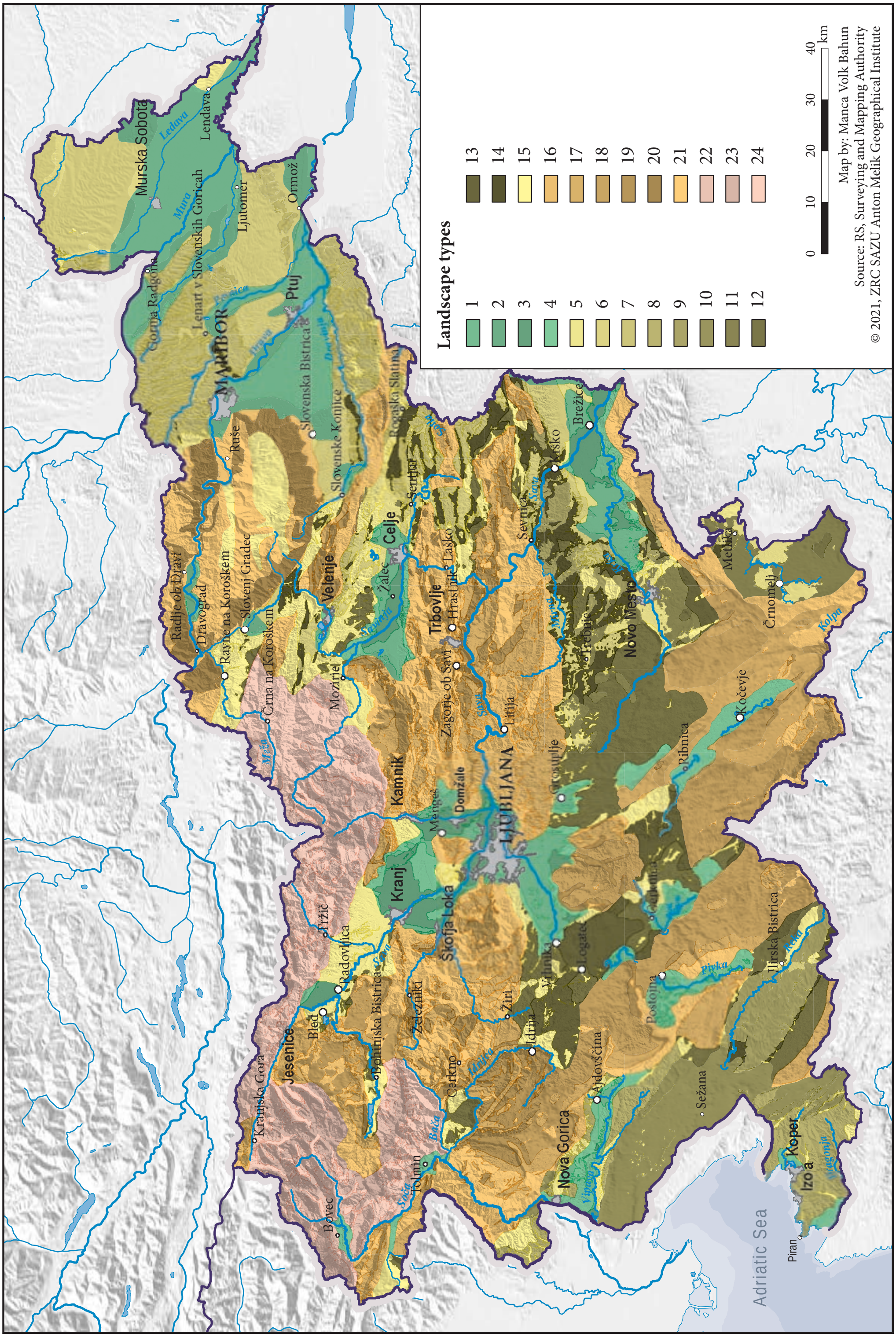
By statistically analyzing the spatial overlap of all three unit types, their combination was determined for each cell. For example, if a cell ranked as low hills in terms of landform unit, as flysch in terms of lithological unit, and as downy oak and sessile oak in terms of vegetation unit, its combination was »low hills + flysch + downy oak, sessile oak.« This means that part of the landscape, which in the GIS virtual reality was represented by this cell, was composed of low hills made of flysch and covered in downy oak and sessile oak.

Combinations with the highest frequency and thus area were defined as important and used for determining the landscape types. Of the 196 unit combinations theoretically possible, 175 were actually identified. The twenty most frequent unit combinations covering nearly two-thirds of Slovenia were defined as landscape types, and the rest were logically categorized under four additional types, in which the landform unit was the key factor.

The landscape types identified were as follows (Figure 15; the number of the type used in the map legend is provided in parentheses):

- *ravnina + nekarbonatne usedline + beli gaber, dob, rdeči bor* 'plains + non-carbonate sediments + European hornbeam, oak, red pine' (1);
- *ravnina + nekarbonatne usedline + bukev, kostanj, hrasti* 'plains + non-carbonate sediments + beech, chestnut, various oaks' (2);
- *ravnina + karbonatne usedline + beli gaber, dob, rdeči bor* 'plains + carbonate sediments + European hornbeam, oak, red pine' (3);
- *ostale ravnine* 'other plains' (4);
- *gričevje + nekarbonatne usedline + beli gaber, dob, rdeči bor* 'low hills + non-carbonate sediments + European hornbeam, oak, red pine' (5) as the smallest type, covering 1.6% of Slovenia;
- *gričevje + nekarbonatne usedline + bukev, kostanj, hrasti* 'low hills + non-carbonate sediments + beech, chestnut, various oaks' (6);
- *gričevje + drobnozrnate klastične kamnine + bukev, kostanj, hrasti* 'low hills + fine clastic rocks + beech, chestnut, various oaks' (7);
- *gričevje + fliš + puhasti hrast, graden* 'low hills + flysch + downy oak, sessile oak' (8);
- *gričevje + fliš + bukev, kostanj, hrasti* 'low hills + flysch + beech, chestnut, various oaks' (9);
- *gričevje + karbonatne kamnine + puhasti hrast, graden* 'low hills + carbonate rocks + downy oak, sessile oak' (10);
- *gričevje + karbonatne kamnine + beli gaber, dob, rdeči bor* 'low hills + carbonate rocks + European hornbeam, oak, red pine' (11);
- *gričevje + karbonatne kamnine + bukev* 'low hills + carbonate rocks + beech' (12);
- *gričevje + karbonatne kamnine + bukev, jelka* 'low hills + carbonate rocks + beech, fir' (13);
- *gričevje + karbonatne kamnine + bukev, kostanj, hrasti* 'low hills + carbonate rocks + beech, chestnut, various oaks' (14);
- *ostala gričevja* 'other low hills' (15);
- *hribovje + grobozrnate klastične kamnine + bukev* 'high hills + coarse clastic rocks + beech' (16);
- *hribovje + karbonatne kamnine + bukev* 'high hills + carbonate rocks + beech' (17);
- *hribovje + karbonatne kamnine + bukev, jelka* 'high hills + carbonate rocks + beech, fir' (18);

Figure 15: Map of the Perko, Hrvatin, and Ciglič landscape typology of Slovenia from 2013 (the type number in the legend corresponds to the type number from the list of types in the text; Perko, Hrvatin, and Ciglič 2013). ➤ p. 30


Landscape types
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Map by: Manca Volk Bahun
Source: RS, Surveying and Mapping Authority
© 2021, ZRC SAZU Anton Melik Geographical Institute
LJUBLJANA
MARIBOR
Murska Sobota
Lendava
Ljutomer
Ormož
Ptuj
Gornja Radgona
Lenart v Slovenskih Goricah
Slovenska Bistrica
Slovenske Konjice
Rogaška Slatina
Ruše
Radlje ob Dravi
Dravograd
Ravne na Koroškem
Slovenj Gradec
Črna na Koroškem
Velenje
Celje
Žalec
Šentjur
Laško
Hrastnik
Trbovlje
Zagorje ob Savi
Litija
Mozirje
Kamnik
Domžale
Mengeš
Kranj
Tržič
Radovljica
Bled
Jesenice
Kranjska Gora
Bohinjska Bistrica
Železniki
Škofja Loka
Žiri
Idrija
Cerkno
Tolmin
Bovec
Nova Gorica
Ajdovščina
Sežana
Koper
Izola
Piran
Adriatic Sea
Postojna
Ilirska Bistrica
Logatec
Vrhnika
Cerknica
Grosuplje
Ribnica
Kočevje
Črnomelj
Metlika
Novo Mesto
Trebnje
Sevnica
Krško
Brežice
Mura
Ledava
Drava
Savinja
Sava
Kolpa
Krka
Soča
Vipava
Idrijca
Bača
Pivka
Reka
Rižana
Pesnica
Dravinja
Sotla
Meža
Ljubljanica

- *hribovje + karbonatne kamnine + bukev, gabrovec* 'high hills + carbonate rocks + beech, European hophornbeam' (19);
- *hribovje + metamorfne in magmatske kamnine s tufi + bukev, kostanj, hrasti* 'high hills + metamorphic and igneous rocks with tuffs + beech, chestnut, various oaks' (20);
- *ostala hribovja* 'other high hills' (21) as the largest type, covering 14.9% of Slovenia;
- *gorovje + karbonatne kamnine + bukev* 'mountains + carbonate rocks + beech' (22);
- *gorovje + karbonatne kamnine + jelka, smreka, visokogorsko rastje* 'mountains + carbonate rocks + fir, spruce, highland vegetation' (23); and
- *ostala gorovja* 'other mountains' (24).

Because the typology was completely computerized, an important part of the typification process was dedicated to testing it on the ground. The researchers first checked a few test areas by themselves and then, based on their experience, selected five test cases on wooded land and five on neighboring, already cleared land for each of the twenty-four landscape types. They also developed a suitable procedure and information form for the geographical institute's researchers that visited and checked the test areas. Fieldwork was documented through written reports, photos, drawings, and other material.

The researchers conceive the landscape types defined and tested in the manner described above as relatively homogenous natural spatial units that have a similar impact on social landscape elements, respond similarly to human-induced changes, and require similar protection.

According to Perko, Hrvatin, and Ciglič, the main advantage of their typology is its flexibility because, on the one hand, organizing data in GIS allows constant updates, additions, and expansions, and, on the other, relatively fast and simple creation of landscape typologies at various levels, with various precision, a different number of types, and for various purposes.

2.6 Comparing the macrotypologies

A great deal of similarity can be established between the macrotypologies of Slovenia presented, but also several important differences (Table 1).

Melik and Ilešič only presented tentative criteria for dividing the territory into types, whereas in the other three typologies the criteria were significantly more refined and other methodological approaches to typification were also comprehensibly described.

The authors of the four oldest landscape typologies manually drew the boundaries of the landscape types presented as polygons, whereas in the most recent typology the landscape types presented as a set of cells were defined by the computer itself based on the criteria selected by the researchers.

There are also differences in aspects related to the purpose of the typology. Špes et al. advocated the ecological aspect of landscape types because they were interested in their vulnerability. Ilešič adopted a similar approach, whereas Melik emphasized the economic aspect because he viewed landscape types through the prism of economic development opportunities. These aspects are also evident from the types' names (Table 1).

Three approaches to hierarchizing and combining types and regions can be observed: Ilešič divided the types at the lowest level into regions, Špes et al. combined similar smaller regions into types, and Perko combined the types and regions at the same levels. In addition, the researchers combined the elements of regionalization with their typologies in other ways. Melik almost never mixed types and regions in the typology itself, but in his descriptions of individual types he consistently listed the microregions into which he divided the types. In turn, Ilešič practically augmented his typology with regionalization: his units at the first and second levels are types and his units at the lower levels are regions.

The fewest types were defined by Melik (eight) and the most by Perko, Hrvatin, and Ciglič (twenty-four, or three times as many). The greatest imbalance in size between the largest and smallest types can be found in Ilešič's typology, where the largest type is over forty times larger than the smallest one. The smallest difference can be observed in Perko's typology, where the largest type is only seven times larger than the smallest one.

The three most recent typologies were partly or fully produced using a geographic information system. Perko and Špes et al. converted the data into raster format using a 100-meter digital elevation model, and the authors of the most recent typology used 25-meter digital elevation model.

To establish similarities between the typologies (Figures 16 to 24), ten contingency tables were created to compare each typology with all the others (ten tables was the maximum number possible for five typologies). The frequency (area) of all types within one typology was determined across all types of the other four typologies and vice versa. Thus, for example, the landscape ecological type mountains in Špes et al.'s typology can be categorized in full under the landscape type Alpine mountains in Perko's typology and, vice versa, the landscape type Alpine mountains in Perko's typology can be categorized under five landscape ecological types in Špes et al.'s typology (about six-tenths under the type mountains and one-tenth under four other types).

Table 1: Comparison of macrotypologies of Slovenia.

Authors	Year	Typology described as	Terminology used for *type*	No. of basic types	Average basic type size (km^2)	Ratio between largest and smallest basic types	Resolution (m)
Melik	1946	Natural--economic	natural component part	8	2,534	19:1	–
Ilešič	1958	Landscape--typological and ecological	landscape type ecological area	11	1,843	41:1	–
Perko	1996	Landscape	landscape type	9	2,252	7:1	100
Špes et al.	2002	Landscape ecological	landscape ecological type	13	1,559	18:1	100
Perko, Hrvatin, and Ciglič	2013	Landscape	landscape type	24	845	9:1	25


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Figure 16: According to the 1996 geographical regionalization of Slovenia produced by Perko et al., the Sava Hills constitute the largest Slovenian region (Perko 1998a; Perko and Ciglič 2020b). Melik largely included the Sava Hills under hills (Melik 1946), Ilešič largely under eastern sub-Alpine landscapes (Ilešič 1972), Perko in full under Alpine hills (Perko and Ciglič 2020a), and Špes et al. mostly under hills of non-carbonate rocks (Špes et al. 2002).

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Figure 17: The Julian Alps are the northwesternmost region in Slovenia (Perko 1998a). Melik largely included the Julian Alps under high Alpine mountains (Melik 1946), Ilešič largely under western Alpine landscapes (Ilešič 1972), Perko in full under Alpine hills (Perko and Ciglič 2020a), and Špes et al. mostly under mountains (Špes et al. 2002). The picture in front shows the Sava River and the town of Jesenice.

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Figure 18: The Sava Plain region (Perko 1998a) occupies the northern part of the Ljubljana Basin. Melik mostly included the Sava Plain under plains and wide valleys (Melik 1946), Ilešič mostly under western sub-Alpine landscapes (Ilešič 1972), Perko in full under Alpine plains (Perko and Ciglič 2020a), and Špes et al. in full under inter-mountain basins (Špes et al. 2002). The picture shows the northeastern part of the region with Lake Bled.

Figure 19: The Slovenian Hills is the largest Pannonian region (Perko 1998a). Melik included the Slovenian Hills in full under low hills (Melik 1946), Ilešič in full under sub-Pannonian landscapes (Ilešič 1972), Perko in full under Pannonian low hills (Perko and Ciglič 2020a), and Špes et al. largely under low hills in inner Slovenia (Špes et al. 2002). All Slovenian Pannonian low hills are characterized by vineyards.

Figure 20: The Mura Plain region (Perko 1998a) is characterized by the interchange of fertile fields and often flooded forests along river meanders. Melik included the Mura Plain in full under plains and wide valleys (Melik 1946), Ilešič in full under sub-Pannonian landscapes (Ilešič 1972), Perko in full under Pannonian plains (Perko and Ciglič 2020a), and Špes et al. in full under plains and wide valleys in low hills in inner Slovenia (Špes et al. 2002).

Figure 21: In the middle of the Inner Carniola Lowland region (Perko 1998a) lies well-known intermittent Lake Cerknica. Melik mostly included the Inner Carniola Lowland under karst hills with low plateaus and lowlands (Melik 1946), Ilešič in full under karst landscapes of inner Slovenia (Ilešič 1972), Perko in full under Dinaric lowlands (Perko and Ciglič 2020a), and Špes et al. largely under karst poljes and lowlands (Špes et al. 2002).

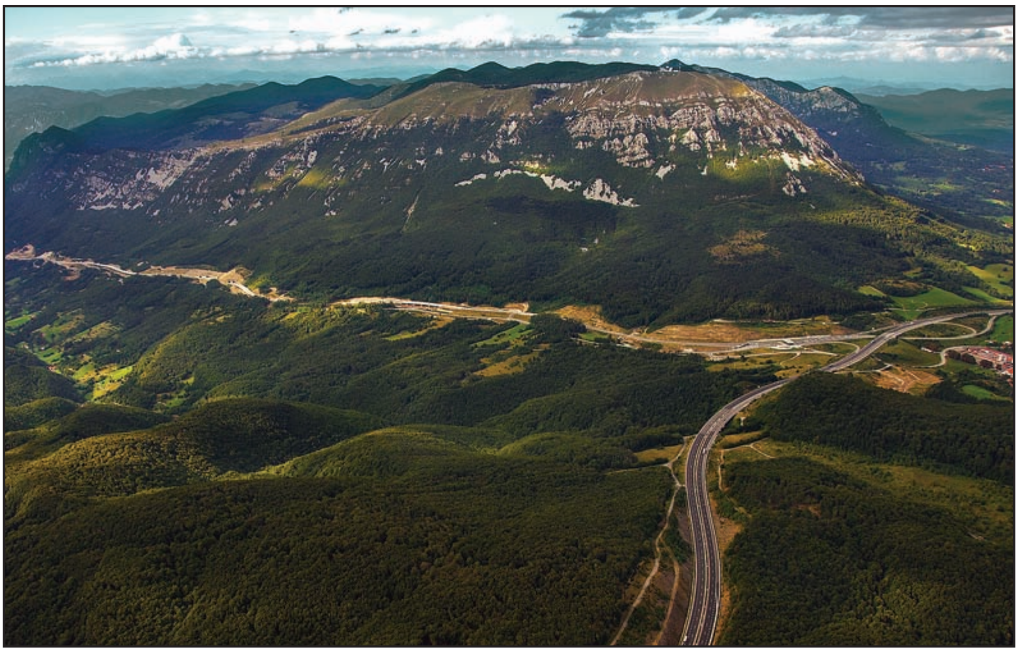

Figure 22: South of the Nanos Plateau, the freeways branch off to Trieste to the south and Gorizia to the west. Melik included the Nanos Plateau in full under Dinaric high plateaus (Melik 1946), Ilešič in full under karst landscapes of inner Slovenia (Ilešič 1972), Perko in full under Dinaric plateaus (Perko and Ciglič 2020a), and Špes et al. in full under high karst plateaus and hills of carbonate rocks (Špes et al. 2002).

Figure 23: The Brkini Hills region on the edge of the Mediterranean is characterized by a cultural terraced landscape. Melik included the Brkini Hills in full under hills (Melik 1946), Ilešič in full under sub-Mediterranean–Dinaric landscapes (Ilešič 1972), Perko in full under Mediterranean low hills (Perko and Ciglič 2020a), and Špes et al. in full under hills of non-carbonate rocks (Špes et al. 2002).

Figure 24: The Podgrad Lowland is a karst region south of the Brkini Hills, less than 30 km from the Adriatic coast. Melik included the Podgrad Lowland in full under karst hills with low plateaus and lowlands (Melik 1946), Ilešič in full under sub-Mediterranean–Dinaric landscapes (Ilešič 1972), Perko in full under Mediterranean plateaus (Perko and Ciglič 2020a), and Špes et al. in full under karst poljes and lowlands (Špes et al. 2002).

Correlation coefficients were calculated. The higher they are, the more similar two typologies are and to a lesser extent the types of one typology are scattered across the types of the other.

The greatest similarity was established between Ilešič's and Perko's typologies, with a correlation coefficient of 0.8302, and the smallest similarity was determined between Ilešič's and Perko, Hrvatin, and Ciglič's typologies (0.4978).

All the typologies have the highest correlation coefficients with Perko's typology: the coefficient established for Melik's typology was 0.7622, for Ilešič's typology it was 0.8302, for Špes et al. it was 0.7393, and for Perko, Hrvatin, and Ciglič it was 0.6819. Therefore, to present Slovenia's basic landscape characteristics, an overview of landscape types in Perko's typology is added below (Table 2).

On average, Perko's typology has the highest correlation coefficient (0.7534), followed by that of Špes et al. (0.6812), Ilešič (0.6796), and Melik (0.6596). Perko, Hrvatin, and Ciglič's typology has the lowest coefficient (0.5782), which makes sense because it uses a different methodology than the four older typologies.

The correlation coefficients between individual macrotypologies are not low, which suggests that the macrotypologies of Slovenia differ from one another in finer details but are similar in general. Their similarity to the macrotypologies of Slovenia produced by researchers from abroad is discussed in the next section.

Table 2: Some basic characteristics of the landscape types in Perko's typology (updated based on Perko and Ciglič 2020a). ➤ p. 38–41

Variable	Landscape type group	
	Alpine landscapes	Pannonian landscapes
Area (km^2)	8,540.95	4,291.51
% of area	42.13	21.17
Mean elevation (m)	731.90	260.61
Mean inclination (°)	20.18	7.48
Most frequent rock type	limestone 17.17%; dolomite 13.40%; carbonate gravel, rubble, and till 13.34%; silicate sandstone and conglomerate 11.03%	clay and silt 30.66%; marl 20.96%; silicate gravel 19.13%; sand 14.65%
Most frequent vegetation type	beech 42.53%; beech, chestnut, and various oaks 19.17%; beech and hophornbeam 10.82%	beech, chestnut, and various oaks 65.53%; hornbeam and pedunculate oak 16.37%; hornbeam 10.03%
Insolation (MJ/m^2)	3,876.93	4,145.64
% of fields	4.23	30.61
% of vineyards	0.09	2.16
% of orchards	1.50	2.83
% of meadows and pastures	18.44	19.02
% of forests	66.88	36.72
% of built-up areas	4,68	7,43
Average landscape diversity	0.182028	0.151146
% of hotspot area	13.68	6.00
% of coldspot area	3.35	7.78
Population in 1931	561,090	439,367
% of population in 1931	40.15	31.44
Population in 1961	696,945	497,312
% of population in 1961	43.79	31.25
Population growth index, 1931–1961	124.21	113.19
Population in 1991	924,174	547,787
% of population in 1991	47.01	27.86
Population growth index, 1931–1991	164.83	124.52
Population growth index, 1961–1991	132.70	110.01
Population in 2011	959,695	540,148
% of population in 2011	46.81	26.35
Population density in 2011 (people per km^2)	112,36	125,86
Population growth index, 1931–2011	171.04	122.94
Population growth index, 1991–2011	103.77	98.73
Number of settlements in 2011	2,237	1,636
Settlement density in 2011 (number per 100 km^2)	26.19	38.12
Average size of settlement in 2011 (people per settlement)	429.01	330.16
Population in 2017 by houses	1,032,122	574,203

Landscape type group		
Dinaric landscapes	Mediterranean landscapes	Slovenia
5,706.25	1,734.29	20,273.30
28.15	8.55	100.00
579.91	351.74	556.83
12.70	11.22	14.62
limestone 54.66%; dolomite 21.17%; clay and silt 11.07%	flysch 45.95%; limestone 37.83%	limestone 26.67%; clay and silt 13.13%; dolomite 12.39%
beech 35.36%; beech and fir 29.78%; hornbeam and fir 12.80%	downy oak and hophornbeam 31.20%; downy oak 16.82%; beech, chestnut, and various oaks 16.04%; sessile oak 15.07%; beech 14.57%	beech 29.53%; beech, chestnut, and various oaks 24.94%
4,006.00	4,376.02	4,012.84
3.84	4.37	9.71
0.30	4.16	0.94
0.83	3.46	1.76
17.91	19.08	18.47
73.33	62.10	61.90
3,31	6,17	5,01
0.147703	0.141510	0.162362
3.86	2.48	8.33
14.89	19.34	8.90
238,274	158,919	1,397,650
17.05	11.37	100.00
253,909	143,357	1,591,523
15.95	9.01	100.00
106.56	90.21	113.87
309,492	184,533	1,965,986
15.74	9.39	100.00
129.89	116.12	140.66
121.89	128.72	123.53
352,941	197,405	2,050,189
17.22	9.63	100.00
61,85	113,82	101,13
148.12	124.22	146.69
114.04	106.98	104.28
1,642	515	6,030
28.78	29.70	29.74
214.95	383.31	340.00
381,404	212,550	2,200,279

Variable	Landscape type			
	Alpine mountains	Alpine hills	Alpine plains	Pannonian low hills
Area (km²)	3,061.77	4,659.97	819.21	2,994.52
% of area	15.10	22.99	4.04	14.77
Mean elevation (m)	1,055.45	582.38	373.09	288.77
Mean inclination (°)	26.24	18.94	4.56	10.29
Most frequent rock type	limestone 37.22%; carbonate gravel, rubble, and till 19.67%; dolomite 14.38%	silicate sandstone and conglomerate 17.26%; metamorphic rocks 16.57%; dolomite 14.87%	carbonate gravel, rubble, and till 51.70%; clay and silt 21.62%; carbonate conglomerate 15.40%	clay and silt 31.10%; marl 29.71%; sand 20.26%
Most frequent vegetation type	beech 49.42%; dwarf pine and other highland vegetation 12.92%; beech and fir 12.10%; beech and hophornbeam 11.48%	beech 41.85%; beech, chestnut, and various oaks 31.37%; beech and hophornbeam 12.25%	hornbeam 65.33%; beech 20.69%; red pine 10.51%	beech, chestnut, and various oaks 88.18%
Insolation (MJ/m²)	3,705.84	3,953.62	4,080.05	4,131.55
% of fields	0.53	3.11	24.43	21.23
% of vineyards	0.00	0.17	0.01	3.00
% of orchards	0.49	2.18	1.40	3.55
% of meadows and pastures	12.68	21.74	21.17	22.97
% of forests	74.38	68.12	31.79	43.07
% of built-up areas	1.64	4.03	19.74	5.56
Average landscape diversity	0.183556	0.182367	0.174393	0.154415
% of hotspot area	12.46	14.10	15.84	6.31
% of coldspot area	1.21	3.35	11.37	3.80
Population in 1931	82,906	263,809	210,332	258,404
% of population in 1931	5.93	18.88	15.05	18.49
Population in 1961	89,621	292,985	314,339	256,737
% of population in 1961	5.63	18.41	19.75	16.13
Population growth index, 1931–1961	108.79	112.32	144.28	100.08
Population in 1991	92,224	338,344	493,606	252,074
% of population in 1991	4.69	17.21	25.11	12.82
Population growth index, 1931–1991	111.95	129.98	226.56	96.04
Population growth index, 1961–1991	102.90	115.71	157.03	95.96
Population in 2011	89,581	354,244	515,870	251,208
% of population in 2011	4.37	17.28	25.16	12.25
Population density in 2011 (people per km²)	29.26	76.02	629.72	83.89
Population growth index, 1931–2011	108.74	135.81	236.77	97.92
Population growth index, 1991–2011	97.13	104.49	104.51	101.96
Number of settlements in 2011	303	1528	406	1252
Settlement density in 2011 (number per 100 km²)	9.90	32.79	49.56	41.81
Average size of settlement in 2011 (people per settlement)	295.65	231.84	1270.62	200.65
Population in 2017 by houses	95,134	398,339	538,649	282,718

Landscape type				
Pannonian plains	Dinaric plateaus	Dinaric lowlands	Mediterranean low hills	Mediterranean plateaus
1,296.99	3,809.32	1,896.93	1,061.02	673.27
6.40	18.79	9.36	5.23	3.32
195.59	668.09	402.83	305.11	425.22
1.00	15.24	7.61	12.66	8.94
silicate gravel 59.62%; clay and silt 20.65%	limestone 59.13%; dolomite 24.29%	limestone 45.69%; clay and silt 28.29%; dolomite 14.90%	flysch 71.56%; clay and silt 13.75%; limestone 10.10%	limestone 82.52%; dolomite 11.22%
hornbeam and pedunculate oak 44.44%; hornbeam 24.22%, pedunculate oak 17.40%; beech, chestnut, and various oaks 13.23%	beech 39.01%; beech and fir 38.65%; beech and hophornbeam 10.02%	hornbeam and fir 32.42%; beech 28.03%; hornbeam and pedunculate oak 13.65%; beech and fir 11.97%	downy oak 26.45%; beech, chestnut, and various oaks 25.66%, sessile oak 20.77%; beech 10.72%	downy oak and hophornbeam 69.80%; beech 20.64%
4,178.22	3,947.64	4,123.22	4,372.86	4,381.01
52.26	1.26	9.02	6.18	1.51
0.22	0.24	0.40	6.03	1.21
1.16	0.61	1.26	5.37	0.46
9.89	12.87	28.02	1.81	24.23
22.06	83.21	53.51	57.89	68.74
11.75	1.47	7.02	7.80	3.61
0.143597	0.144251	0.154634	0.149312	0.129215
5.31	3.20	5.17	3.86	0.29
16.98	16.37	11.90	14.18	27.46
182,780	102,324	137,160	129,568	30,367
13.08	7.32	9.81	9.27	2.17
240,575	77,143	176,766	120,570	22,787
15.12	4.85	11.11	7.58	1.43
131.59	75.18	130.30	93.65	75.52
295,713	63,940	245,552	160,791	23,742
15.04	3.25	12.49	8.18	1.21
164.49	62.36	180.97	124.89	78.68
125.01	82.95	138.88	133.36	104.19
288,940	65,565	287,376	172,369	25,036
14.09	3.20	14.02	8.41	1.22
222.78	17.21	151.50	162.46	37.19
158.04	63.90	211.83	133.88	82.97
96.08	102.46	117.06	107.20	105.45
384	809	833	380	135
29.61	21.24	43.91	35.81	20.05
752.45	81.04	344.99	453.60	185.45
291,485	77,076	304,328	183,488	29,062

3 Slovenia in European macrotypologies

All the authors of the landscape typologies discussed (Melik 1946; Ilešič 1958; Perko 1998a; Špes et al. 2002; Perko, Hrvatin, and Ciglič 2015) and other Slovenian geographers highlight the landscape diversity of Slovenia's small territory, resulting from its location at the intersection of four major European geographical units: the Alps, the Pannonian Basin, the Dinaric Alps, and the Mediterranean (Melik 1935; Gams 1998; Kladnik and Perko 1998; Plut 1999; Perko, Hrvatin, and Ciglič 2017; Perko, Ciglič, and Zorn 2020b). The landscape and similar divisions of Europe that also include Slovenia reveal how the country is viewed by professionals outside Slovenia.

Nine such classifications of Europe were reviewed to examine which macrounits Slovenia is categorized under and to what extent these divisions are similar to Slovenian landscape typologies. They include:
1. The Environmental Stratification of Europe (Mücher et al. 2003; Metzger et al. 2005; Jongman et al. 2006);
2. The European Landscape Classification (LANMAP2; Mücher et al. 2003; Mücher et al. 2006; Mücher et al. 2010);
3. The Digital Map of European Ecological Regions (DMEER 2003);
4. Biogeographical Regions (2016);
5. The Physical-Geographical Classification of Europe (Germ. *Physisch-geographische Gliederung Europas*; Bohn et al. 2003);
6. The Pan-European Landscape Types (Meeus 1995);
7. The Terrestrial Ecoregions of the World (Olson et al. 2001);
8. The Biogeographical Provinces of Europe (European Environment Agency 1995); and
9. The Biogeographic Map of Europe (Rivas-Marínez, Penas and Díaz 2004b) and Bioclimatic Map of Europe (Rivas-Marínez, Penas and Díaz 2004a).

Older classifications of Europe were still produced in a more traditional and subjective manner (Mücher et al. 2003), whereas more recent ones (e.g., the Environmental Stratification of Europe and the European Landscape Classification) were produced using geographic information systems and digital data layers. The size of the basic spatial data unit (cell) of some is only 1 km². A detailed description of all nine classifications is provided in Ciglič and Perko (2012). For easier comparison between the typologies, Slovenia's territory is displayed at the same scale on all the maps (Figures 25 to 34).

3.1 Environmental Stratification of Europe

A group of researchers (Mücher et al. 2003; Metzger et al. 2005; Jongman et al. 2006) used quantitative methods and digital data on natural factors (elevation, slope, proximity of the ocean, latitude, and various climatic factors) to produce an environmental stratification of Europe with a resolution of 1 km².

They defined eighty-four environmental classes and combined them into thirteen environmental zones, which were further combined into six biogeographical regions. Including islands in the Atlantic Ocean, the stratification comprises fourteen zones and seven regions.

Slovenia is categorized under three of the six environmental regions: Alpine, Mediterranean, and Continental (Figure 25), and under five of the thirteen environmental zones: Alpine south, Mediterranean mountains, Mediterranean north, Pannonian, and Continental. At the lowest level, twelve of the eighty-four classes can be identified in Slovenia (Metzger et al. 2005).

3.2 European Landscape Classification

This classification was produced based on climate, elevation, soil, and land-use data. Major urban areas, water surfaces, and tide areas were specified separately (Mücher et al. 2006).

The authors defined eight types at the first level, thirty-one at the second level, and seventy-six at the third level, and they specified 350 landscape types at the lowest (i.e., fourth) level (Mücher et al. 2006).

At the first level, Slovenia is classified under three types: Mediterranean, Continental, and Alpine (Figure 26). Practically the entire country lies in the Mediterranean type but, interestingly, the Gorizia Hills, a typical Mediterranean landscape, are part of the Alpine type. At the second level, Slovenia includes eight types (without separately defined urban areas of Ljubljana and Maribor). The third level includes twelve of a total of seventy-six types, and the final, fourth level includes nineteen of a total of 350.

3.3 Digital Map of European Ecological Regions

This digital map was produced based on climate, topography, and geobotanical data. The authors' goal was to present areas with homogenous ecological conditions. This typology relies heavily on vegetation, with ecological regions largely named after the type of vegetation (Mücher et al. 2003; DMEER 2003).

It includes sixty-eight European ecological regions (DMEER 2003). On the map (Figure 27), Slovenia lies in four units and borders one: Dinaric mountains mixed forests, Illyrian deciduous forests, Alpine coniferous and mixed forests, Pannonian mixed forests, and Po river Basin mixed forests.

3.4 Biogeographical Regions

Biogeographical regions were specified for the purposes of the Natura 2000 network, as stipulated in Council Directive 92/43/EEC. This is the first time that non-administrative borders were defined in an official EU document (Mücher žet al. 2003). The last version is from 2016. Earlier versions were based on combining natural vegetation in the member states of the European Community and the Council of Europe (Noirfalise 1987). Forest communities were combined into biogeographical regions, and the map was generalized. Later versions also used the Map of Potential Vegetation produced by the German Federal Agency for Nature Conservation (The indicative map … 1996).

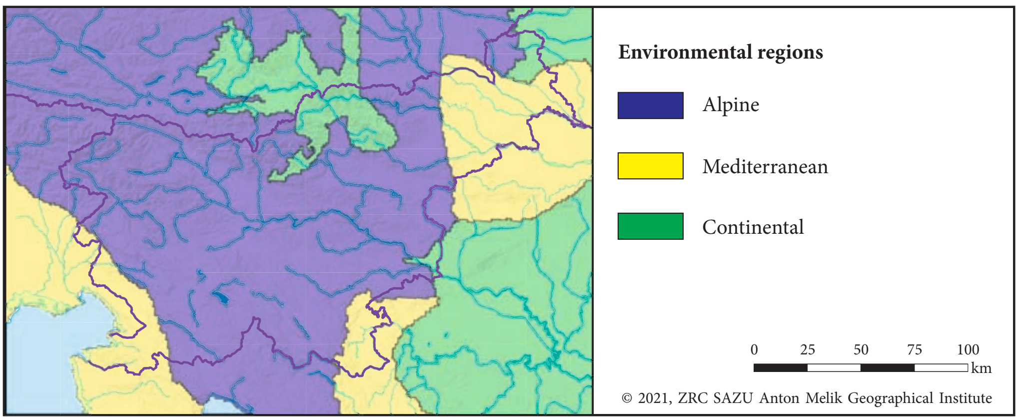

Figure 25: Environmental Stratification of Europe, level 2 (Metzger et al. 2005, Jongman et al. 2006).

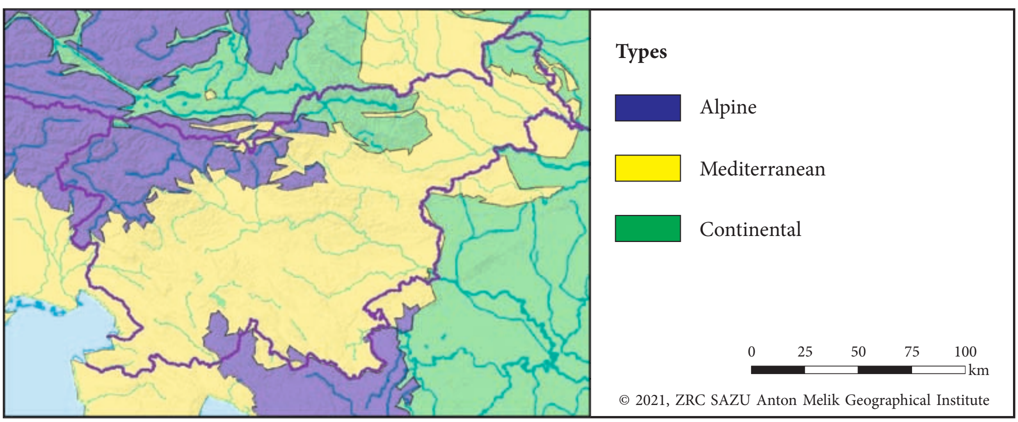

Figure 26: European Landscape Classification, level 1 (Mücher et al. 2003, 2006, 2010).

The 2016 classification includes eleven biogeographical regions. It relies on natural vegetation, but some boundaries also run along administrative (national) borders, which is why it deviates from a completely natural division.

According to the 2016 division, Slovenia is part of the Continental and Alpine regions, bordering the Pannonian region to the northeast and the Mediterranean region to the southwest (Figure 28).

3.5 Physical-Geographical Classification of Europe

The German Federal Agency for Nature Conservation produced a physical-geographical classification of Europe (Germ. *Physisch-geographische Gliederung Europas*) based on climate, rocks, and soil, which formed the basis for the 1:2,500,000 *Map of Natural Vegetation of Europe* (Germ. *Karte der natürlichen Vegetation Europas*).

Europe was divided into four subcontinents (Germ. *Subkontinent*): Northern Europe (*Nordeuropa*), Western and Central Europe (*West- und Mitteleuropa*), Southern Europe (*Südeuropa*), and Eastern Europe (*Osteuropa*). These were then divided into nine major areas (*Großraum*) and forty-seven physical-geographical regions (*physisch-geographische Region*), which were further divided into subunits or subregions (Bohn et al. 2003).

Slovenia is part of two subcontinents (i.e., Western and Central Europe, and Southern Europe), three major areas (Alpine, Carpathian, and Mediterranean; Figure 29), and four regions (the Alps, the North Italian Plain, the Pannonian Basin, and the Balkan Peninsula).

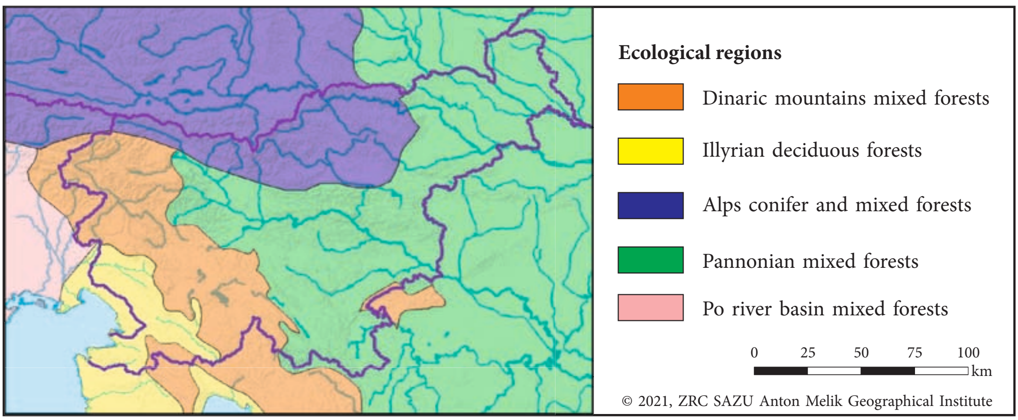

Figure 27: European ecological regions (DMEER 2003).

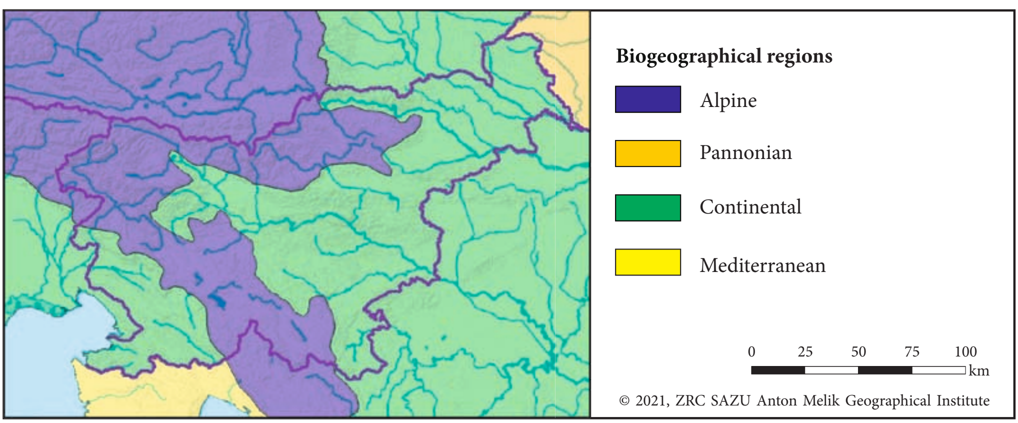

Figure 28: Biogeographical Regions, 2016 version.

3.6 Pan-European Landscape Types

Meeus (1995) produced a map of pan-European landscape types based on landforms (as a consequence of the rock base and climate), economic land-use potential, sustainability of human activity, nature conservation, settlement pattern, field pattern, visual impression, and the quality of the view.

The typology includes thirty landscape types combined into nine groups. Worth mentioning among them is the group Regional landscapes, which comprises types that only appear in one or several places thanks to their exceptional natural or cultural features (Meeus 1995).

Nearly all of Slovenia falls under a single landscape type: Mediterranean semi-bocage (Figure 30). The French word *bocage* denotes a landscape of mixed farmland and forests or trees. This type is characterized by a Mediterranean climate, diverse land use, and the predominance of rural settlements (Meeus 1995). Three other types can be found on the edges of Slovenia and its immediate vicinity: the Collective open field in the east, the Delta type in the west, and the Mountain type in the north (Meeus 1995).

3.7 Terrestrial Ecoregions of the World

This map was produced based on the biogeographical characteristics of landscapes around the world. Ecoregions are characterized by special combinations of natural communities and species. The borders

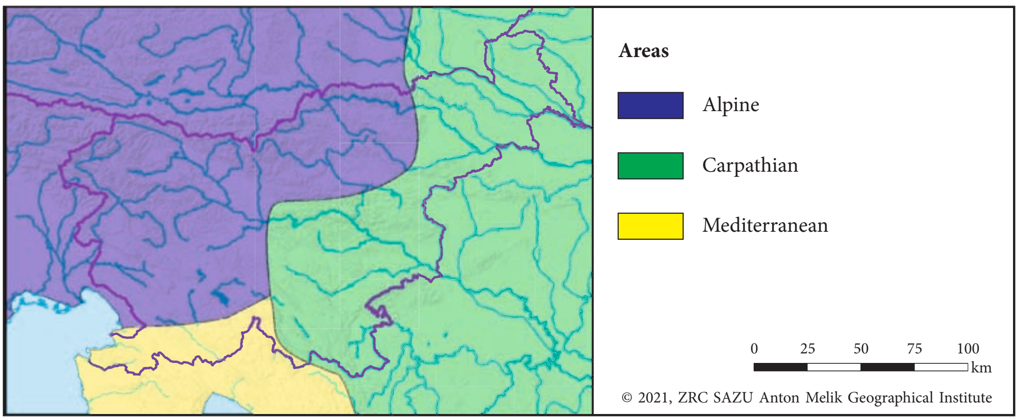

Figure 29: Physical-Geographical Classification of Europe, level 2 (Bohn et al. 2003).

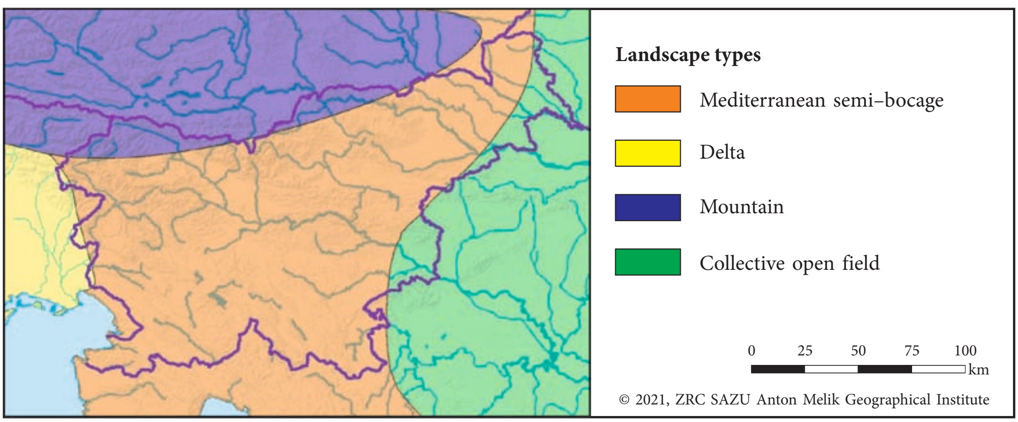

Figure 30: Pan-European Landscape Types, level 1 (Meeus 1995).

between these areas match the natural conditions prior to major changes introduced by man. The Digital Map of European Ecological Regions (see Section 3.3) was used to identify units in Europe. In areas for which no biogeographical divisions were found, the authors relied on landforms and vegetation (Olson et al. 2001).

The terrestrial part of the world was divided into eight geographical realms and fourteen biomes. Within these, the authors further defined 867 ecoregions (Olson et al. 2001).

At the level of biomes, of the fourteen in the world and eight in Europe, three are present in Slovenia: Mediterranean forests, woodland and scrub, temperate broadleaf and mixed forests, and temperate coniferous forests (Figure 31). Ecoregions in Slovenia or its immediate vicinity include Pannonian mixed forests, Dinaric mountains mixed forests, Illyrian deciduous forests, Alpine coniferous and mixed forests, and Po basin mixed forests.

3.8 Biogeographical Provinces of Europe

The *Europe's Environment* report of 1995 used biogeographical provinces of the world, which were based on Udvardy's Classification of the Biogeographical Provinces of the World (1975).

Europe is divided into nineteen provinces. The classification also covers northern Africa, Turkey, and the area east of the Caspian Sea. In addition to Europe's biogeographical provinces, the report also showed four EU biogeographical zones covering the territory of the EU at that time. Nearly all units are named

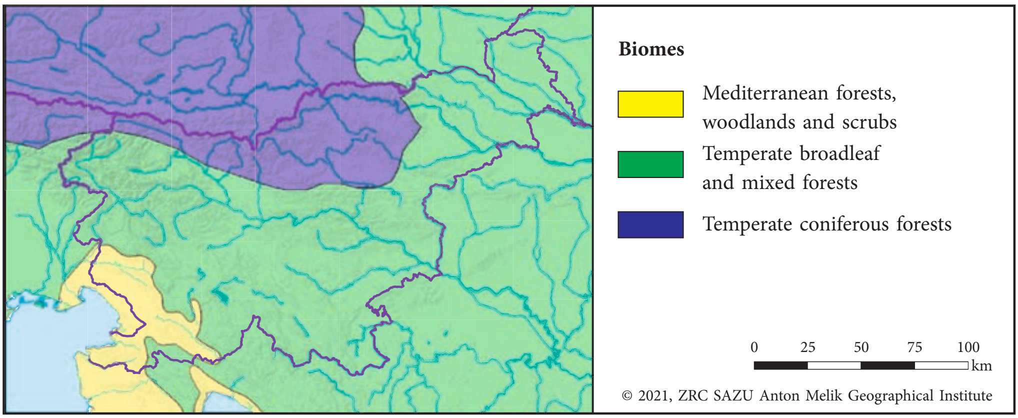

Figure 31: Terrestrial Ecoregions of the World, level 2 (Olson et al. 2001).

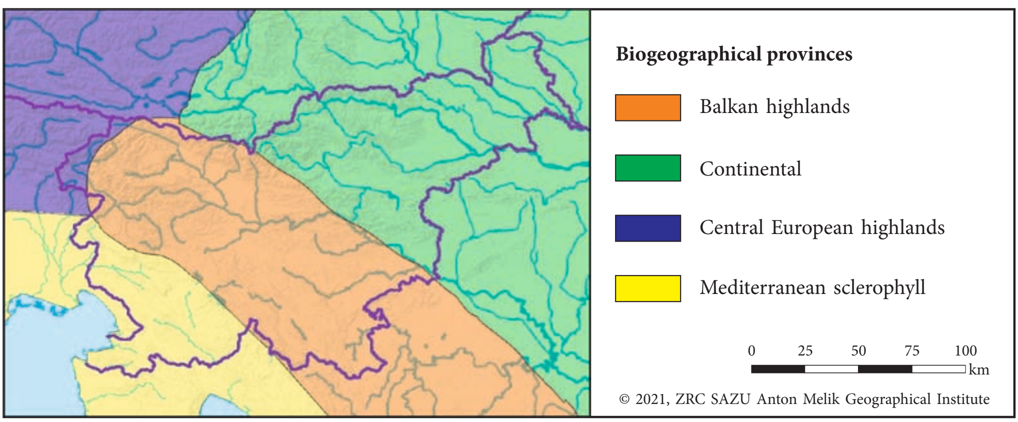

Figure 32: Biogeographical Provinces of Europe, level 2 (European Environment Agency 1995).

after geographical names and occur only once, which makes this more of a regionalization than a typification (European Environment Agency 1995).

Slovenia is part of four provinces: Balkan highlands, Continental, Mediterranean sclerophyll, and Central European highlands (Figure 32).

3.9 The Biogeographic Map of Europe and the Bioclimatic Map of Europe

Rivas-Martínez, Penas, and Díaz (2004b) produced an extensive biogeographical map of Europe, which covers the area from the Arabian Peninsula and the Caspian Sea to the Canary Islands, Spitsbergen, Novaya Zemlya, and Franz Josef Land.

It includes five regions: Circumarctic, Eurosiberian, Mediterranean, Irano-Turanian, and Saharo-Arabian. The first two regions are further divided into three subregions each. The third level includes thirty provinces, and the last (i.e., fourth) level includes seventy-two sectors. The higher levels can be considered more as a typification and the lower levels more as a regionalization.

All of Slovenia is part of the Eurosiberian region and the Alpino-Caucasian subregion, which is further divided into the Alpine province and the Apennino-Balkan province (Figure 33). At the lowest level, it belongs to the Eastern Alpine, Illyrian, and Padanian sectors.

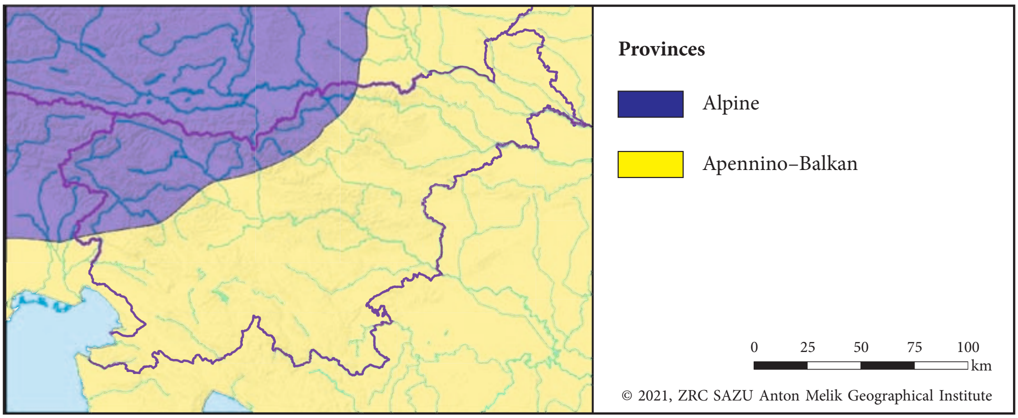

Figure 33: Biogeographic Map of Europe, level 3 (Rivas-Martínez, Penas, and Díaz 2004b).

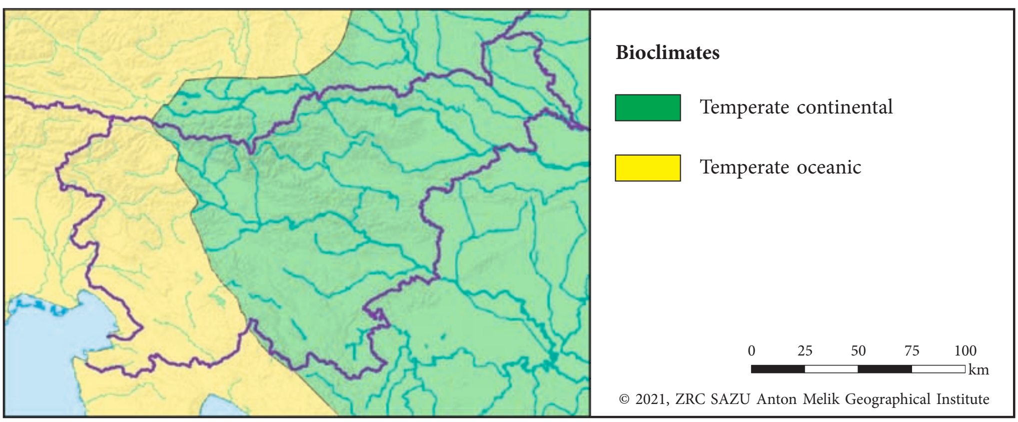

Figure 34: Bioclimatic Map of Europe, level 2 (Rivas-Martínez, Penas, and Díaz 2004a).

Rivas-Martínez, Penas, and Díaz (2004a) also produced the Bioclimatic Map of Europe, which contains three levels and is based on climatic features.

Europe is divided into four macrobioclimates, which are further divided into sixteen bioclimates with certain variants for some.

Western Slovenia is part of the Temperate Oceanic bioclimate and eastern Slovenia is part of the Temperate Continental bioclimate (Figure 34). The border between them runs in the Dinaric direction from the northwest toward the southeast. Taking into account both maps provides a better idea of the natural conditions in Slovenia.

3.10 Comparing the European divisions

In terms of the levels of the divisions presented on the maps (Figures 25 to 33), Slovenia is most often (i.e., in four divisions) found in three types (classes), in three divisions it is found in four types, and in two divisions it is found in two and five types, respectively.

In an individual typology, the highest share of all types in Slovenia appears in the Environmental Stratification of Europe (Metzger et al. 2005; Jongman et al. 2006): three of a total of six types (i.e., half), which theoretically corresponds to 148 types per million km² of the country's area. Estonia, which is twice the size of Slovenia, has only one type, which corresponds to twenty-two types per million km² of its territory or nearly seven times fewer types than Slovenia. Italy, which is fifteen times larger than Slovenia, has two types, which means only seven types per million km² or that Slovenia has twenty-one times more types.

The smallest share of all types in Slovenia is found on the Biogeographic Map of Europe (Rivas-Martínez, Penas, and Díaz 2004b) – that is, only two of a total of thirty types, which corresponds to ninety-eight types per million km² or less than a tenth of all types in this classification. Nonetheless, here, too, Slovenia is more diverse than Estonia and Italy. The former has two types, corresponding to forty-four per million km² or half the number of types as in Slovenia, and the latter has five types, corresponding to seventeen per million km² or one-sixth the number of types as in Slovenia.

Similar ratios between Slovenia and other countries also apply to other divisions. In general, in terms of the number of types extending into its territory alone, Slovenia is comparable to the largest European countries, and it even outranks them in terms of type density. This confirms Slovenia's above-average landscape diversity and demonstrates that professionals outside Slovenia also perceive it that way – that is, similar to Slovenian geographers (Perko, Ciglič, and Zorn 2020b).

The map showing how the borders of the types featured in the European divisions examined are interconnected (Figure 35) shows the extent of similarity between these divisions in Slovenia's territory and how they overlap with the most established landscape typology of Slovenia (Perko 2007a), which is believed to display Slovenia's actual geographical features relatively well.

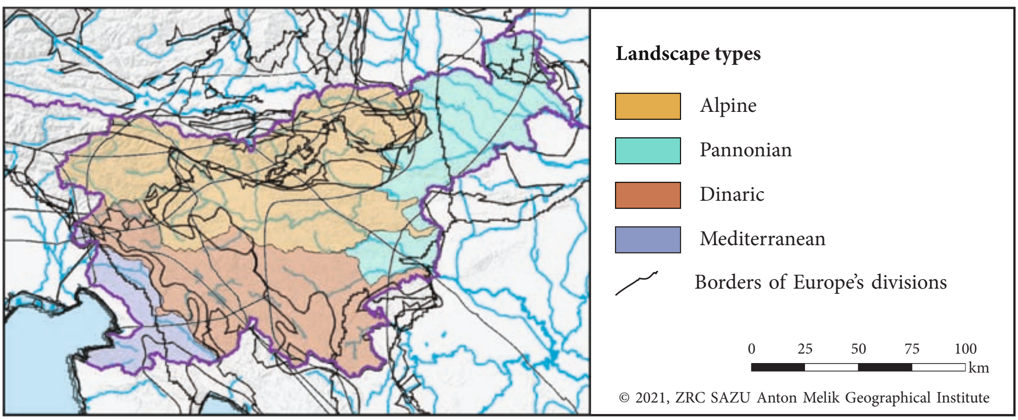

Figure 35: Interconnection of borders of the divisions of Europe examined compared to the landscape typology of Slovenia (Perko 2007a).

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Figure 36: The White Carniola corrosion plain is the southeasternmost region in Slovenia (Perko 1998a). The European macrotypologies have included White Carniola in full in very diverse landscape types: under the Mediterranean environmental region (Figure 25), the Mediterranean type (Figure 26), the Pannonian mixed forests ecological region (Figure 27), the Continental biogeographical region (Figure 28), the Carpathian area (Figure 29), the Mediterranean semi-bocage landscape type (Figure 30), the temperate broadleaf and mixed forests biome (Figure 31), the Balkan highland biogeographical province (Figure 32), the Apennine–Balkan province (Figure 33), and the Temperate continental bioclimate (Figure 33).

Because these divisions used different methods, different landscape elements, and data of different quality (Ciglič and Perko 2012), there are clear differences between them (Figure 36), but they roughly all come close to the landscape typology of Slovenia (Perko 2007a), indicating its position at the intersection of the main European landscape types (i.e., the Alpine, Pannonian, Dinaric, and Mediterranean), even though they may sometimes be referred to with different names (e.g., Illyrian or Carpathian).

4 Examples of microtypifications of parts of Slovenia

In addition to landscape typologies covering all of Slovenia, the institute has also produced a significant number of landscape typologies of smaller parts of Slovenia, or microtypologies, for various purposes and using various methods.

Geographers have also produced many classifications of parts of Slovenia outside the institute, among which classifications based on a single landscape element and microregionalizations distinctly predominate. More complex classifications and landscape typifications are rare, and they largely rely on terrain and rocks.

For example, Ivan Gams divided southeastern Carinthia into eight landform types (Gams 1970), part of the Upper Soča Valley into five landscape-ecological units (Gams 1975), and the Maribor region into five landscape-ecological units (Gams 1979). In addition, together with other researchers, he divided the Voglajna and Upper Sotla drainage basins in eastern Slovenia into eight natural geographical units (Gams et al. 1974), the area surrounding the village of Breginj in Slovenia's extreme west into five landscape-ecological units (Gams, Lovrenčak, and Plut 1978), and the area around the village of Kamen into four landscape-ecological units (Gams, Lovrenčak, and Plut 1978). Černe, Klemenčič, and Plut (1981) defined twelve landscape-ecological units in the Municipality of Tržič, and Plut (1981) identified sixteen microchores, Ferreira (2006) divided northern Upper Carniola into five landscape-ecological types, and Topole (1992) divided the Mirna drainage basin into four morphological types. Worth highlighting here is also a study of soil in the Pohorje Mountains, in which Repe (2017) used quantitative methods and geographic information systems to determine soil types based on pedogenetic factors, using many layers with natural landscape elements, which could also provide a basis for determining natural landscape types.

A historical overview of selected examples of microtypologies produced at the institute between 1985 and 2020 (Figure 37) shows the development of the methodology for determining landscape types, especially how traditional geography using paper thematic maps was enriched by geographic information systems with digital thematic layers that rely on increasingly accurate data. The methodologies used for some landscape microtypifications relate to the methodologies of landscape macrotypifications of Slovenia, and others are completely unique.

4.1 The Kokra Valley

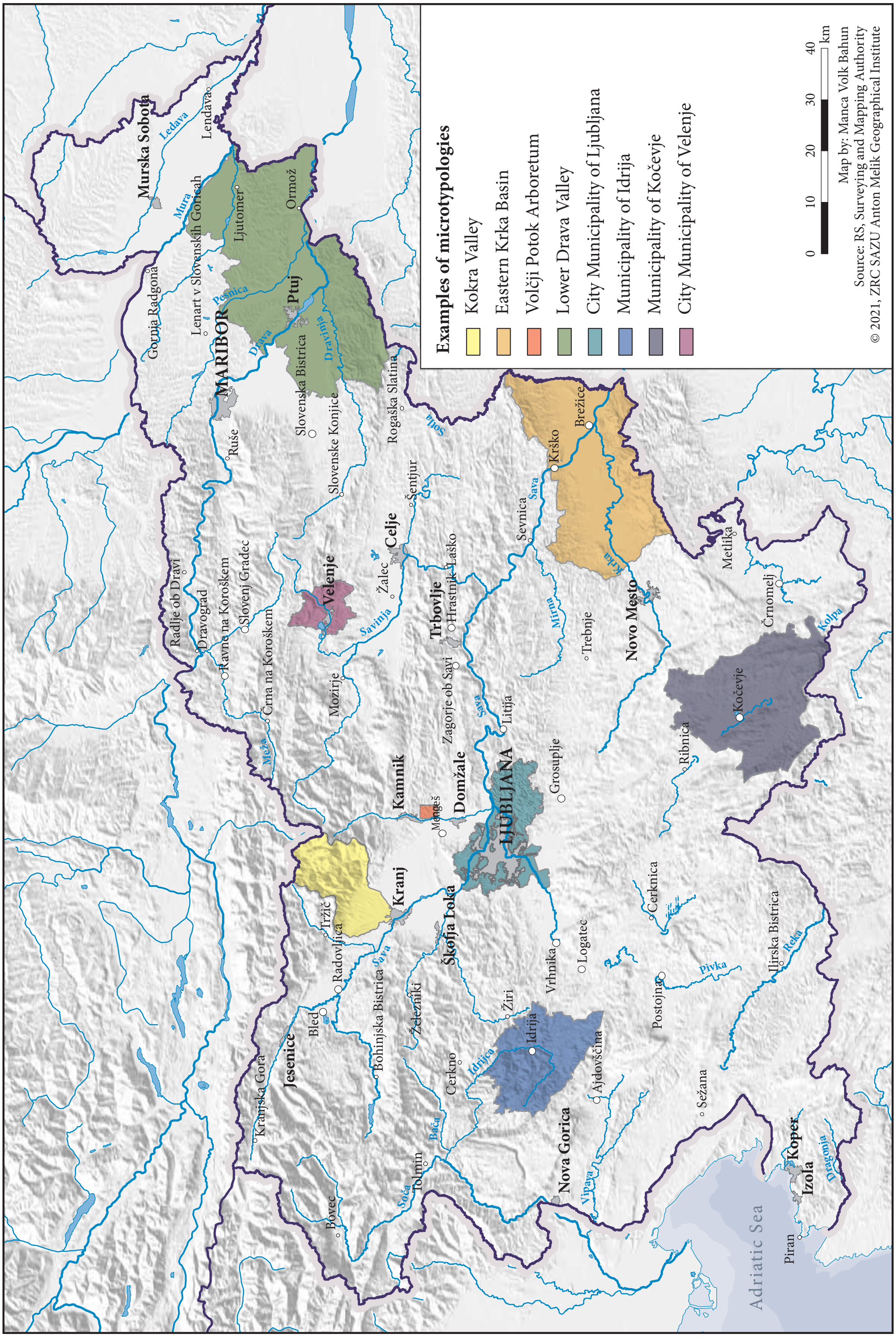
The first microtypification example originates from the mid-1980s, when initial steps were still being made to use computers more widely and frequently in geography and elsewhere. The Kokra Valley was selected because it extends from a wide plain to the high mountains and hence provides a relatively good example for illustrating Slovenia's geographical characteristics (Perko, Hrvatin, and Ciglič 2017).

The Kokra Valley covers 222 km², or 1% of Slovenia. The Kokra is 54 km long. It rises in the Karawanks, makes its way through the Kamnik–Savinja Alps into the Ljubljana Basin, and eventually flows into the Sava at Kranj, 25 km northwest of Ljubljana, through a conglomerate canyon, which is a protected natural site.

A landscape microtypology of the Kokra Valley was produced in 1985 as part of a study examining the connection between the natural and cultural landscape in the basin. A detailed description of the method and data sources used is provided in a 1986 article (Perko 1986).

This typology was still produced the traditional, analog way, although conceptually already along the lines of a geographic information system. All calculations were made on a computer, whereas the maps were still manually produced. All areas were measured by counting the squares on transparent graph paper placed over the maps. In this way, a type of a simple geographic information system was created, with raster layers

Figure 37: Distribution of the microtypologies in Slovenia presented. ➤


Examples of microtypologies
Kokra Valley
Eastern Krka Basin
Volčji Potok Arboretum
Lower Drava Valley
City Municipality of Ljubljana
Municipality of Idrija
Municipality of Kočevje
City Municipality of Velenje
0 10 20 30 40 km
Map by: Manca Volk Bahun
Source: RS, Surveying and Mapping Authority
© 2021, ZRC SAZU Anton Melik Geographical Institute
Adriatic Sea
LJUBLJANA
MARIBOR

with a 420 × 440 square resolution and a 50 m baseline. Before the microtypology was published (Perko 1986), the measurements were also checked through manual planimeter surveying – that is, by measuring the areas using a planimeter. The area of the Kokra Valley measured with a planimeter was 22,330 hectares and the number of squares counted was 89,376, corresponding to 22,344 hectares. The total area covered by the squares was larger than that measured with the planimeter because all the squares into which the basin at least partially extended were added to the area. It is interesting that the difference between the two areas established this way and today's accurate digital measurement of 22,191 hectares is only 0.6 or 0.7%.

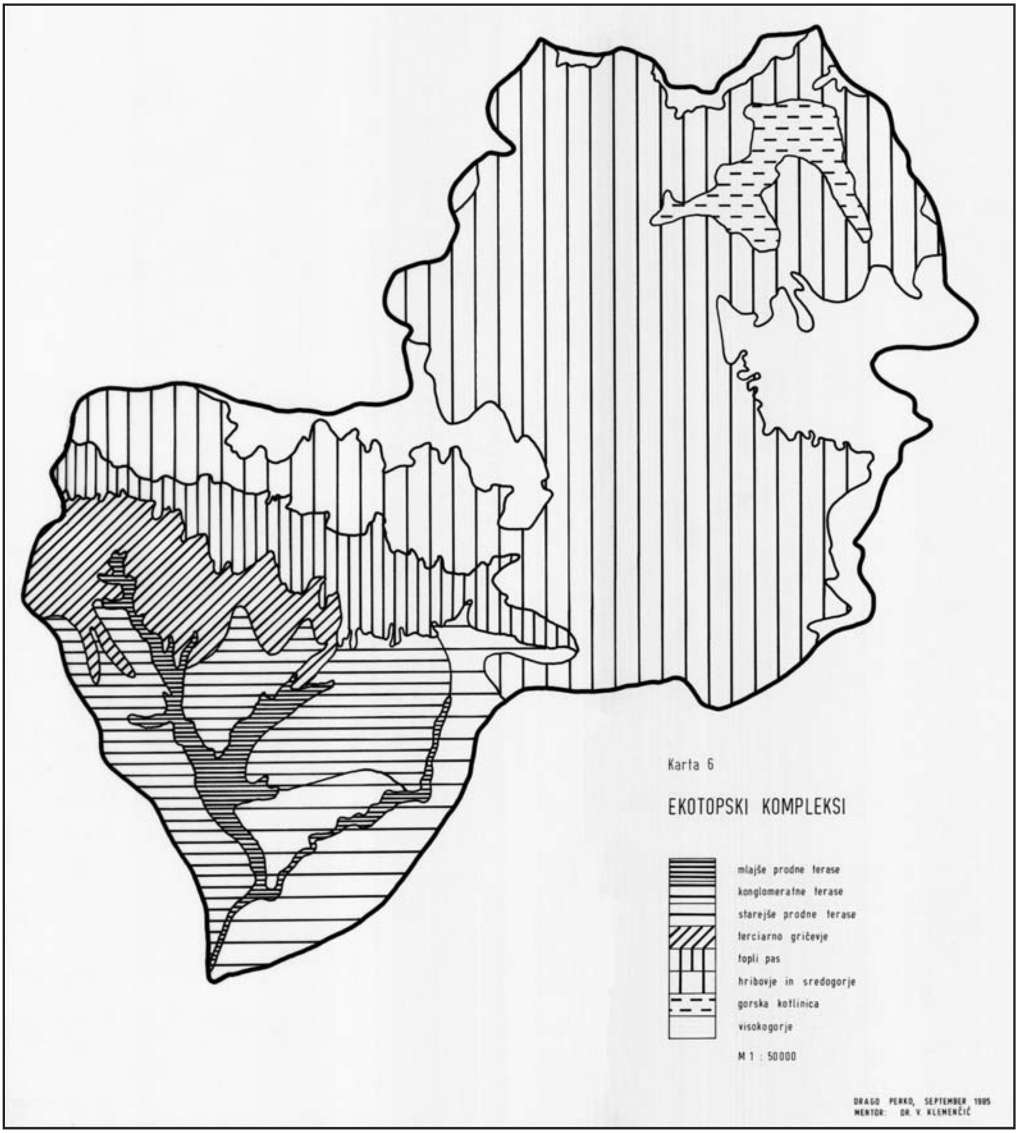
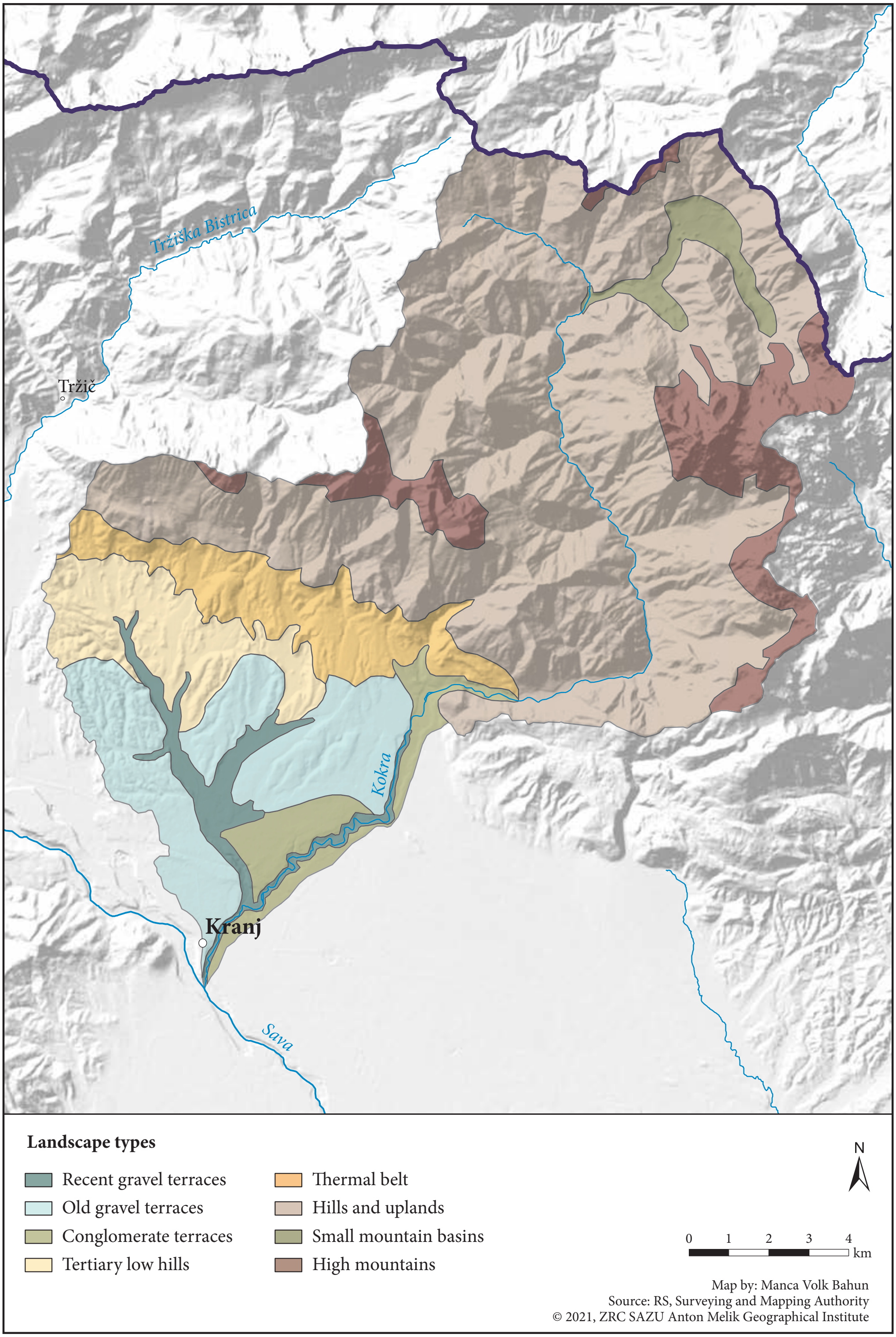


Figure 38: Original map of landscape types in the Kokra Valley (Perko 1992) with legend: 1. Recent gravel terraces, 2. Old gravel terraces, 3. Conglomerate terraces, 4. Tertiary low hills, 5. Thermal belt, 6. Hills and uplands, 7. Small mountain basins, and 8. High mountains.

Figure 39: Updated map of landscape types in the Kokra Valley. ► p. 53


Tržiška Bistrica
Tržič
Kokra
Kranj
Sava
Landscape types
Recent gravel terraces
Old gravel terraces
Conglomerate terraces
Tertiary low hills
Thermal belt
Hills and uplands
Small mountain basins
High mountains
N
0 1 2 3 4
km
Map by: Manca Volk Bahun
Source: RS, Surveying and Mapping Authority
© 2021, ZRC SAZU Anton Melik Geographical Institute

This study did not yet apply the term *landscape type*; instead, it used the term *tope* to refer to an almost completely homogenous area (landscape unit) in terms of one or several landscape elements, and the term *topic complex* or *topic family*, which combines topes that are still sufficiently similar to constitute a relatively homogenous whole.

Based on various data sources and maps, five synthetic thematic maps were drawn at a scale of 1:50,000:

- A map of morphological topic complexes with three units or morphocomplexes: plains and basins (21.7% of the area), low hills (12.8%), and hills and mountains (65.5%);
- A map of lithological topic complexes with eight units or lithocomplexes: igneous rock (3.0%), slate (7.5%), limestone and dolomite (31.8%), marl (14.2%), moraine (1.0%), scree (16.5%), conglomerate (11.3%), and gravel (14.0%);
- A map of climatic topic complexes with five units or climatic complexes: basins and plains (21.7%), thermal belt (12.8%), hills and uplands (49.7%), small mountain basins (2.9%), and high mountains (12.9%);
- A map of pedological topic complexes with six units or pedocomplexes: lithosol (10.0%), rendzina (48.8%), ranker (9.9%), fluvial soil (6.1%), brown rendzina (9.6%), and acidic brown soil (15.6%); and
- A map of phytological topic complexes with seven units or phytocomplexes: alpine vegetation (10.0%), beech on acidic soil (20.6%), beech on alkaline soil (37.5%), beech and fir (6.4%), pine on acidic soil (11.3%), sessile oak and hornbeam (8.2%), and alder and willow (6.0%).

By overlapping these maps, it was established that the borders of the topic complexes overlapped relatively well, and therefore it was easy to produce a map of ecological topic complexes, again at a scale of 1:50,000, with the following eight units or eco-complexes (Figure 38):

- *mlade (holocenske) prodne terase* 'recent (Holocene) gravel terraces' (3.7%);
- *stare (würmske) prodne terase* 'old (Würm) gravel terraces' (7.4%);
- *konglomeratne terase* 'conglomerate terraces' (10.6%);
- *terciarno gričevje* 'Tertiary low hills' (6.1%);
- *topli pas* 'thermal belt' (6.7%);
- *hribovje in sredogorje* 'hills and uplands' (49.7%);
- *gorska kotlinica* 'small mountain basins' (2.9%); and
- *visokogorje* 'high mountains' (12.9%).

Later on, the term *ecological topic complex* was replaced by *landscape type* (Perko 1992). The names of the eight landscape types are as follows (Figure 39):

- *mlajše prodne terase* 'recent gravel terraces';
- *starejše prodne terase* 'old gravel terraces';
- *konglomeratne terase* 'conglomerate terraces';
- *terciarno gričevje* 'Tertiary low hills';
- *topli pas* 'thermal belt';
- *hribovje in sredogorje* 'hills and uplands';
- *gorska kotlinica* 'small mountain basins'; and
- *visokogorje* 'high mountains'.

4.2 Eastern Krka Basin

The Eastern Krka Basin and its edges cover 733 km², or 3.6% of Slovenia. It forms the eastern part of a long tectonic basin at the intersection of the Alps, the Dinaric Alps, and the Pannonian Plain along the Slovenian–Croatian border. Three large rivers deposit their material in the basin. The alpine Sava, which crosses it diagonally from the northwest to the southeast, deposits mostly gravel and sand. In turn, its two tributaries, the karst Krka, which flows along the basin's southern edge in a north–south direction, and the Pannonian Sotla, which meanders along the basin's eastern edge from north to south, deposit material that is sandier and more clay-like in nature. It is the watercourses that create the main landscape differences in this part of Slovenia by depositing and transporting material of various granulation and flooding every year.

A landscape microtypology of the Eastern Krka Basin was produced in 1989 as part of research on the connection between natural and social landscape elements, especially the impact of natural elements on settlement. A detailed description of the method and data sources used is provided in an article published that same year (Perko 1989).

Maps at various scales and 1:10,000 aerial photos, mostly taken in 1986, constituted the main source of data on natural landscape elements that this microtypology is based on. First, all the maps and aerial photos were enlarged or reduced to the 1:50,000 scale and then overlapped with a 2 × 2 cm square grid, which at the 1:50,000 scale corresponds to 1 km². By entering data on landscape elements by square into a computer, a geographic information system with raster layers consisting of 41 × 33 squares with a 1 km baseline was created. Of the total of 1,353 squares, 733 covered the Eastern Krka Basin.

Because the features on the maps and aerial photos were presented either as points, lines, or polygons, data were primarily entered into the square grid in three ways:

- By counting point features (e.g., dolines), measuring the length of line features (e.g., watercourses), and measuring the area covered by features (e.g., flood plains) in a square;
- By determining the lowest and highest values of features (e.g., lowest and highest elevation) in a square; and
- By identifying the predominant feature (e.g., the predominant type of soil) in a square.

Seventeen maps and layers were prepared, containing more analytical natural landscape elements or variables (e.g., ridge lengths), which were then combined into five further synthetic maps and layers (e.g., rock types or lithocomplexes).

Each of the twenty-three variables had its own map drawn on a transparent sheet and a corresponding layer in the geographic information system acquired by reading data by squares in the kilometer grid placed over the map.

In combining maps with analytical variables into maps with synthetic variables and the final landscape type map, the maps were overlapped on a transparent desk with light shining through all the transparent sheets from below.

This study already applied the terms *landscape* and *landscape types*, even though the term *topic complex* or simply *complex* was still largely used for the synthetic layers, and *eco-complex* was still used instead of *landscape type*.

The following five synthetic maps formed the basis for producing the microtypology:

- Morphocomplexes with three units: plains (40% of the area), low hills (41%), and hills (19%);
- Lithocomplexes with eight units: clay, loam, and sand (37%), sand and gravel (15%), marl (11%), marl and limestone (14%), limestone (5%), limestone and dolomite (7%), dolomite (11%), and slate (1%);
- Hydrocomplexes with six units: floodplains (19%), areas with impeded drainage on plains and in the valleys (16%), areas with normal drainage on plains and in the valleys (10%), areas with impeded drainage in the low hills and hills (20%), areas with normal drainage in the low hills and hills (21%), and areas with karst and partially karst drainage (14%);
- Pedocomplexes with seven units: gley (20%), pseudo-gley (7%), fluvial soil (10%), acidic brown soil on clay and loam (10%), brown soil on gravel (8%), brown soil on marl (10%), and rendzina, chromic cambisol, or brown skeletal soil (35%); and
- Phytocomplexes with nine units: willow, alder, and poplar (22%), pedunculate oak with European hornbeam (5%), common hornbeam on acidic soil (13%), common hornbeam on alkaline soil (8%), oak on acidic soil (6%), beech on acidic soil (27%), beech on alkaline soil (11%), beech with hop hornbeam (4%), and beech with common hornbeam (4%).

An overview of complex values by square showed that many squares had the same or similar values – that is, that they were similar or even the same. In this sense, two squares are considered the same if they have completely the same combination of complex values.

In theory, the number of possible combinations equaled the product of possible different combinations for individual complexes. Because the morphocomplexes had three units or possible values, the lithocomplexes had eight, the hydrocomplexes had six, the pedocomplexes had seven, and the phytocomplexes had nine possible values, 9,072 combinations were theoretically possible (3 × 8 × 6 × 7 × 9), but in reality 140 combinations were identified (1.5%), with only twenty-three combinations (0.3%) appearing at least ten times. The most frequent was the combination of the morphocomplex *plains*, the lithocomplex *sand and gravel*, the hydrocomplex *normal drainage on plains and in the valleys*, the pedocomplex *brown soil on gravel*, and the phytocomplex *common hornbeam on alkaline soil*. This combination was found in forty-seven squares, which means it was typical of 47 km² of the basin.

The map of eco-complexes was produced by overlapping the maps of partial complexes and identifying the most common combinations of square values in the layers of these same complexes.

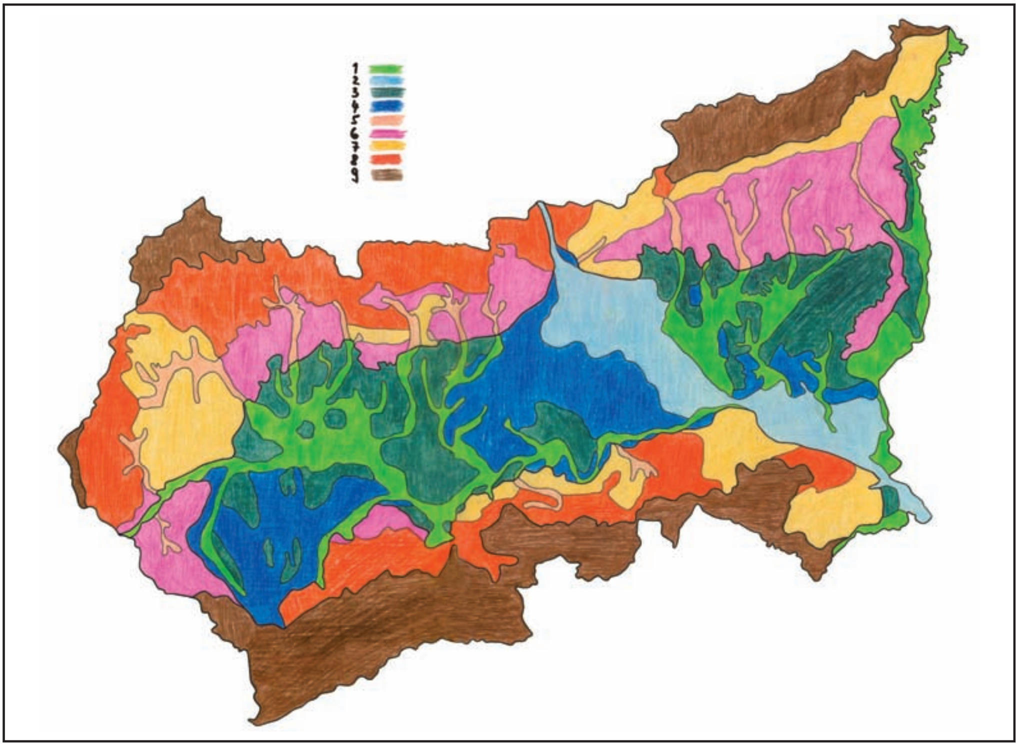


Figure 40: Original map of landscape types in the Eastern Krka Basin (Perko 1989) with legend: 1. Plain made of Holocene clay, loam, and sand, 2. Plain made of Holocene gravel and sand, 3. Plain made of Pleistocene clay, loam, and sand, 4. Plain made of Pleistocene sand and gravel, 5. Low hills made of Holocene clay and loam, 6. Low hills made of Pleistocene and Pliocene clay and loam, 7. Low hills made of Miocene marl, 8. Low hills made of Mesozoic marl, limestone, and dolomite, 9. Hills.

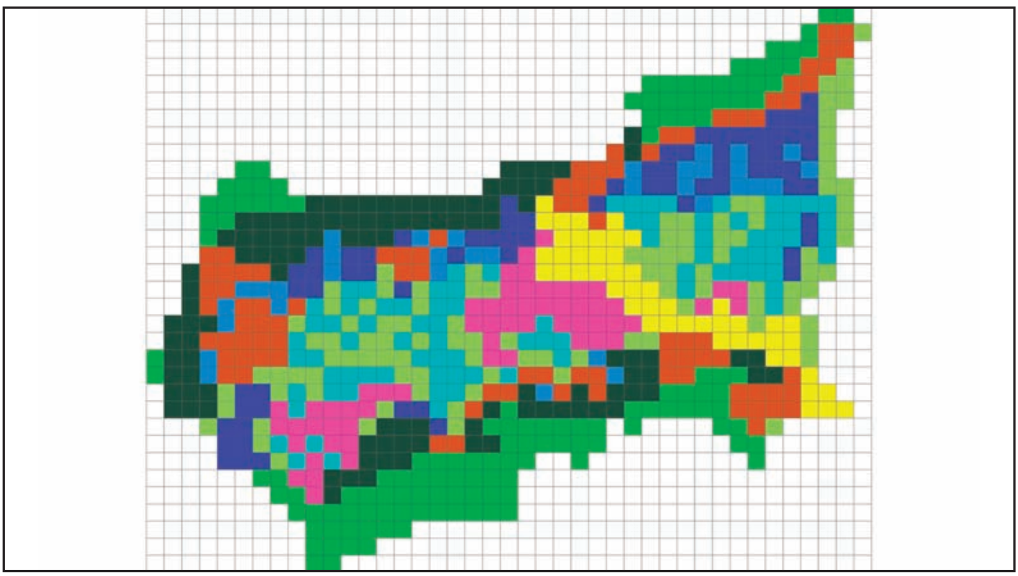


Figure 41: Layer of landscape types by cells in the Eastern Krka Basin (Perko 1989).

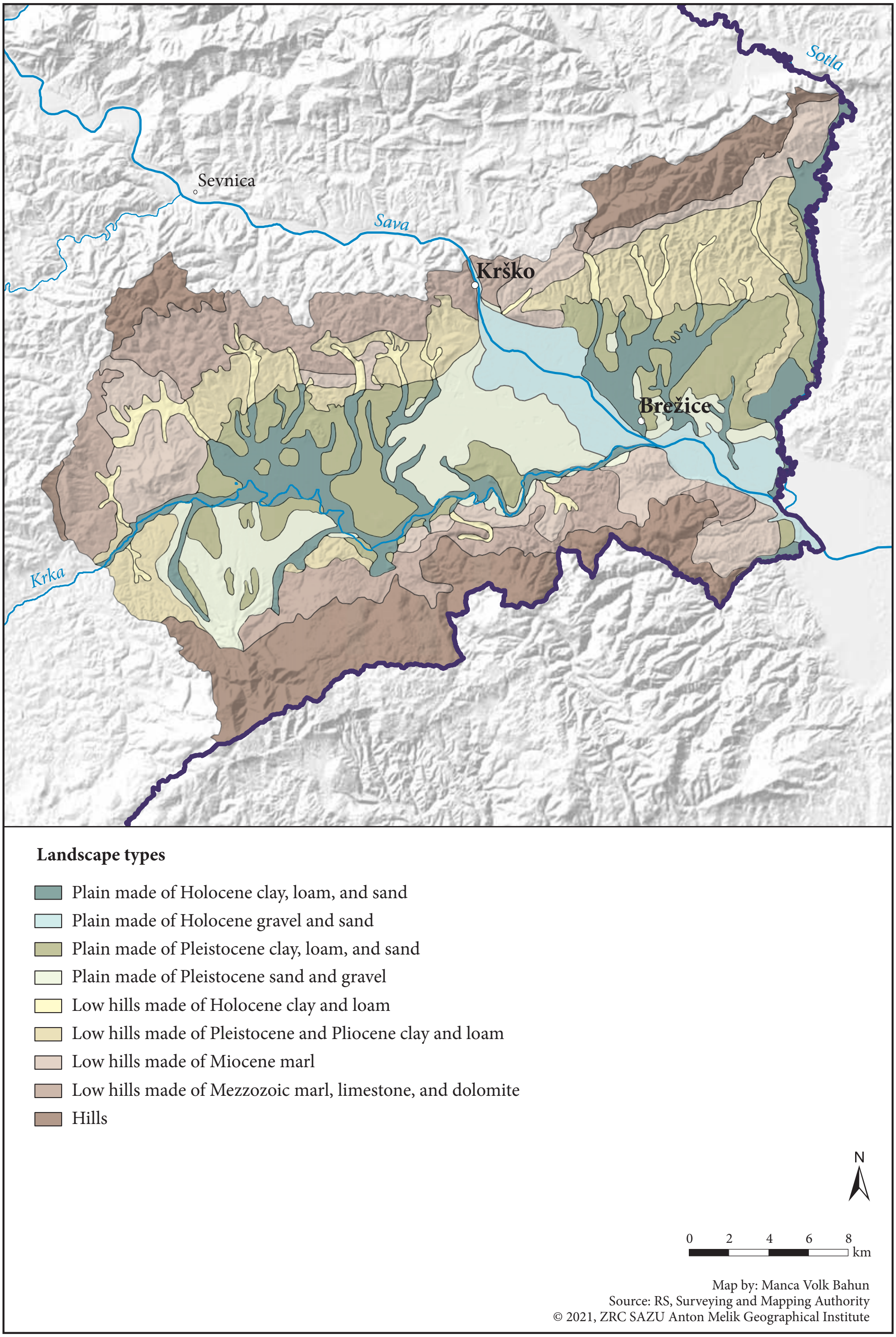

Sevnica
Sava
Sotla
Krško
Brežice
Krka
Landscape types
Plain made of Holocene clay, loam, and sand
Plain made of Holocene gravel and sand
Plain made of Pleistocene clay, loam, and sand
Plain made of Pleistocene sand and gravel
Low hills made of Holocene clay and loam
Low hills made of Pleistocene and Pliocene clay and loam
Low hills made of Miocene marl
Low hills made of Mezzozoic marl, limestone, and dolomite
Hills
N
0 2 4 6 8 km
Map by: Manca Volk Bahun
Source: RS, Surveying and Mapping Authority
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Figure 42: Updated map of landscape types in the Eastern Krka Basin. ◄ p. 57

The eco-complex map (Figures 40 and 42) and layer (Figure 41) include nine types:
- *ravnina iz holocenske gline, ilovice in peska* 'plain made of Holocene clay, loam, and sand' (105 km², 14.3% of the area);
- *ravnina iz holocenskega proda in peska* 'plain made of Holocene gravel and sand' (49 km², 6.7%);
- *ravnina iz pleistocenske gline, ilovice in peska* 'plain made of Pleistocene clay, loam, and sand' (85 km², 11.6%);
- *ravnina iz pleistocenskega peska in proda* 'plain made of Pleistocene sand and gravel' (59 km², 8.1%);
- *gričevje iz holocenske gline in ilovice* 'low hills made of Holocene clay and loam' (34 km², 4.6%);
- *gričevje iz pleistocenske in pliocenske gline in ilovice* 'low hills made of Pleistocene and Pliocene clay and loam' (70 km², 9.5%);
- *gričevje iz miocenskega laporja* 'low hills made of Miocene marl' (88 km², 12.0%);
- *gričevje iz mezozojskega laporja, apnenca in dolomita* 'low hills made of Mesozoic marl, limestone, and dolomite' (107 km², 14.6); and
- *hribovje* 'hills' (136 km², 18.6%).

4.3 Volčji Potok Arboretum

The Volčji Potok Arboretum is located approximately 15 km north of Ljubljana, between Domžale and Kamnik, east of the Kamnik Bistrica River. Its most prominent part is *Volčji hrib* (literally Wolf Hill), which rises to an elevation of 398 m and where there are the ruins of a medieval castle. The arboretum covers just under 1 km², and the square study area with the arboretum measures 2.25 km², which is by far the smallest example among the microtypologies presented. Despite its small size, the area has a diverse landscape, ranging from the most recent Holocene deposits via older Pleistocene deposits to Mesozoic and Paleozoic rocks, which differences in soil, vegetation, landforms, and other natural features are associated with. This is where, with its first low hills, the bottom of the Ljubljana Basin begins to ascend to the extensive Sava Hills, which extend all the way to the Croatian border to the east.

A landscape microtypology of this area was produced in 1992 as a geographical basis for protecting the arboretum, which was declared a cultural site of national importance in 1999 due to its important garden architecture heritage.

This microtypology is primarily interesting because a digital elevation model was applied for the first time for the typification and because it covers a very small area with even smaller landscape types. A detailed description of the method and data sources used is provided in a 1993 article (Perko 1993).

At that time, the whole of Slovenia was only covered by a 100-meter digital elevation model, and so a more accurate one was produced in house. First, the mostly one-meter contour lines from the basic 1:5,000 topographic map were digitized, and in some places intermediate points were added if needed. The resulting vector layer was converted into a 5 × 5 m raster grid, through which a five-meter 1,500 × 1,500 m digital elevation model was obtained, in which every cell or square measured 25 m² (a quarter of an are). This digital elevation model was used to draw three-dimensional spatial images of the area (Figure 43), calculate the elevations, slopes, and surface aspect, and identify four landform units (low hills, a small valley, an alluvial fan, and a plain).

Because of the small size of the area, the cartographic bases were able to be extensively updated and then digitized. Data were processed using the IDRISI software. The entire square area was processed separately from the are within the arboretum, which at that time covered 8,252 ares.

The study used the terms *landscape type* and *geoecological unit* as synonyms.

The main landscape differences were related to the age of fluvial sediments (Šifrer 1961) and surface aspect, which is why these two landscape elements were crucial in the area's microtypification and microregionalization.

Fifteen microregions were identified: *Volčji hrib*, *Kopasti hrib*, *Dolina jezerc*, *Dolina rododendronov*, *Hribarica*, *Rusula*, *Jelova draga*, *Jamce*, *V hribih*, *Dobrava*, *Volčji vršaj*, *Graščinsko*, *Zalše*, *Spodnje polje*, and *Srednje polje*. They were largely named after old microtoponyms (Figure 43). In addition, the following five main landscape types or geological units were defined (Figures 44 and 45):
- *aluvialna ravnina z drobnozrnatimi usedlinami* 'Alluvial plain with fine-grained sediments' (characteristics: located immediately along creeks, predominance of silicate particles, thin and acidic soil, floodplain; microregions: *Dolina jezerc*, *Dolina rododendronov*, and *Jelova* draga);

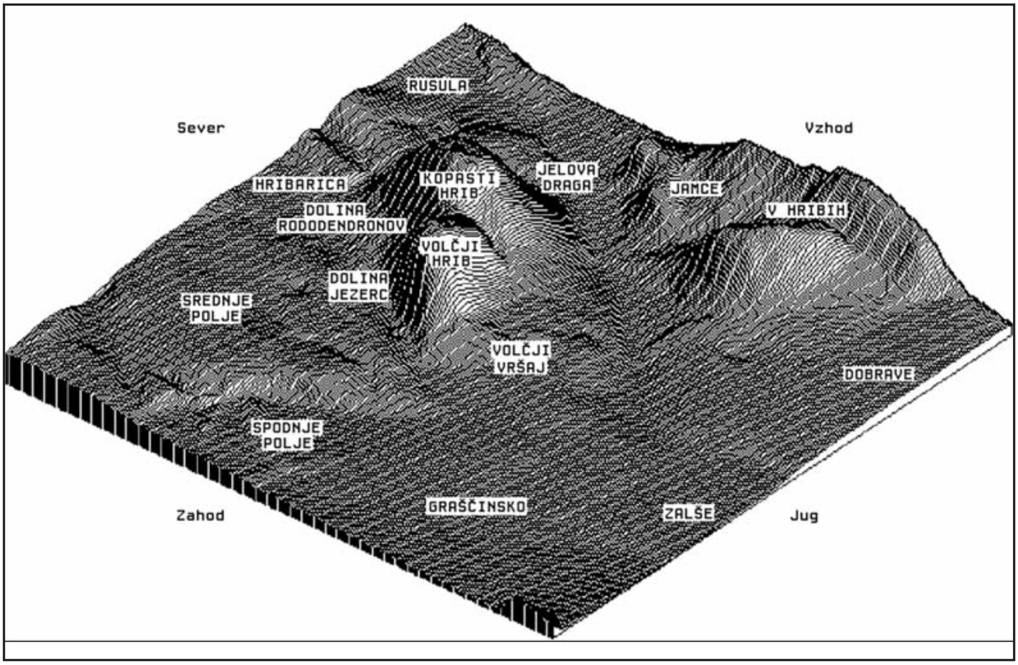


Figure 43: Original three-dimensional representation of microregion names in the Volčji Potok Arboretum area (Perko 1993).

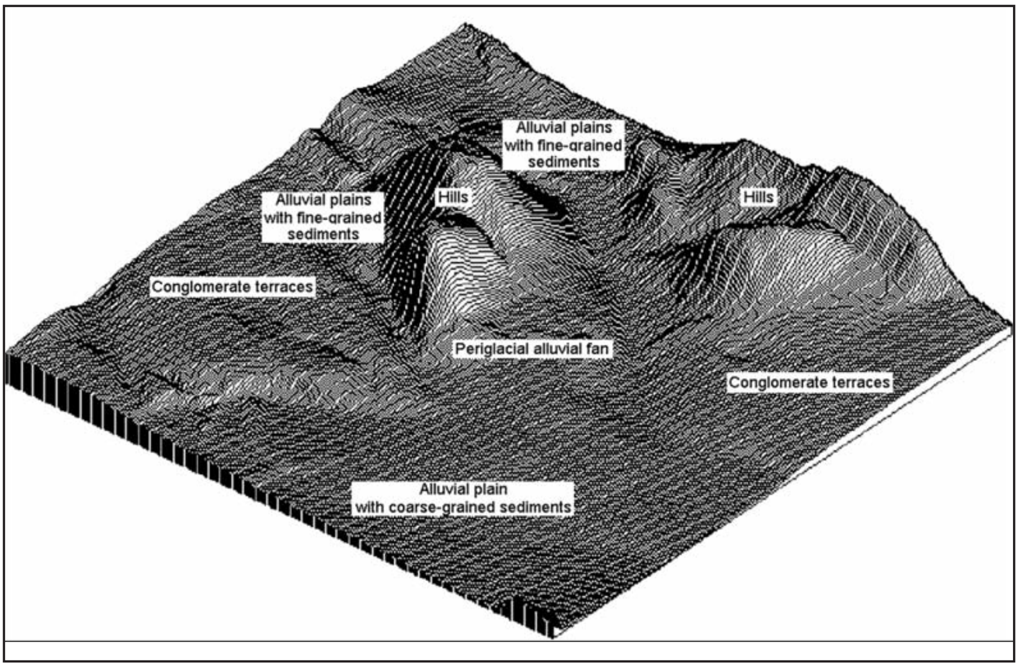


Figure 44: Original three-dimensional representation of landscape types in the Volčji Potok Arboretum area.

Figure 45: Updated map of landscape types in the Volčji Potok Arboretum area. ➤ p. 60


Kamniška Bistrica
Landscape types
Alluvial plain with fine–grained sediments
Alluvial plain with coarse–grained sediments
Periglacial alluvial fan
Conglomerate terrace
Hills
N
0 50 100 150 200 250
m
Map by: Manca Volk Bahun
Source: RS, Surveying and Mapping Authority
© 2021, ZRC SAZU Anton Melik Geographical Institute

- *aluvialna ravnina z debelozrnatimi usedlinami* 'Alluvial plain with coarse-grained sediments' (characteristics: mix of silicate and carbonate particles, thinner, less acidic, and more permeable soil; microregions: *Spodnje polje*, *Graščinsko*, and *Zalše*);
- *periglacialni vršaj* 'Periglacial alluvial fan' (characteristics: fine-grained deposits are older and more inclined than those in the alluvial plains at lower elevations; microregion: *Volčji vršaj*);
- *konglomeratna terasa* 'conglomerate terrace' (characteristics: predominance of carbonate gravel, thicker, more acidic, and less permeable soil; microregions: *Srednje polje*, *Hribarica*, *Rusula*, and *Dobrava*); and
- *hribovje* 'hills' (characteristics: predominance of Triassic dolomite and Permo-Carboniferous claystone and sandstone, oak and hornbeam are common on the sunny slopes (the southern slopes of *Volčji hrib* and *Kopasti hrib*), and Scots pine and beech on the shady sides; microregions: *Volčji hrib*, *Kopasti hrib*, *Jamce*, and *V hribih*).

4.4 Lower Drava Valley

The Lower Drava Valley was processed within the confines of today's twenty-three municipalities: Cirkulane, Destrnik, Dornava, Gorišnica, Hajdina, Juršinci, Kidričevo, Križevci, Ljutomer, Majšperk, Markovci, Ormož, Podlehnik, Ptuj, Razkrižje, Središče ob Dravi, Sveti Andraž v Slovenskih Goricah, Sveti Tomaž, Trnovska Vas, Veržej, Videm, Zavrč, and Žetale. Together they cover 1,034.5 km², or 5.1% of Slovenia. The valley lies southeast of Maribor along the Mura and Drava rivers, before they enter Croatia. It is composed of a plain along the Mura to the northeast, low hills in the center, a plain along the Drava with the oldest Slovenian town of Ptuj to the south, and low rugged hills to the southwest.

The area's landscape microtypology was produced in 1996 as part of a study of the connection between natural landscape elements and natural hazards because within the landscape types as relatively homogenous units the risk of natural hazards and protection against them are similar. A good knowledge of landscape types and the differences between them helps prevent natural hazards, reduce their number, or at least decrease their impacts. A detailed description of the method and data sources used is provided in an article published the same year (Fridl et al. 1996).

The data were based on a 100-meter 59 × 42 km digital elevation model. The researchers had the elevation, slope, surface aspect, and insolation raster layers at their disposal, along with the rock type, soil type, potential vegetation type, real vegetation type, and groundwater vector layers. In determining the correlation between them, it was established that rocks, potential vegetation, and slope were the most important factors, which is why these three layers were also taken into account in identifying the landscape types.

Because the rocks were combined into five classes, the vegetation into four classes, and the slopes into six classes, 120 different combinations of these three natural elements were theoretically possible. In reality, half of them (i.e., sixty) were established. The microtypification only took into account the combinations covering over 1,000 hectares, and combinations covering a smaller area were added to their most similar types. Hence, the following nineteen combinations (Figures 46 and 47) or landscape types (rock + vegetation + slope in degrees) remained:

- *silikatni prod + beli gaber in dob + 0 do 2º* 'silicate gravel + hornbeam and pedunculate oak + 0 to 2º' (208.8 km², 20.2% of the terrain);
- *silikatni prod + brest in dob + 0 do 2º* 'silicate gravel + elm and pedunculate oak + 0 to 2º' (19.6 km², 1.9%);
- *silikatni prod + beli gaber + 0 do 2º* 'silicate gravel + hornbeam + 0 to 2º' (21.7 km², 2.1%);
- *silikatni prod + bukev, kostanj in hrasti* + 0 do 2º 'silicate gravel + beech, chestnut, and various oaks + 0 to 2º' (44.4 km², 4.3%);
- *silikatni prod + bukev, kostanj in hrasti + 2 do 6º* 'silicate gravel + beech, chestnut, and various oaks + 2 to 6º' (31.0 km², 3.0%);
- *silikatni prod + bukev, kostanj in hrasti + 6 do 12º* 'silicate gravel + beech, chestnut, and various oaks + 6 to 12º' (14.5 km², 1.4%);
- *pesek + bukev, kostanj in hrasti + 0 do 2º* 'sand + beech, chestnut, and various oaks + 0 to 2º' (15.5 km², 1.5%);
- *pesek + bukev, kostanj in hrasti + 2 do 6º* 'sand + beech, chestnut, and various oaks + 2 to 6º' (45.5 km², 4.4%);
- *pesek + bukev, kostanj in hrasti + 6 do 12º* 'sand + beech, chestnut, and various oaks + 6 to 12º' (71.3 km², 6.9%);

- *pesek + bukev, kostanj in hrasti + 12.0 do 19.9°* 'sand + beech, chestnut, and various oaks + 12 to 19.9°' (40.3 km², 3.9%);
- *glina in melj + beli gaber in dob + 0 do 2°* 'clay and silt + hornbeam and pedunculate oak + 0 to 2°' (95.1 km², 9.2%);
- *glina in melj + bukev, kostanj in hrasti + 0 do 2°* 'clay and silt + beech, chestnut, and various oaks + 0 to 2°' (51.7 km², 5.0%);
- *glina in melj + bukev, kostanj in hrasti + 2 do 6°* 'clay and silt + beech, chestnut, and various oaks + 2 to 6°' (52.7 km², 5.1%);
- *glina in melj + bukev, kostanj in hrasti + 6 do 12°* 'clay and silt + beech, chestnut, and various oaks + 6 to 12°' (50.6 km², 4.9%);
- *glina in melj + bukev, kostanj in hrasti + 12 do 20°* 'clay and silt + beech, chestnut, and various oaks + 12 to 20°' (33.1 km², 3.2%);

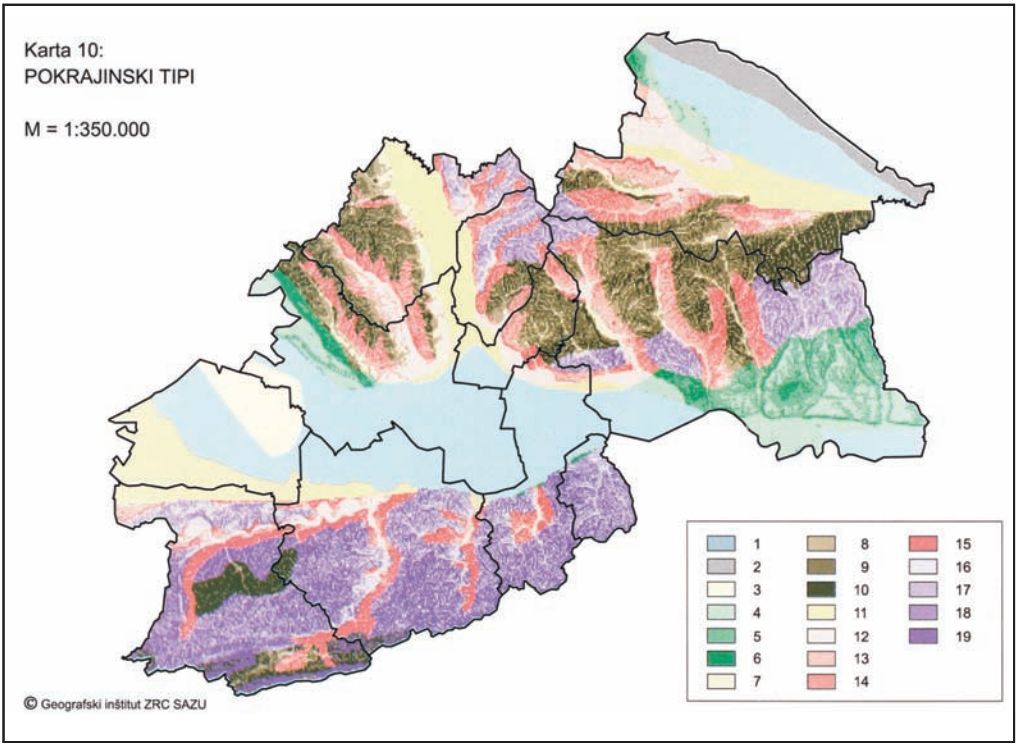
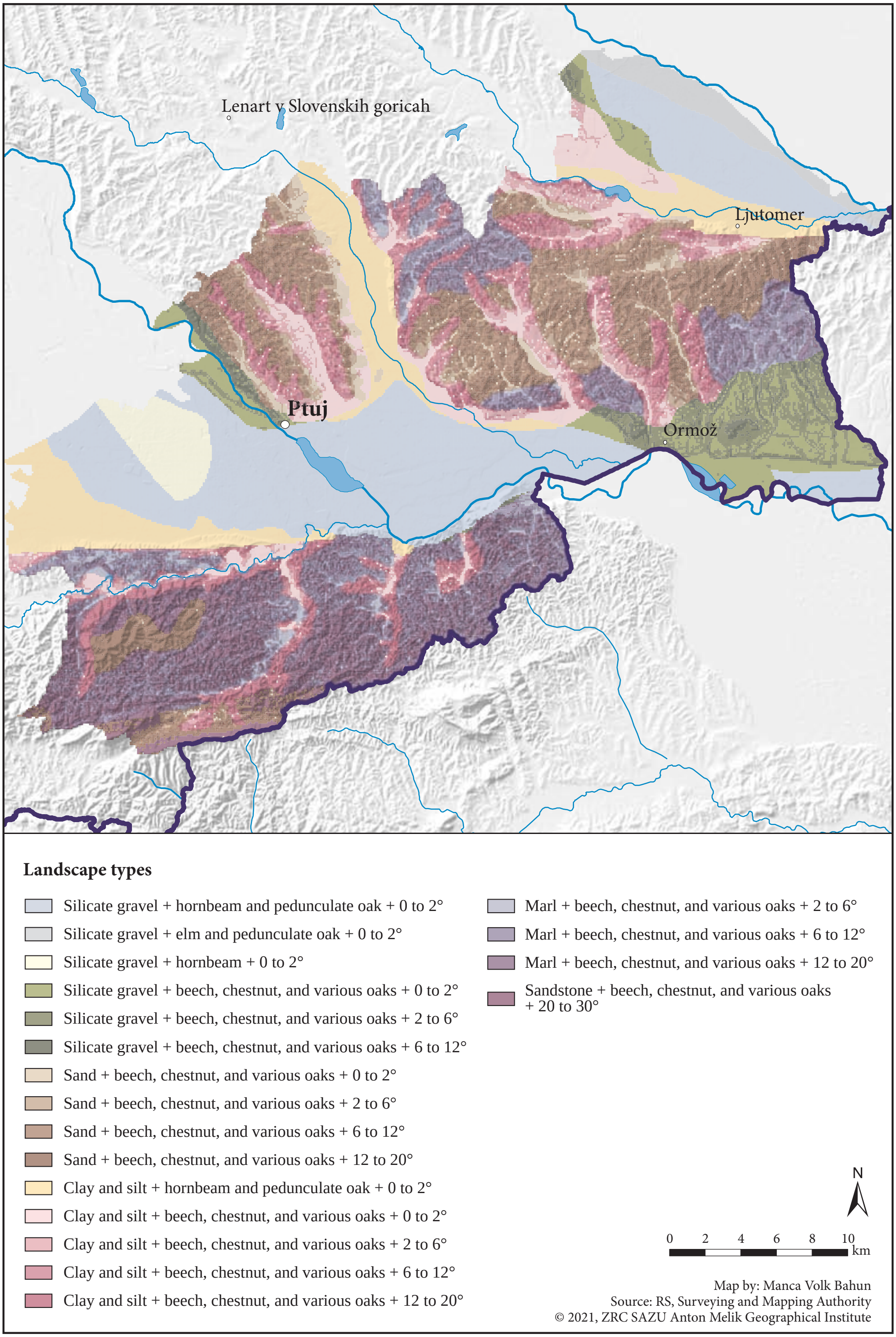


Figure 46: Original map of landscape types in the Lower Drava Valley and Prlekija region (Fridl et al. 1996) with legend:

1. Silicate gravel + hornbeam and pedunculate oak + 0 to 2°;
2. Silicate gravel + elm and pedunculate oak + 0 to 2°;
3. Silicate gravel + hornbeam + 0 to 2°;
4. Silicate gravel + beech, chestnut, and various oaks + 0 to 2°;
5. Silicate gravel + beech, chestnut, and various oaks + 2 to 6°;
6. Silicate gravel + beech, chestnut, and various oaks + 6 to 12°;
7. Sand + beech, chestnut, and various oaks + 0 to 2°;
8. Sand + beech, chestnut, and various oaks + 2 to 6°;
9. Sand + beech, chestnut, and various oaks + 6 to 12°;
10. Sand + beech, chestnut, and various oaks + 12 to 20°;
11. Clay and silt + hornbeam and pedunculate oak + 0 to 2°;
12. Clay and silt + beech, chestnut, and various oaks + 0 to 2°;
13. Clay and silt + beech, chestnut, and various oaks + 2 to 6°;
14. Clay and silt + beech, chestnut, and various oaks + 6 to 12°;
15. Clay and silt + beech, chestnut, and various oaks + 12 to 20°;
16. Marl + beech, chestnut, and various oaks + 2 to 6°;
17. Marl + beech, chestnut, and various oaks + 6 to 12°;
18. Marl + beech, chestnut, and various oaks + 12 to 20°; and
19. Sandstone + beech, chestnut, and various oaks + 20 to 30°.

Figure 47: Updated map of landscape types in the Lower Drava Valley and Prlekija region. ➤


Lenart v Slovenskih goricah
Ljutomer
Ptuj
Ormož
Landscape types
Silicate gravel + hornbeam and pedunculate oak + 0 to 2°
Silicate gravel + elm and pedunculate oak + 0 to 2°
Silicate gravel + hornbeam + 0 to 2°
Silicate gravel + beech, chestnut, and various oaks + 0 to 2°
Silicate gravel + beech, chestnut, and various oaks + 2 to 6°
Silicate gravel + beech, chestnut, and various oaks + 6 to 12°
Sand + beech, chestnut, and various oaks + 0 to 2°
Sand + beech, chestnut, and various oaks + 2 to 6°
Sand + beech, chestnut, and various oaks + 6 to 12°
Sand + beech, chestnut, and various oaks + 12 to 20°
Clay and silt + hornbeam and pedunculate oak + 0 to 2°
Clay and silt + beech, chestnut, and various oaks + 0 to 2°
Clay and silt + beech, chestnut, and various oaks + 2 to 6°
Clay and silt + beech, chestnut, and various oaks + 6 to 12°
Clay and silt + beech, chestnut, and various oaks + 12 to 20°
Marl + beech, chestnut, and various oaks + 2 to 6°
Marl + beech, chestnut, and various oaks + 6 to 12°
Marl + beech, chestnut, and various oaks + 12 to 20°
Sandstone + beech, chestnut, and various oaks + 20 to 30°
N
0 2 4 6 8 10
km
Map by: Manca Volk Bahun
Source: RS, Surveying and Mapping Authority
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- *lapor + bukev, kostanj in hrasti + 2 do 6°* 'marl + beech, chestnut, and various oaks + 2 to 6°' (39.3 km², 3.8%);
- *lapor + bukev, kostanj in hrasti + 6 do 12°* 'marl + beech, chestnut and various oaks + 6 to 12°' (75.4 km², 7.3%);
- *lapor + bukev, kostanj in hrasti + 12 do 20°* 'marl + beech, chestnut and various oaks + 12 to 20°' (74.4 km², 7.2%); and
- *peščenjak + bukev, kostanj in hrasti + 20 do 30°* 'sandstone + beech, chestnut and various oaks + 20 to 30°' (48.6 km², 4.7%).

4.5 City Municipality of Ljubljana

The City of Ljubljana covers 274.9 km², or 1.4% of Slovenia. It lies along the Sava River and its tributary, the Ljubljanica, where the hills nearly cut the bottom of the Ljubljana Basin into two parts: the Sava Plain to the north and the Ljubljana Marsh to the south. This makes the basin's landscape relatively diverse.

A landscape microtypology of this area was produced, together with its microregionalization, in 2000 for the 18th Conference of Slovenian Geographers, which took place in Ljubljana that year and covered the municipality from most geographical angles. A detailed description of the method and data sources used is provided in an article published the same year (Hrvatin and Perko 2000).

The geographic information system was based on a 100-meter 29.3 × 21.7 km digital elevation model. This time around, the typification used the rock type and potential vegetation type vector layers and, for the first time, a relief coefficient raster layer.

The relief coefficient or the surface roughness coefficient (Perko 2000) is a more complex indicator compared to elevation and slope because it combines both. Conceptually it is based on spatial changes in surface elevation and slope, and methodologically it relies on their coefficient of variation. It is the geometric mean of the elevation coefficient (i.e., the ratio between the standard deviation in the elevations of a square cell and its eight neighbors, multiplied by 100) and the slope coefficient (i.e., the ratio between the standard deviation in the slopes of a square cell and its eight neighbors, multiplied by 100; Perko 2000).

In calculating the relief coefficient for all of Slovenia, it was determined that the results yield a better approximation of Slovenia's actual surface roughness if the average of all cells (the entire area) is used instead of the local average of nine cells. The relief coefficient calculated using the local nine cells was later renamed the local relief coefficient, and the one calculated using all cells was renamed the regional relief coefficient. At the same time, in calculating the coefficient, the slope was replaced by surface aspect, so that the resulting coefficient combined the vertical and horizontal spatial variability (i.e., elevations and aspects; Perko 2007b).

Using the relief coefficient makes it possible to compute homogenous areas of the same or similar surface roughness or morphological units or morphological surface types. The lowest value of the regional relief coefficient for all of Slovenia was 0, the highest was 111.5, and the average was 9.3 (Perko 2000)).

After reviewing the frequency distribution of regional relief coefficient values in the most typical Slovenian plains, low hills, hills, and mountains, the coefficients were logically combined into four basic morphological classes (Perko 2000):

- Flat surface or plain with values ranging between 0 and 1 (223,843, or 11.0% of cells);
- Slightly rough surface or low hills with values ranging between 1 and 10 (974,279, or 48.1% of cells);
- Very rough surface or hills with values ranging between 10 and 20 (701,095, or 34.6% of cells); and
- Extremely rough surface or mountains with values over 20 (127,981, or 6.3% of cells).

In all cases, the values at the lower limit of a class are included in that class and the values at the upper limit of a class are included in the next higher class.

Because there are only a few cells in the City Municipality of Ljubljana with a relief coefficient over 20, the third and fourth classes were combined and thus only three classes remained:

- Flat surface (39.3% of cells);
- Slightly rough surface (26.9% of cells); and
- Very rough surface (33.8% of cells).

Before the typification, rocks were combined into four classes:

- Late Paleozoic non-carbonate rocks (Carboniferous and Permian shale, quartz sandstone, and quartz conglomerate) are the oldest and also most widespread (33.6% of the area);

- Mesozoic carbonate rocks (limestone and dolomite), in some places including layers of marl, shale, siltstone, sandstone, tuff, and tuffite (10.3%);
- Pleistocene sand gravel, in some places forming a conglomerate, and Holocene gravel and sand (37.2%); and
- Quaternary clay, silt, sand, and peat (18.9%).

Potential vegetation, which could grow under today's ecological conditions (climate, bedrock, soil, and so on) without human and animal intervention, were also combined into four classes:

- Communities of beech forests cover over a third of the municipality and mostly grow in the hills; beech and hard-fern forests (*Blechno-Fagetum*) primarily grow on silicate rock and pre-Dinaric beech; and broad-leaved sanicle forests grow on carbonate rock (*Hacquetio-Fagetum*; 36.8%);
- Hornbeam and sessile oak forests (*Querco-Carpinetum*) grow on Holocene gravel plains and the Würm gravel terrace of the Ljubljana Plain (31.2%);
- Hornbeam and pedunculate oak forests (*Querco roboris-Carpinetum*) primarily grow in areas influenced by a high groundwater level, especially in the Ljubljana Marsh (20.8%); and
- Scots pine and blueberry forests (*Vaccinio myrtilli-Pinetum*) grow in shallow, nutrient-deficient soil; Scots pine is often mixed with spruce (11.2%).

Based on the spatial overlapping of these three natural landscape elements, the landscape types were then identified.

Values were determined for every cell or hectare of the City Municipality of Ljubljana in terms of the surface roughness, rock, and vegetation classes, and their combinations were defined. Because surface roughness included three classes, and rocks and vegetation included four, forty-eight combinations were theoretically possible. Thirty-nine were actually identified. Only seven combinations appeared over a thousand times, together covering 76.7% or over three-quarters of the municipality.

However, not only the absolute frequency of a specific combination is important in typification, but also its relative frequency. Therefore, the theoretical probability of occurrence or theoretical frequency was calculated for each combination by multiplying its partial probabilities, along with its actual frequency and the ratio between the actual and theoretical frequency. For example, the combination of flat surface, gravel, and hornbeam and sessile oak forests was typical of 5,254 cells. Its actual frequency was 0.19 (the ratio between 5,254 cells with this combination and the number of all cells, 27,489) and its theoretical frequency was 0.046, which was obtained by multiplying the theoretical probabilities of the occurrence of flat surface (the ratio between 10,787 cells and the number of all cells), gravel (the ratio between the 10,216 cells with gravel and the number of all cells), and hornbeam and sessile oak forests (the ratio between the 8,583 cells with these forests and the number of all cells). The ratio between the actual and theoretical frequency was 4.20, which meant that the combination described was over four times more frequent than theoretically expected.

All combinations with ratios between the actual and theoretical frequency higher than 0.5 were defined as important to the area. Fifteen such combinations were established, covering as much as 91.6% of the area. The remaining combinations, which were partly also the result of inaccurate digitization of vector layers, were logically added to these fifteen combinations.

The fifteen combinations selected were referred to as *natural landscape types* (Figure 48 and 49). They included:

- *pokrajina z nerazgibanim površjem, glino ter gozdom belega gabra in doba* 'landscape with a flat surface, clay, and hornbeam and pedunculate oak forests' (4,255.3 km², 15.5% of the area);
- *pokrajina z močno razgibanim površjem, karbonatnimi kamninami ter gozdom bukve* 'landscape with a very rough surface, carbonate rocks, and beech forests' (1,990.2 km², 7.2%);
- *pokrajina z močno razgibanim površjem, nekarbonatnimi kamninami ter gozdom bukve* 'landscape with a very rough surface, non-carbonate rocks, and beech forests' (5,090.9 km², 18.5%);
- *pokrajina z nerazgibanim površjem, prodom ter gozdom belega gabra in gradna* 'landscape with a flat surface, gravel, and hornbeam and sessile oak forests' (5,442.8 km², 19.8%);
- *pokrajina z rahlo razgibanim površjem, nekarbonatnimi kamninami ter gozdom rdečega bora* 'landscape with a slightly rough surface, non-carbonate rocks, and Scots pine forests' (1,314.0 km², 4.8%);

- *pokrajina z močno razgibanim površjem, nekarbonatnimi kamninami ter gozdom rdečega bora* 'landscape with a very rough surface, non-carbonate rocks, and Scots pine forests' (1,586.1 km², 5.8%);
- *pokrajina z rahlo razgibanim površjem, karbonatnimi kamninami ter gozdom bukve* 'landscape with a slightly rough surface, carbonate rocks, and beech forests' (791.7 km², 2.9%);
- *pokrajina z rahlo razgibanim površjem, prodom ter gozdom belega gabra in gradna* 'landscape with a slightly rough surface, gravel, and hornbeam and sessile oak forests' (2,504.2 km², 9.1%);

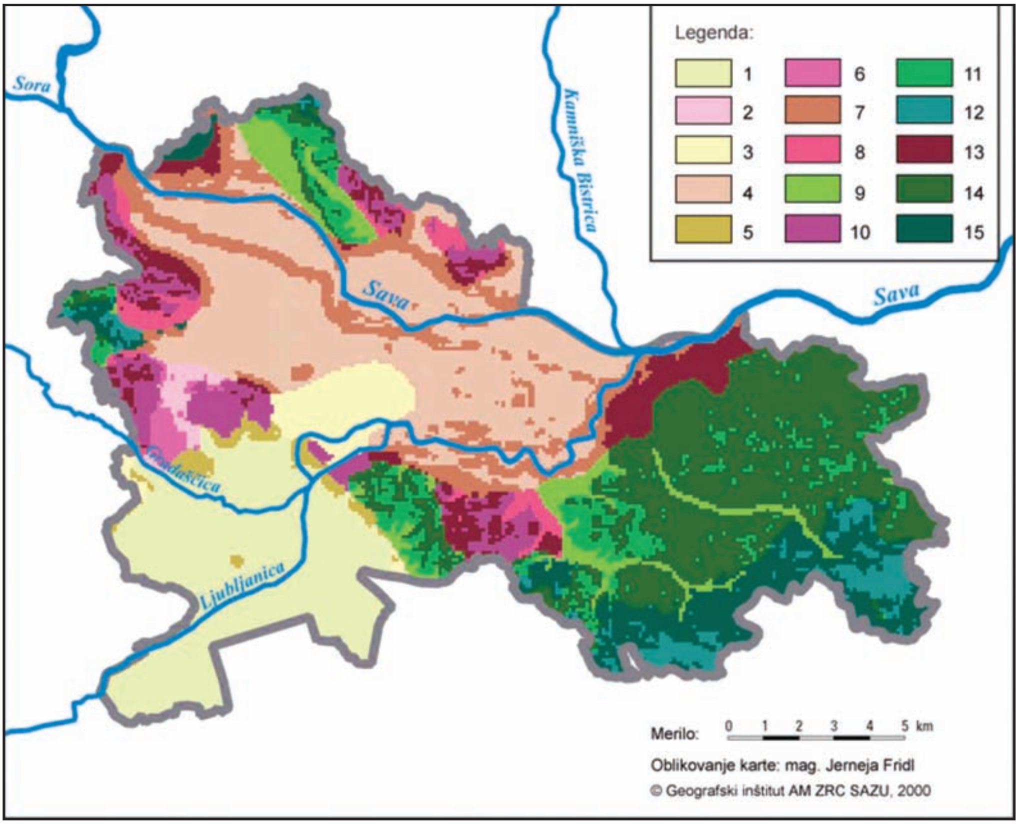
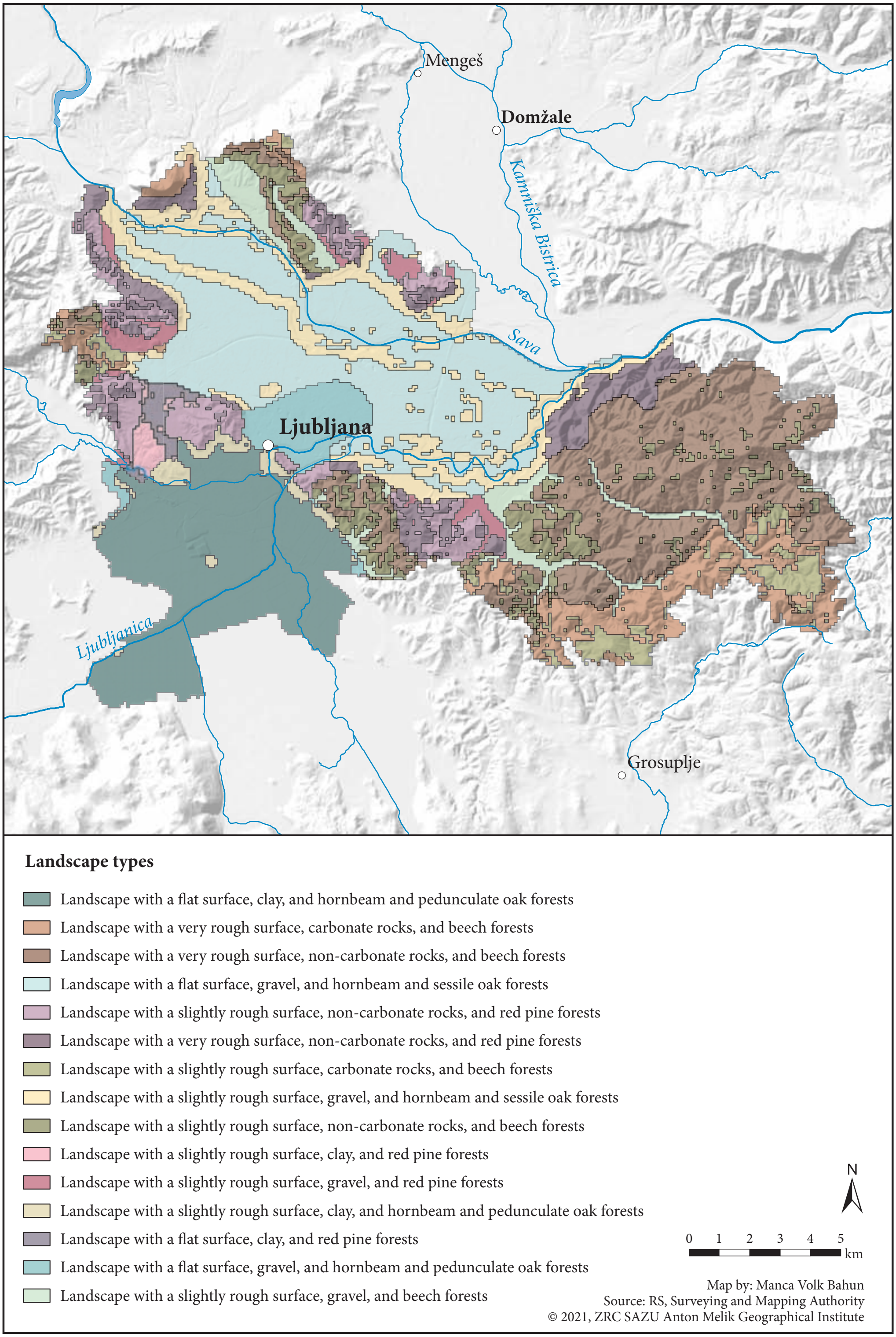


Figure 48: Original map of landscape types in the City Municipality of Ljubljana (Perko and Hrvatin 2000) with legend:

1. Landscape with a flat surface, clay, and hornbeam and pedunculate oak forests;
2. Landscape with a very rough surface, carbonate rocks, and beech forests;
3. Landscape with a very rough surface, non-carbonate rocks, and beech forests;
4. Landscape with a flat surface, gravel, and hornbeam and sessile oak forests;
5. Landscape with a slightly rough surface, non-carbonate rocks, and red pine forests;
6. Landscape with a very rough surface, non-carbonate rocks, and red pine forests;
7. Landscape with a slightly rough surface, carbonate rocks, and beech forests;
8. Landscape with a slightly rough surface, gravel, and hornbeam and sessile oak forests;
9. Landscape with a slightly rough surface, non-carbonate rocks, and beech forests;
10. Landscape with a slightly rough surface, clay, and red pine forests;
11. Landscape with a slightly rough surface, gravel, and red pine forests;
12. Landscape with a slightly rough surface, clay, and hornbeam and pedunculate oak forests;
13. Landscape with a flat surface, clay, and red pine forests;
14. Landscape with a flat surface, gravel, and hornbeam and pedunculate oak forests; and
15. Landscape with a slightly rough surface, gravel, and beech forests.

Figure 49: Updated map of landscape types in the City Municipality of Ljubljana. ➤


Mengeš
Domžale
Kamniška Bistrica
Sava
Ljubljana
Ljubljanica
Grosuplje
Landscape types
Landscape with a flat surface, clay, and hornbeam and pedunculate oak forests
Landscape with a very rough surface, carbonate rocks, and beech forests
Landscape with a very rough surface, non-carbonate rocks, and beech forests
Landscape with a flat surface, gravel, and hornbeam and sessile oak forests
Landscape with a slightly rough surface, non-carbonate rocks, and red pine forests
Landscape with a very rough surface, non-carbonate rocks, and red pine forests
Landscape with a slightly rough surface, carbonate rocks, and beech forests
Landscape with a slightly rough surface, gravel, and hornbeam and sessile oak forests
Landscape with a slightly rough surface, non-carbonate rocks, and beech forests
Landscape with a slightly rough surface, clay, and red pine forests
Landscape with a slightly rough surface, gravel, and red pine forests
Landscape with a slightly rough surface, clay, and hornbeam and pedunculate oak forests
Landscape with a flat surface, clay, and red pine forests
Landscape with a flat surface, gravel, and hornbeam and pedunculate oak forests
Landscape with a slightly rough surface, gravel, and beech forests
N
0 1 2 3 4 5
km
Map by: Manca Volk Bahun
Source: RS, Surveying and Mapping Authority
© 2021, ZRC SAZU Anton Melik Geographical Institute

- *pokrajina z rahlo razgibanim površjem, nekarbonatnimi kamninami ter gozdom bukve* 'landscape with a slightly rough surface, non-carbonate rocks, and beech forests' (1,347.0 km², 4.9%);
- *pokrajina z rahlo razgibanim površjem, glino ter gozdom rdečega bora* 'landscape with a slightly rough surface, clay, and Scots pine forests' (195.2 km², 0.7%);
- *pokrajina z rahlo razgibanim površjem, prodom ter gozdom rdečega bora* 'landscape with a slightly rough surface, gravel, and Scots pine forests' (505.8 km², 1.8%);
- *pokrajina z rahlo razgibanim površjem, glino ter gozdom belega gabra in doba* 'landscape with a slightly rough surface, clay, and hornbeam and pedunculate oak forests' (357.4 km², 1.3%);
- *pokrajina z nerazgibanim površjem, glino ter gozdom rdečega bora* 'landscape with a flat surface, clay, and Scots pine forests' (206.2 km², 0.8%);
- *pokrajina z nerazgibanim površjem, prodom ter gozdom belega gabra in doba* 'landscape with a flat surface, gravel, and hornbeam and pedunculate oak forests' (887.9 km², 3.2%); and
- *pokrajina z rahlo razgibanim površjem, prodom ter gozdom bukve* 'landscape with a slightly rough surface, gravel, and beech forests' (1,019.8 km², 3.7%).

4.6 Municipality of Idrija

The Municipality of Idrija covers 293.7 km², or 1.4% of Slovenia. It lies on very rough terrain at the intersection of the Alps and the Dinarides, approximately 50 km west of Ljubljana. The town of Idrija is well known for its now abandoned mercury mine.

A landscape microtypology of the area, together with its microregionalization, was produced in 2010 as part of the geographical expert bases for the municipality's development strategy. A detailed description of the method and data sources used is provided in an article published the same year (Perko and Hrvatin 2010).

For the first time, the geographic information system was based on a 25-meter 14.0 × 14.4 km digital elevation model. Available were the raster layers for elevation, slope, surface aspect, and insolation, and vector layers for rock types, soil types, potential vegetation types, and land use types. However, the values for all layers changed so quickly from one location to another that the researchers ended up with an uncontrollable number of combinations, of which most covered only a negligible area. Therefore, the microtypification was ultimately carried out by only taking into account the relief indicators (i.e., surface slope and elevation, relative elevation difference, and morphological surface type) or terrain, which contributes the most to the external appearance of this area.

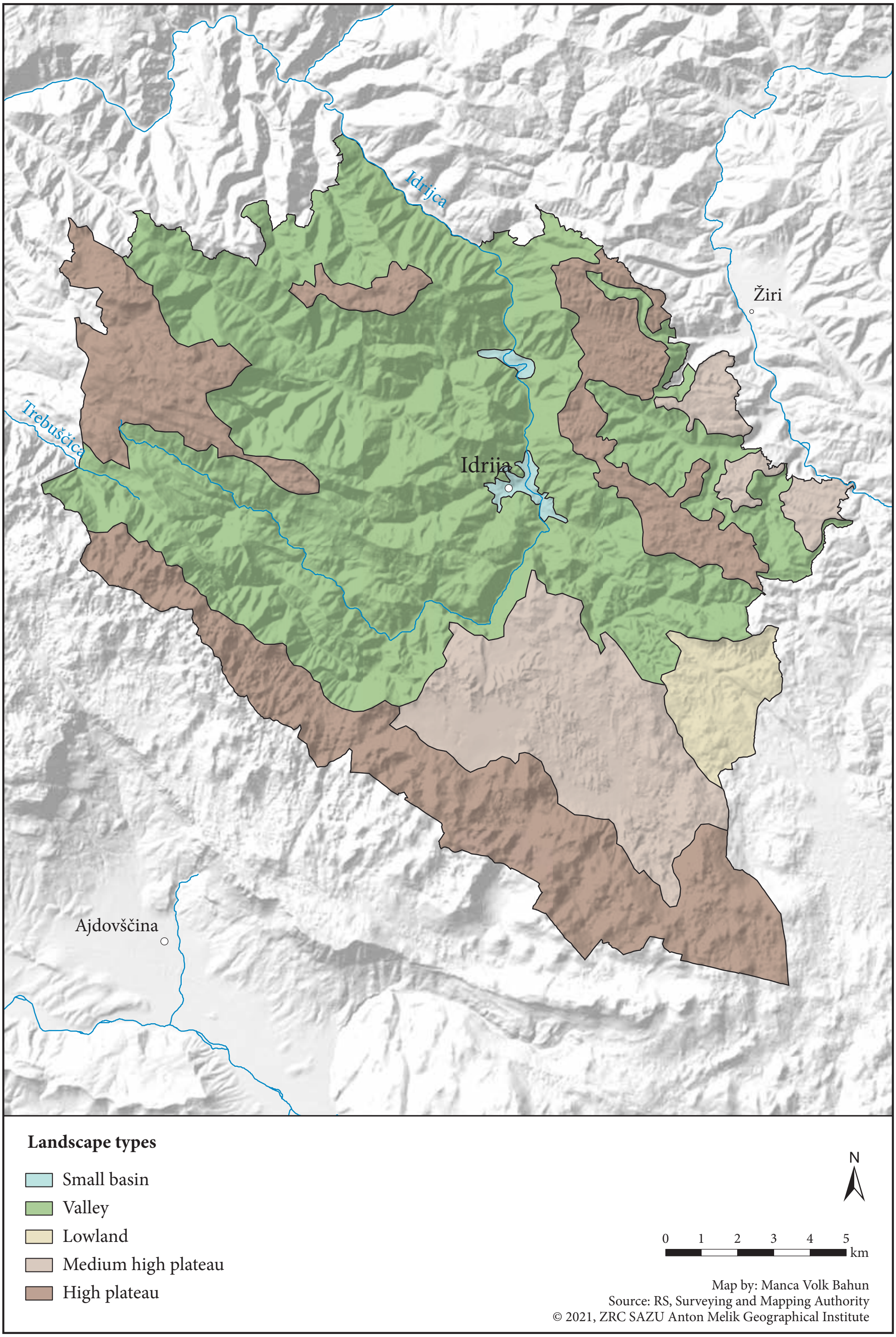
Seventeen microregions (Figure 50) and five landscape types (Figure 51) were identified:

- *kotlinica* 'small basin' (2.0 km², 0.7%, over two-thirds of the area with elevations between 300 and 400 m, and slopes ranging between 0 and 20°; microregions: the Idrija Basin, the Spodnja Idrija Basin);
- *dolina* 'valley' (159.5 km², 54.3%, over two-thirds of the area with elevations between 400 and 800 m, and slopes between 12 and 45°; microregions: the Kanomlja Valley, the Sovra Valley, the Lower Idrija Valley, the Zala Valley, the Upper Idrija Valley);
- *podolje* 'lowland' (9.2 km², 3.1%, over two-thirds of the area with elevations between 500 and 700 m, and slopes between 0 and 12°; microregion: the Godovič Lowland);
- *srednje visoka planota* 'medium-high plateau' (41.8 km², 14.2%, over two-thirds of the area with elevations between 600 and 800 m, and slopes between 2 and 12°; microregions: the Črni Vrh Plateau, the Ravne Plateau, the Vrsnik Plateau, the Zavratec Plateau); and
- *visoka planota* 'high plateau' (81.2 km², 27.7%, over two-thirds of the area with elevations between 700 and 1,000 m, and slopes between 6 and 30°; microregions: the Dole Plateau, the Trnovo Forest Plateau, the Krnice Plateau, the Ledine Plateau, the Vojsko Plateau).

Figure 50: Map of microregions in the Municipality of Idrija (Perko and Hrvatin 2010). ➤

Figure 51: Map of landscape types in the Municipality of Idrija (Perko and Hrvatin 2010). ➤ p. 70


Idrijca
Trebuščica
Lower Idrijca Valley
Krnice Plateau
Vojsko Plateau
Kanomlja Valley
Spodnja Idrija Basin
Ledine Plateau
Žiri
Vrsnik Plateau
Sovra Valley
Idrija
Idrija Basin
Ravne Plateau
Zavratec Plateau
Dole Plateau
Upper Idrijca Valley
Zala Valley
Godovič Lowland
Črni Vrh Plateau
Trnovo Forest Plateau
Ajdovščina
Microregions
Dole Plateau
Godovič Lowland
Idrija Basin
Kanomlja Valley
Krnice Plateau
Ledine Plateau
Lower Idrijca Valley
Ravne Plateau
Sovra Valley
Spodnja Idrija Basin
Trnovo Forest Plateau
Upper Idrijca Valley
Vojsko Plateau
Vrsnik Plateau
Zala Valley
Zavratec Plateau
Črni Vrh Plateau
N
0 1 2 3 4 5 km
Map by: Manca Volk Bahun
Source: RS, Surveying and Mapping Authority
© 2021, ZRC SAZU Anton Melik Geographical Institute


Idrijca
Trebuščica
Žiri
Idrija
Ajdovščina
Landscape types
Small basin
Valley
Lowland
Medium high plateau
High plateau
N
0 1 2 3 4 5 km
Map by: Manca Volk Bahun
Source: RS, Surveying and Mapping Authority
© 2021, ZRC SAZU Anton Melik Geographical Institute

4.7 Municipality of Kočevje

The Municipality of Kočevje covers 555.6 km², or 2.7% of Slovenia. It lies about 50 km southeast of Ljubljana. The area is dominated by Dinaric lowlands and plateaus (Perko 1998a) characterized by a karst surface, a sparse network of surface streams, and a high percentage of forest cover.

The microtypology of the Municipality of Kočevje was one of the four microtypologies selected as part of a 2013–2015 research project that focused on developing a method for identifying natural landscape types at the local level and mapping these types for selected Slovenian municipalities. Among other things, the purpose of that research was to check the applicability of geographic information tools and digital data in designing landscape typologies at the local level. Placed at the forefront was thus an attempt to develop a suitable methodology that could be used as a model for producing landscape typologies at the local level. The microtypification was primarily based on using segmentation and supervised and unsupervised classification. A detailed description of the method and data sources used is provided in a report published in 2015 (Ciglič 2015).

Based on the findings of research conducted as part of this project and previous research (e.g., Ciglič 2014), the following general steps were defined for producing a natural landscape typology:

- Collecting and preparing data layers;
- Assessing data layers (their interconnection and significance at various spatial scales by calculating the average moderate coefficient of variation; for more details, see Ciglič and Perko 2017);
- Converting raster data into vector data using segmentation (Acharya and Ray 2005; Pratt 2007; Lotufo et al. 2008; Eastman 2012) because the basic unit used from there on was segments or polygons;
- Assigning values to polygons for the cells they covered (e.g., the minimum, maximum, and average values in terms of numerical data and the most frequent category in terms of nominal data);
- Classifying polygons using various unsupervised classification models and estimating the number of types;
- Reviewing the unsupervised classification data and results, and conducting a field inspection;
- Selecting test polygons and validation polygons of envisaged landscape types to determine the supervised classification model; and
- Selecting the most suitable model, classifying the entire area, and reviewing and manually revising any discrepancies with the real landscape.

The data layers were selected based on their applicability for an individual municipality. They included:

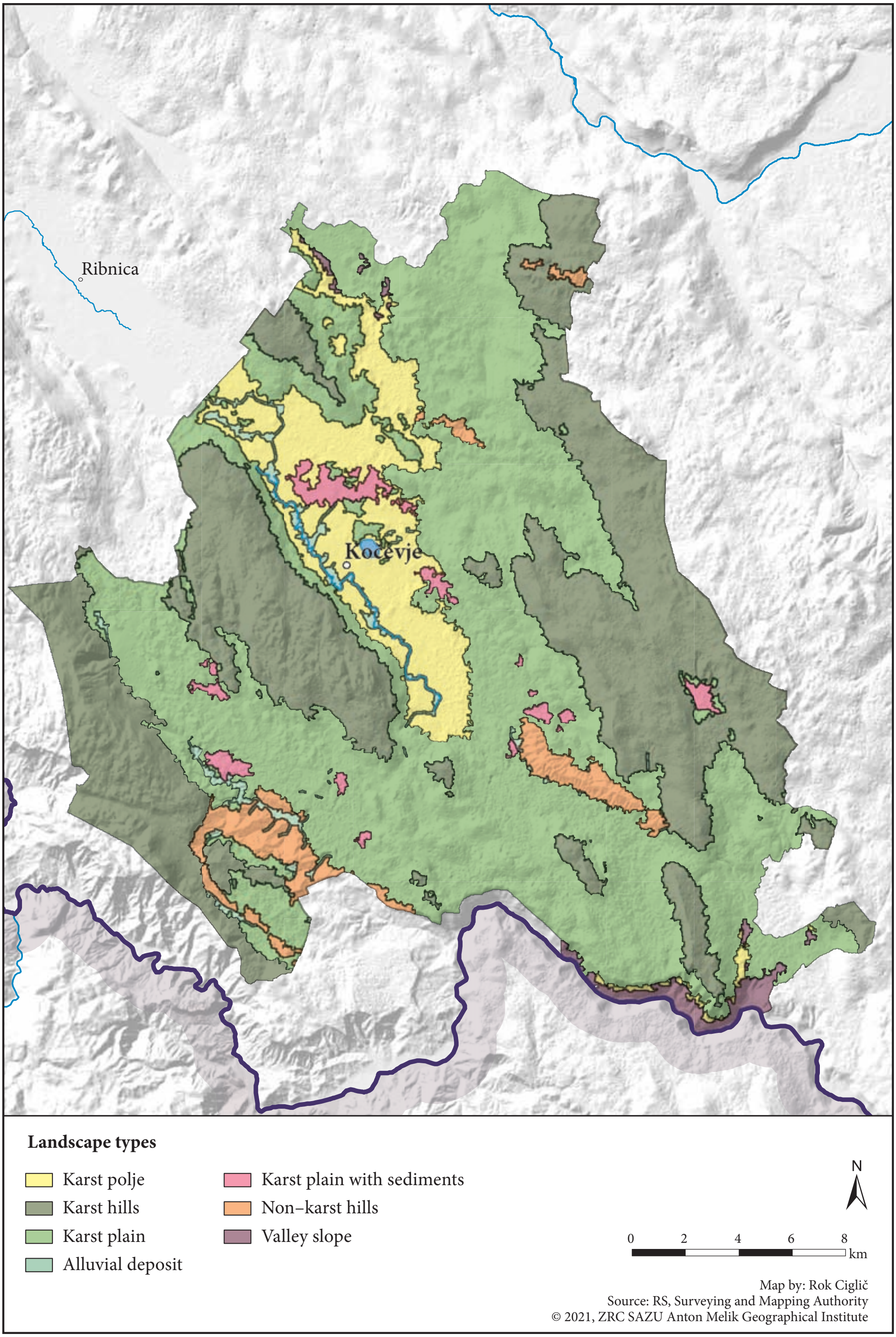
- A 12.5 m and 25 m digital elevation model;
- Average monthly and annual precipitation and temperature;
- Watercourses;
- Soil types;
- Solar radiation (Gabrovec 1996);
- Solar radiation (Zakšek 2005);
- Cave sites;
- Landslide sites;
- Landsat 8 images; and
- Rock types.

Based on these data layers, several other layers were also prepared. The final dataset included the following: elevation, slope, elevation variation, slope variation, total slope curvature, vertical slope curvature, horizontal slope curvature, depression sites, density of dolines according to the 12.5 m and 25 m DEM, annual precipitation, Mediterranean character index, average annual temperature, annual temperature difference, April and October temperature difference, rock types, permeability, annual solar radiation (Gabrovec 1996, Zakšek 2005), network of major perennial and non-perennial streams, stream density, soil types, cave sites, cave density, and normalized difference vegetation index (NDVI).

Four test areas were selected: one in the Slovenian alpine region, one in the Pannonian region, one in the Dinaric region, and one in the Mediterranean region. The Municipality of Kočevje was the Dinaric area selected. Several models were produced for each area, and the most suitable one was then selected.

First, the average moderate coefficient of variation and the Pearson correlation coefficients were analyzed to evaluate the data layers, after which several attempts of segmentation at a 12.5 m resolution were made. Ultimately, a segmentation with the following settings was selected:

Figure 52: Map of modeled landscape types in the Municipality of Kočevje. ➤ p. 72


Ribnica
Kočevje
Landscape types
Karst polje
Karst hills
Karst plain
Alluvial deposit
Karst plain with sediments
Non–karst hills
Valley slope
N
0 2 4 6 8
km
Map by: Rok Ciglič
Source: RS, Surveying and Mapping Authority
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- Data layers (with weights): stream density (weight: 1/3), slope (weight: 1/3), NDVI (weight: 1/3);
- Window width: 9;
- Weight mean factor: 0.6;
- Weight variance factor: 0.4; and
- Similarity tolerances: 0, 1, 2, 3, 4, 5.

After segmentation, several unsupervised polygon classifications were conducted. Based on the quality of data, their correlation, and the analysis of the average moderate coefficient of variation, for the purposes of unsupervised hierarchical classification, which shows changes in the homogeneity of types according to their number, the minimum and mean polygon values were selected for stream density, and the mean polygon value was selected for the density of dolines (12.5 m DMV), slope, annual solar radiation, precipitation index, permeability, and elevation. Ward's method with squared Euclidean distance was used for the classification.

As part of unsupervised classification experiments, different sets of input data layers were tested, primarily to establish how the data characteristics change by level. Up to the level of four or five types, the decrease in the average moderate coefficients of variation of all layers was 0.2, and then up to the level of fifteen types it was smaller than 0.2. A review of decrease in the average moderate coefficient of variation for individual layers showed that most of them recorded smaller decreases at least at the level of seven to nine types. Therefore, at least four and a maximum of nine types had to be found for the typification.

The results of the analysis of hierarchical classifications and the area's geographical characteristics (rocks, terrain and insolation, climate, and settlement) were then taken into account in the supervised classification. Ultimately, the following seven landscape types were identified:
- *kraško polje* 'karst polje';
- *kraško hribovje* 'karst hills';
- *kraški ravnik* 'karst plain';
- *naplavna ravnica* 'Alluvial plain';
- *nekraško hribovje* 'karst plain with sediments';
- *nekraško hribovje* 'non-karst hills'; and
- *dolinsko pobočje* 'valley slope'.

After that, 298 segments or polygons were selected as landscape type case samples, corresponding to 2% of all polygons. A decision tree with the Classification and Regression Tree (Lin, Noe, and He 2006) algorithm was used for the supervised classification. The input data layers included rock type, average rock permeability, average elevation, average slope, average stream density, and average density of dolines. In conclusion, several minor manual corrections were made to the polygon classification (Figure 52).

The typology produced is a test case of using various geographic information tools for landscape typification. The entire procedure includes several steps that can be combined as follows:
- Assessing data;
- Converting raster data into vector data (polygons);
- Checking unsupervised classifications; and
- Performing a supervised classification.

4.8 City Municipality of Velenje

The City Municipality of Velenje covers 8.5 km², or 0.4% of Slovenia. It lies on the southeastern edge of the Alps, where the mountains descend toward the Pannonian Basin, roughly 60 km northeast of Ljubljana. This is a landscape that has been significantly transformed by years of mining, with several lakes having been formed due to subsidence.

A microtypology of this area was produced, together with its microregionalization, in 2020 as part of the geographical recommendations for the municipality's further development.

In this case, a landscape microtypology was first produced based on landscape diversity, which became very important in the twenty-first century, and both Slovenia and the EU have been incorporating it into various strategies and similar documents (Ciglič and Perko 2013b). A detailed description of the method and data sources used is provided in an article published in 2020 (Perko and Hrvatin 2020).

Municipalities can effectively use their above-average landscape diversity as a development advantage and thus increase their economic competitiveness and raise the quality of life of individuals and social groups.

The City Municipality of Velenje is one of them. It is characterized by highly diverse natural landscape elements and includes five microregions: the Plešivica Hills, Paka Hills, Velenje Basin, Pirešica Lowland, and Ložnica Low Hills. As a former mining-industry municipality, it is becoming increasingly innovative, creative, and friendly to its residents and the environment, to which landscape diversity can contribute significantly, especially in terms of accelerating the development of tourism and recreational and sports activities, and improving the quality of life of both its residents and visitors. This will be facilitated even further by the planned improvement of its transport accessibility or transport connections.

The geographic information system used was based on a 25-meter 13.4 × 14.6 km digital elevation model. Landscape diversity was determined based on surface roughness and variation in rocks and vegetation (Perko, Hrvatin, and Ciglič 2017). The data was combined into seven relief, fifteen rock, and fifteen vegetation types. The ratio between the number of relief, rock, and vegetation types within a 1 km radius and the number of all relief, rock, and vegetation types was calculated for each cell, using a moving window. The lowest possible ratio was 0.092 if only one relief, rock, and vegetation type occurred within a 1 km radius ((1/7 + 1/15 + 1/15) / 3), and the highest possible ratio was 1.00 if all seven relief types, fifteen rock types, and fifteen vegetation types occurred within a 1 km radius at the same time (Perko, Ciglič, and Hrvatin 2015).

The average landscape diversity of the City Municipality of Velenje was 0.2186, which is 34.6% higher than that of Slovenia as the European landscape hotspot or the EU country with the highest average landscape diversity, or 20.1% higher than that of the Slovenian part of the Alps. The average landscape diversity of Slovenia is 0.1624 and that of the Slovenian Alps microregion is 0.1820 (Perko, Hrvatin and Ciglič 2017). The lowest value in the municipality was 0.0920 recorded for the Plešivica Hills, and the highest value was 0.3905 recorded for the Pirešica Lowland (Figure 54).

The municipality is characterized by two diagonal belts of above-average landscape diversity extending from the northwest to the southeast and from the northeast to the southwest, and intersecting east of Velenje, roughly in the center of the municipality.

The belts also include two landscape hotspots with the greatest concentration of different natural landscape elements. The larger one is at the intersection of both belts east of Velenje and the smaller one is in the extreme northeastern corner of the municipality along the Paka Valley, where there is also the cell with the greatest landscape diversity in the municipality. It is located at the intersection of the Paka Hills, Velenje Basin, and Pirešica Lowland.

The most distinct areas of below-average landscape diversity, with the lowest concentration of different natural landscape elements, can be found on the southwestern and eastern edges of the municipality.

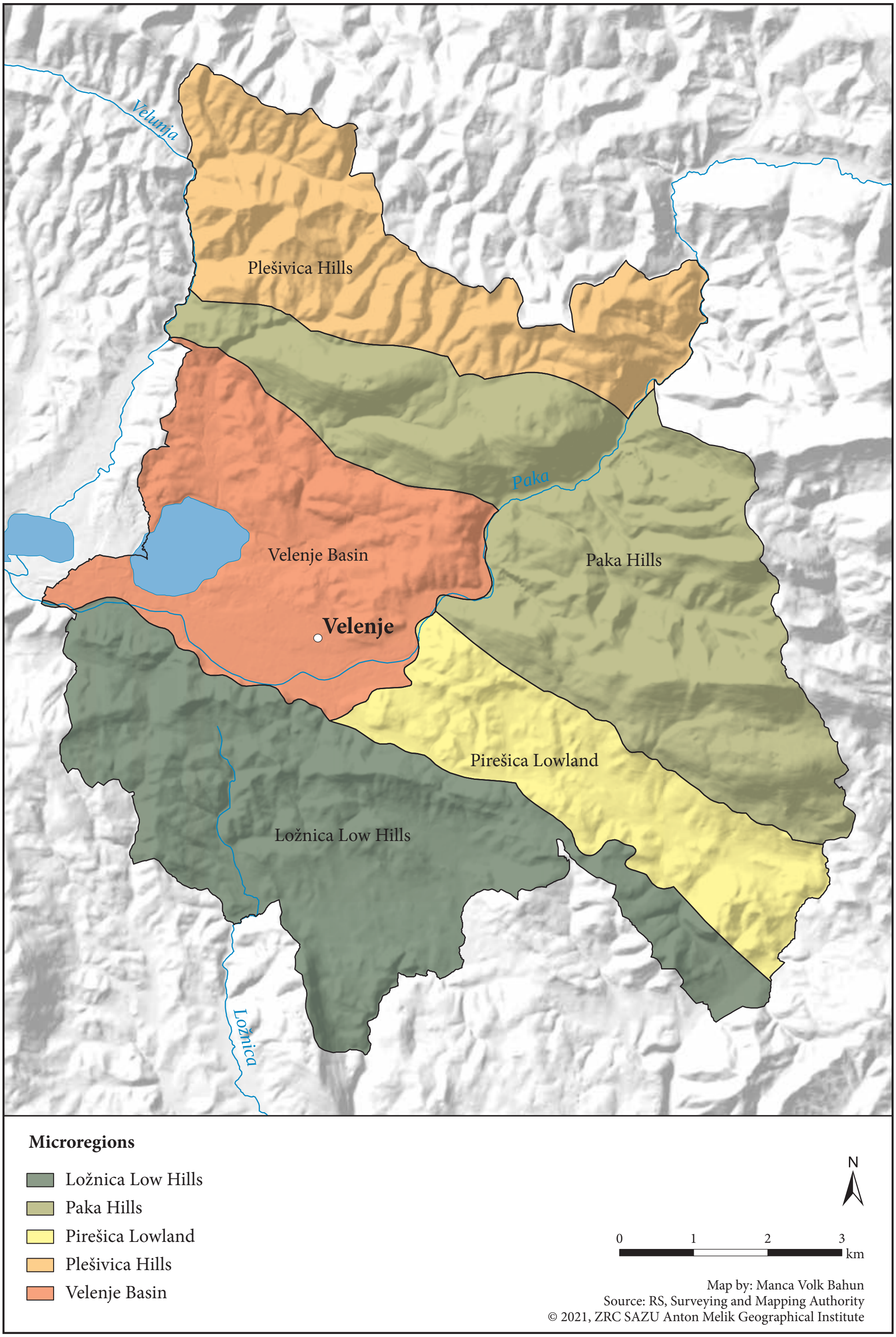
The Pirešica Lowland has the greatest landscape diversity among the microregions (Figure 53): its landscape diversity is 27.9% greater than that of the municipality's average and 47.4% greater than that of the Ložnica Low Hills, the microregion with the lowest landscape diversity in the municipality – which, however, is still 16.8% higher than the Slovenian average.

Five landscape diversity types (Figure 54) were identified:

- *območje zelo nizke pokrajinske raznolikosti* 'a very low landscape diversity area' (coefficient ranging from 0.0000 to 0.1499);
- *območje nizke pokrajinske raznolikosti* 'a low landscape diversity area' (coefficient ranging from 0.1500 to 0.1999);
- *območje srednje pokrajinske raznolikosti* 'a medium landscape diversity area' (coefficient ranging from 0.2000 to 0.2499);
- *območje visoke pokrajinske raznolikosti* 'a high landscape diversity area' (coefficient ranging from 0.2500 to 0.2999); and
- *območje zelo visoke pokrajinske raznolikosti* 'a very high landscape diversity area' (coefficient ranging from 0.3000 to 0.3999).

Figure 53: Map of microregions in the City Municipality of Velenje (Perko and Hrvatin 2020). ➤

Figure 54: Map of landscape types in the City Municipality of Velenje (Perko and Hrvatin 2020). ➤ p. 76


Velunja
Plešivica Hills
Paka
Velenje Basin
Paka Hills
Velenje
Pirešica Lowland
Ložnica Low Hills
Ložnica
Microregions
Ložnica Low Hills
Paka Hills
Pirešica Lowland
Plešivica Hills
Velenje Basin
N
0 1 2 3 km
Map by: Manca Volk Bahun
Source: RS, Surveying and Mapping Authority
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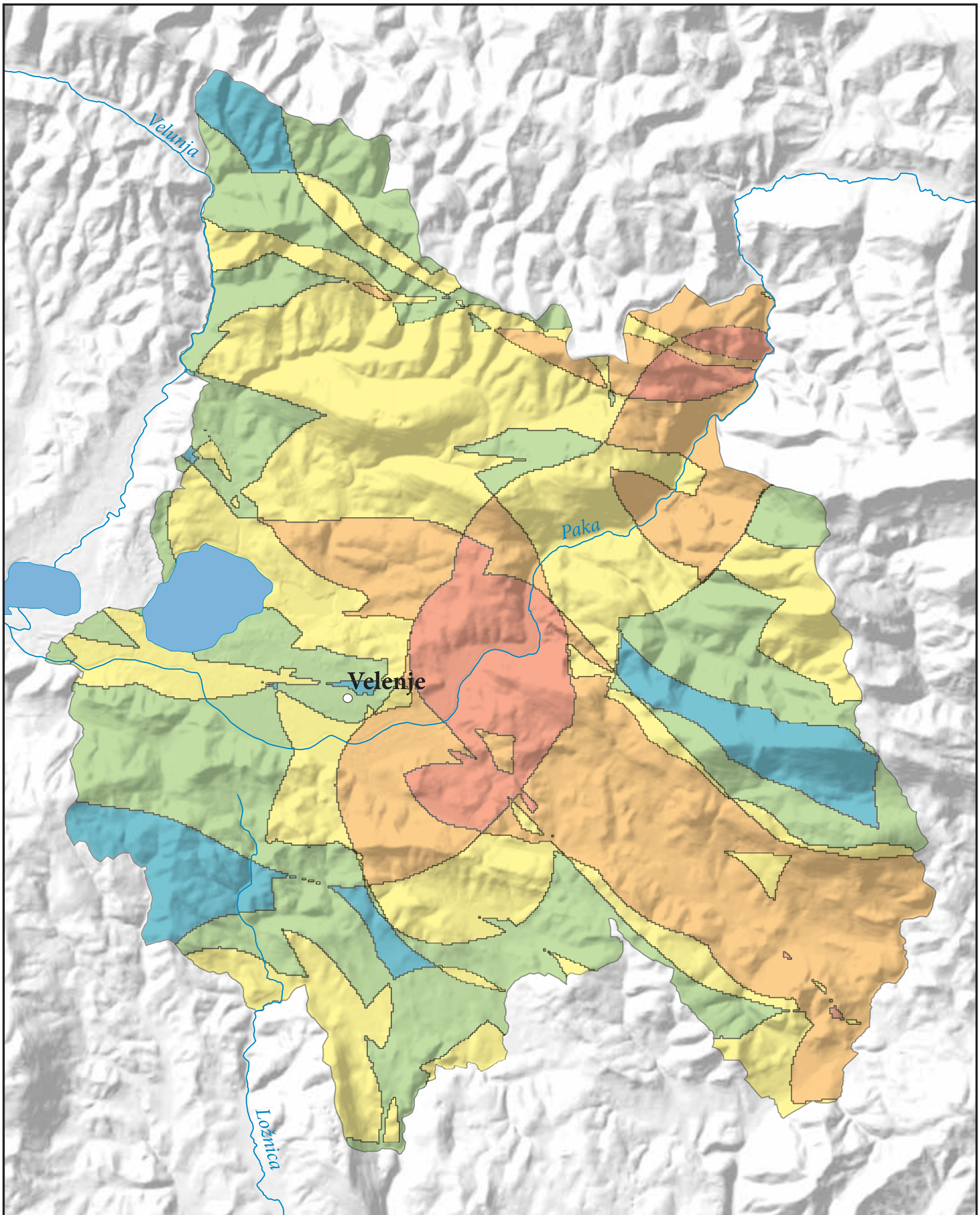

Landscape types

- A very low landscape diversity area (coefficient ranging from 0.0000 to 0.1499)
- A low landscape diversity area (coefficient ranging from 0.1500 to 0.1999)
- A medium landscape diversity area (coefficient ranging from 0.2000 to 0.2499)
- A high landscape diversity area (coefficient ranging from 0.2500 to 0.2999)
- A very high landscape diversity area (coefficient ranging from 0.3000 to 0.3999)

Map by: Manca Volk Bahun
Source: RS, Surveying and Mapping Authority

4.9 Comparing the microtypifications

The microtypification examples presented primarily differ in term of the location in Slovenia (Figure 37), the size of the area covered, the number and size (resolution) of square cells, the year produced (Table 3), and the methodology used, and they tend to differ less in terms of the data layers used or the landscape elements observed.

In terms of the landscape typology of Slovenia produced in 1996 (Perko 1998a; Perko, Hrvatin, and Ciglič 2015), all the examples are relatively diverse, with not even a single area including only one landscape type. Two landscape types are included in the Kokra Valley (Alpine mountains and Alpine plains), the Volčji Potok Arboretum (Alpine plains and Alpine hills), the Lower Drava Valley (Pannonian low hills and Pannonian plains), the Municipality of Kočevje (Dinaric plateaus and Dinaric lowlands), and the Municipality of Velenje (Alpine mountains and Alpine hills), and three landscape types can be found in the Eastern Krka Basin (Pannonian low hills, Pannonian plains, and Dinaric plateaus), the City Municipality of Ljubljana (Alpine plains, Alpine hills, and Dinaric lowlands), and the Municipality of Idrija (Alpine hills, Dinaric plateaus, and Dinaric lowlands).

In terms of Slovenia's regionalization produced in 1996, extending over two regions are the Kokra Valley (the Kamnik–Savinja Alps and the Sava Plain) and the Volčji Potok Arboretum (the Sava Plain and the Sava Hills), extending over three regions are the Municipality of Kočevje (the Ribnica–Kočevje Lowland; the Big Mountains, Stojna Plateau, and Gotenica Mountains; the Little Mountains, Kočevje Rog Plateau, and Poljane Mountains) and the City Municipality of Velenje (the Eastern Karawanks; the Velenje and Konjice Hills; the Ložnica and Hudinja Low Hills), and extending across four regions are the Eastern Krka Basin (the Sava Hills; the Krško, Senovo, and Bizeljsko Low Hills; the Krka Plain; and the Gorjanci Hills), the Lower Drava Valley (the Mura Plain, the Slovenian Hills, the Drava Plain, and the Haloze Hills), the City Municipality of Ljubljana (the Sava Plain; the Cerkno, Škofja Loka, Polhov Gradec, and Rovte Hills; the Sava Hills; and the Ljubljana Marsh), and the Municipality of Idrija (the Idrija Hills; the Cerkno, Škofja Loka, Polhov Gradec, and Rovte Hills; the Trnovo Forest Plateau, Mount Nanos, and the Hrušica Plateau; and the Inner Carniolan Lowland).

The average size of a quadrant is 848.51 km^2 and of the area typified inside this quadrant is 396.24 km^2. The smallest example is the Volčji Potok Arboretum (quadrant: 2.25 km^2, area typified: 0.83 km^2) and the largest one is the Lower Drava Valley (quadrant: 2,478.00 km^2, area typified: 1,034.45 km^2). The ratio between the smallest, average, and largest quadrants is 1:377:1,101, and the ratio between the smallest, average, and largest areas typified is 1:477:1,246.

The Eastern Krka Basin has the smallest number of cells (i.e., 1,763 squares) and the Municipality of Kočevje has the largest number (i.e., 6,718,400 squares); the ratio between them is 1:3,811.

The Eastern Krka Basin has the lowest cell resolution (i.e., 1,000 m) and the Volčji Potok Arboretum has the highest (i.e., 5 m), the ratio being 200:1.

A comparison of the typification methods used in the examples presented shows gradual changes or development of methods over the past few decades. In the case of the Kokra Valley in 1985, first maps were prepared for all the landscape elements observed, after which they were overlapped to create five new maps showing the types of relief, rocks, climate, soil, and vegetation. By overlapping the synthesized maps, ultimately a final map of the Kokra Valley landscape typology with eight types was produced. All areas on the maps were first measured with a square grid on transparent paper placed over the maps, through which a simple geographic information system was created. The size of the areas was later checked with a planimeter. All statistical and other calculations were already performed on a computer (Perko 1987).

In the case of the Eastern Krka Basin (Perko 1989) four years later, maps were also produced for all the landscape elements. By overlapping these maps, synthetic maps were created and, based on this, the final landscape typology map with nine types was produced. However, this time the square grid with which the maps were covered was used not only to measure the areas, but also to read data from the maps, enter them in the computer, and develop a proper geographic information system, albeit with a low resolution.

In the case of the Volčji Potok Arboretum (Perko 1993), all data were already entered in the geographic information system through digitization, including the digital elevation model, which was produced by digitizing the contour lines from a 1:5,000 map. Its five-meter resolution was a great achievement back in 1992. A special feature of this typology was that, due to the small size of the area covered, the data and the final landscape typology with five types were able to be updated and checked on the ground.

With the three typologies mentioned above, the types were spatially complete units (i.e., irregular polygons), whereas the landscape typology of the Lower Drava Valley was the first one that was produced at the level of a square cell. In determining the spatial and statistical correlation between individual data layers, it was established that rocks, slope, and vegetation were the most important landscape elements. Therefore, the landscape types were defined based on the combinations of types of rock and vegetation and slope classes within an individual cell. The nineteen most frequent combinations were selected as landscape types, and the combinations that were rarer were added to their most similar types (Fridl et al. 1996).

Four years later, the landscape typology for the City Municipality of Ljubljana (Hrvatin and Perko 2000) was produced in a similar way, only that surface roughness units were used instead of surface slopes. These units were defined based on the relief coefficient (Perko 2000, 2007), which simultaneously takes into account the spatial changes in slopes and elevations. The final landscape typology produced included fifteen types.

The previous two landscape typologies relied on a 100-meter digital elevation model, but in 2010 the landscape types in the Municipality of Idrija were identified based on a 25-meter digital elevation model. Examining the correlation between the layers revealed that practically all landscape differences were associated with surface roughness, and therefore a microtypology with five types was produced using only slope, elevation, difference in elevation, and morphological surface type (Perko and Hrvatin 2000).

A methodological innovation in the case of the microtypification of the Municipality of Kočevje (Ciglič 2015) was modeling with segmentation and supervised and unsupervised classification. In the end, seven landscape types were identified. A 12.5-meter digital elevation model and some artificial intelligence algorithms were used for the first time (Ciglič et al. 2019; Perko, Ciglič, and Hrvatin 2019).

The last example presented, the 2020 landscape microtypology of the City Municipality of Velenje, landscape diversity based on the concentration of different landscape elements was used to define the types for the first time (Perko and Hrvatin 2020). This time, a 25-meter digital elevation model was used again. Landscape diversity was defined based on surface roughness and variation in rocks and vegetation. The final microtypology included five types.

A comparison of all eight microtypifications presented also shows the development of the basic typification term *landscape type*. With the Kokra Valley , priority was given to the term *eco-complex* and with the Eastern Krka Basin both terms were used fairly equally. With the Volčji Potok Arboretum, the term *geological unit* was also used with the same meaning, whereas in later microtypologies only the term *landscape type* was used.

Table 3: Comparing the microtypologies of parts of Slovenia.

Name	Quadrant size in km^2	Quadrant size in km^2	Quadrant size in squares	Resolution in meters	Size of typified landscape in km^2 (current digital measurement)	No. of landscape types	Year produced
Kokra Valley	21.0 × 22.0	462.00	420 × 440	50	221.91	8	1987
Eastern Krka Basin	41.0 × 43.0	1,763.00	41 × 43	1,000	704.54	9	1989
Volčji Potok Arboretum	1.5 × 1.5	2.25	300 × 300	5	0.83	5	1992
Lower Drava Valley	59.0 × 42.0	2,478.00	590 × 420	100	1,034.45	19	1996
City Municipality of Ljubljana	29.3 × 21.7	635.81	293 × 217	100	275.03	15	2000
Municipality of Idrija	14.0 × 14.4	201.60	560 × 576	25	293.47	5	2010
Municipality of Kočevje	32.3 × 32.5	1,049.75	2,584 × 2,600	12.5	555.64	7	2015
City Municipality of Velenje	13.4 × 14.6	195.64	536 × 584	25	84.08	5	2020

5 The future of landscape typologies of Slovenia

To our knowledge, this is the first article that provides a systematic overview of all landscape typologies at various levels for a specific country in the world.

It presents all five landscape macrotypologies of Slovenia produced by Slovenian authors (Melik 1946; Ilešič 1958; Perko 1998a; Špes et al. 2002; Perko, Hrvatin, and Ciglič 2015) and compares them with the landscape macrotypologies of Europe produced by authors outside Slovenia (Meeus 1995; European Environment Agency 1995; Olson et al. 2001; Bohn et al. 2003; Mücher et al. 2003, 2006, 2010; Rivas-Marínez, Penas, and Díaz 2004a; 2004b; Jongman et al. 2006; Biogeographical regions 2016; DMEER 2003) and Slovenia's position within them. In addition, it presents several examples of microtypologies of individual parts of Slovenia (Perko 1986, 1989, 1993; Fridl et al. 1996; Hrvatin and Perko 2000; Perko and Hrvatin 2010, 2020; Ciglič 2015), some of which were created under the influence of macrotypologies or represent their further development at the microlevel. For example, the microtypology and microregionalization of the Municipality of Idrija (Perko and Hrvatin 2010) are a development of Perko's landscape macrotypology (Perko 1998a). In the article, all Slovenian landscape macrotypologies and microtypologies are presented with the original map and an updated one at the same scale, which facilitates comparison between them and especially between the landscape types. In general, the comparison between landscape macrotypologies primarily shows development in the methodology of classifying landscapes, moving from a distinctly subjective method using manually drawn borders between the landscape types as seen in the macrotypology produced by Melik (1946) and Ilešič (1958) to a more automatic one, which is nonetheless still tested on the ground, as seen in Perko, Hrvatin, and Ciglič (2015). Melik's (1946) and Ilešič's (1958) landscape macrotypologies are the work of a single author, Perko (1998a) was assisted by experts in his detailed definition of borders, and the two most recent landscape typologies (Špes et al. 2002; Perko, Hrvatin, and Ciglič 2015) are the work of a group of researchers. What stands out in the microtypologies is the great diversity of the methodologies used to achieve the same result.

The terminology developed from various expressions for spatial units in the oldest macrotypologies and microtypologies to the predominant term *pokrajinski tip* 'landscape type' in the ones produced after 2000. The development of concrete names of landscape types proceeded from mixing the names of regions and landscape types in older typologies to distinguishing more consistently between the names of regions as geographical regionalization units (e.g., *regija Ljubljanska kotlina* 'Ljubljana Basin region') and types as landscape typology units (e.g., *kotlina* 'basin'). Distinguishing between proper nouns referring to regions and common nouns referring to types is the more complex because, except for Perko, Hrvatin, and Ciglič (2015), all authors link Slovenia's macrotypologies with its regionalizations, especially at the microlevel, which means that landscape types are common as units at the macrolevel and mesolevel, and regions are common at the microlevel.

However, what stands out the most is how geographic information systems and related digital thematic cartography have almost completely supplanted other landscape typification methods at all levels, from the macrolevel to the microlevel. However, this is also typical of other areas of geography.

5.1 The importance of landscape typologies

Research directly and indirectly influences people in various ways, which is why it will continue to occupy an important place in the future. Because landscape classifications, including landscape typologies, can affect the life of every individual, they not only pose a research challenge, but also have a practical or applied value.

Defining landscape types de facto means defining homogenous areas, and familiarity with homogenous spatial units is important in a wide range of areas. For example, in natural disasters areas of the same landscape type, even though they may be far apart, are similarly threatened and they demand similar protection against natural disasters and similar measures (Perko 1992a; Fridl et al. 1996). Areas with the same landscape type allow for similar spatial and regional planning (Perko 2009), similar economic use (e.g., in agriculture and tourism; Ciglič and Perko 2013b), similar protection of natural and cultural heritage (Tičar, Perko, and Volk Bahun 2018; Perko and Tičar 2020), and similar military defense, and some landscape types are even associated with geographical names (Geršič, Ciglič, and Perko 2018). The development of the entire society can also be more successfully directed based on a good knowledge of landscape types (Nared et al. 2015).

In this century, Europe has been promoting awareness of the importance of landscape diversity (Van Eetvelde 2009; Dempsey and Wilbrand 2017), and in countries where landscape diversity is an important feature (e.g., in Slovenia) research on landscape types also strengthens national identity (Geršič and Perko 2020). Landscape typologies and geographical regionalizations are often part of geography textbooks at all levels of education, which means that practically everyone gets to know them (Urbanc et al. 2016).

The methodology and approaches developed while producing landscape typologies can also be applied to other geographical areas and similar disciplines (e.g., thematic cartography). In addition, landscape types can also be studied in less directly related research areas, such as machine learning or artificial intelligence (Ciglič et al. 2019).

The following description or proposed approach to improving existing landscape typologies, using the example of the 1996 landscape macrotypology of Slovenia (Perko 1998a), illustrates how important landscape typology can be, how it may concretely impact the life of individuals, or how an improved landscape typology may contribute to a fairer society.

5.2 Improving the landscape typology of Slovenia for a fairer society

Many researchers see the future of classifying landscapes in evaluation and correction of existing landscape classifications with modern quantitative methods (Congalton 1991; Ciglič and Perko 2015). Therefore, the authors of this article suggest several methodological steps for improving a landscape typology, illustrating them with the example of Slovenia.

A landscape typology is a part of Slovenia's legislation defining financial obligations, and therefore it is important for a large part of the populace. Thus, for example, the location of agricultural land in terms of landscape typology can decisively influence the amount of taxes for a particular farm. This means that a defective landscape typology can lead to unfair distribution of taxes, and thus unfairness or even discrimination between people.

Since 2008 in Slovenia, an important element for determining the quality of agricultural land and its taxation has been the location of individual parcels in relation to the landscape type, within which relatively similar natural conditions exist. Slovenian legislation from 2008 takes into account Perko's landscape macrotypology from 1996 (Perko 1998a), which divides Slovenia into nine landscape types and four landscape type groups. Perko produced this landscape macrotypology at a scale of 1:250,000 in 1996, and in 2008 he also prepared it as a digital data layer for the relevant ministry. When it was established a quarter of a century ago, the accuracy and diversity of landscape data were much lower. The landscape macrotypology was produced for publication in the volume *Geographical Atlas of Slovenia* (Fridl et al. 1998a), but not as a basis for taxes. Due to the availability of statistical data, the authors drew up the borders between the landscape types in such a way that they did not divide the nuclei of settlements, and so in some cases the lines do not fully follow natural conditions (Perko 1998a; Perko and Ciglič 2020a). Because it was designed on a relatively rough scale, many parcels of agricultural land, especially at the borders between individual landscape types, are classified in the wrong landscape type and farmers are therefore unfairly taxed. This means that a defective landscape classification can lead to an unfair distribution of taxes, and thus unfairness or even discrimination between people. To solve the problem, we propose some methods of machine learning and geographic information systems for evaluating existing landscape typology and determining their errors. Based on the results, it would be possible to correct the landscape typology, thus contributing to better and more effective taxation, and thus to a fairer society.

There are two main ways to tackle this problem: by creating a completely new landscape typology, or by updating the 1996 landscape typology. The application of a new typology would require changing legislative acts and a lengthy and unpredictable legal procedure. In contrast, implementing an updated existing typology by the same group of researchers would only require replacing the data layer at the relevant ministry. This is considered data maintenance, and it allows the immediate use and implementation of an improved and revised typology, thereby eliminating the unfair taxation of some farmers and providing greater social justice.

In 2012, the Surveying and Mapping Authority of the Republic of Slovenia and the Geodetic Institute of Slovenia proposed that using the nine landscape types instead of four landscape type groups as provided by the 1996 landscape typology would serve better. Farmers and others have also suggested improvements to the input data for determining land quality (Berk et al. 2012). However, both proposals have remained unfulfilled.

The development of technology makes it possible to obtain and process an increasing amount of more accurate data. For example, the digital elevation model had a resolution of 100 m in 1996, and now it has a resolution of 1 m (Hrvatin 2016). Other landscape data have also been improved, making it possible to respond to these demands and improve the landscape typology.

Researchers around the world also point out the importance of evaluating and correcting existing classifications. Some of them have drawn attention to the insufficient evaluation of the results obtained and have called for more transparent and replicable procedures to help scientifically verify the classifications produced (McMahon et al. 2004; Hargrove and Hoffman 2005). Therefore, different evaluations of landscape classifications have been presented; for example, in the United Kingdom (Warnock and Griffiths 2015). Congalton (1991) collected and presented some basic methods for accuracy assessment (error matrix, user's and producer's accuracy, and kappa). Drăguț and Eisank (2012) evaluated topographical units with mean intra-object variance, spatial auto-correlation, and an online survey; Breskvar Žaucer and Marušič (2006) used a neural network to confirm existing landscape classifications; Strand (2011) used binary logistic regression to evaluate the existing landscape map of Norway; Mezősi (2016) evaluated Hungarian landscape unit delimitation with multidimensional scaling and agglomerative hierarchical clustering; Wieczorek and Migoń (2014) compared automatic classification of landforms with morphographic landform classification mapping in the field; Vannametee et al. (2014) modeled a map of landforms with multiple-point geostatistics and compared it to the referenced map using a kappa coefficient and landform similarity; Jasiewicz et al. (2014) analyzed similarity between two landscapes calculated using their signatures (histograms of features) and a modified Wave Hedges similarity function; and Zawadzka et al. (2015) compared the classification of landforms and classification of soil categories with the use of Cramér's *V* and multidimensional scaling. Klingseisen et al. (2008) compared a map of landforms made with fuzzy set algorithm and a map generated by expert visual photo-interpretation. Brown and Brabyn (2012, 2012b) analyzed how landscape values associate with landscape characters using a chi-square residual. Some authors have used several different methods to evaluate existing classifications (e.g., Ciglič and Perko 2015; Ribeiro et al. 2016). Lausch et al. (2015) provided a review of methods with which one can evaluate existing classifications.

With modern methods and data sets now available, we presume it is possible to objectively quantitatively evaluate existing classifications and correct them if necessary. Namely, there are still many open issues in the landscape classification process, in particular the objectivity and transparency of classification. With the (re)modeling of an existing landscape classification and an explanation of its structure, it is possible to add missing pieces of information to its original description.

An excellent tool for achieving this goal is machine learning, a subfield of artificial intelligence, which is based on the idea that machines are able to automatically learn and adapt through experience. Such a tool develops algorithms for data analysis and knowledge discovery in databases (data mining) and constructs computer models for better decisions in real life. Machine learning can produce a better future through past experiences.

The most widely used groups of machine learning methods are classification, regression, logical relations, equations, and clustering (Ciglič et al. 2019).

The authors of this article have already dealt with the evaluation of landscape typology, data layers, and different methods at the theoretical level (Perko 1998a; Ciglič 2012, 2018; Ciglič and Perko 2012, 2015, 2017; Perko, Hrvatin, and Ciglič 2015; Perko, Ciglič, and Hrvatin 2019; Ciglič et al. 2019; Perko and Ciglič 2020a), but now, armed with more precise data, the newer methodological steps are even more feasible.

We seek to apply and add to knowledge that we mainly acquired through two basic projects already mentioned in the first section of this article. In the project Determination of Natural Landscape Types of Slovenia Using a Geographic Information System, in which we produced several new landscape typologies at various levels and with a different number of classes (see Section 2.5), we already addressed the problem of landscape classification with the help of modern databases and produced new classifications at different levels (Perko, Hrvatin, and Ciglič 2015). In the project Advancement of Computationally Intensive Methods for Efficient Modern General-Purpose Statistical Analysis and Inference, we tested modern mathematical and statistical methods in geography in collaboration with researchers from the Department of Machine Learning and Artificial Intelligence at the University of Ljubljana's Faculty of Computer and

Information Science (Ciglič et al. 2019). Both projects offer much fundamental knowledge and guidance on how to improve existing landscape classifications more effectively based on more detailed data.

In a methodological sense, the proposed landscape macrotypology improvement is roughly divided into three sections:

- Evaluating and modeling the existing landscape macrotypology of Slovenia from 1996 with machine learning algorithms;
- Checking the results in the field; and
- Creating a revised landscape macrotypology of Slovenia.

The first section includes the following:

- Selecting and testing different machine learning algorithms and methods; and
- Experimental modeling of the landscape macrotypologies of Slovenia with various manners of sampling learning examples and the most effective machine learning algorithms for supervised classification (e.g., decision tree or *k*-nearest neighbors), and analysis of results.

The second section includes the following:

- Checking the results of the modeled landscape macrotypologies in the field in selected areas; and
- Field study of the differences between the existing and modeled landscape macrotypologies of Slovenia in disputed areas.

The third section includes the following:

- Final modeling of the landscape macrotypology of Slovenia with multiple repetition and validation (Figure 55);
- Determining the number of inhabitants, houses, and hectares for individual land-use types that do not belong to the same landscape type in relation to the existing and revised landscape macrotypology of Slovenia and that are wrongly and therefore unfairly taxed;
- Producing a revised landscape macrotypology of Slovenia; and
- Preparing a revised landscape macrotypology data layer for the relevant ministry to eliminate potentially unfair taxation of some farmers and to provide greater social justice.

An important step (in addition to the use of modern classification models and the latest data) should be the use of the segmentation method, whereby we can switch from raster-based modeling to object-based

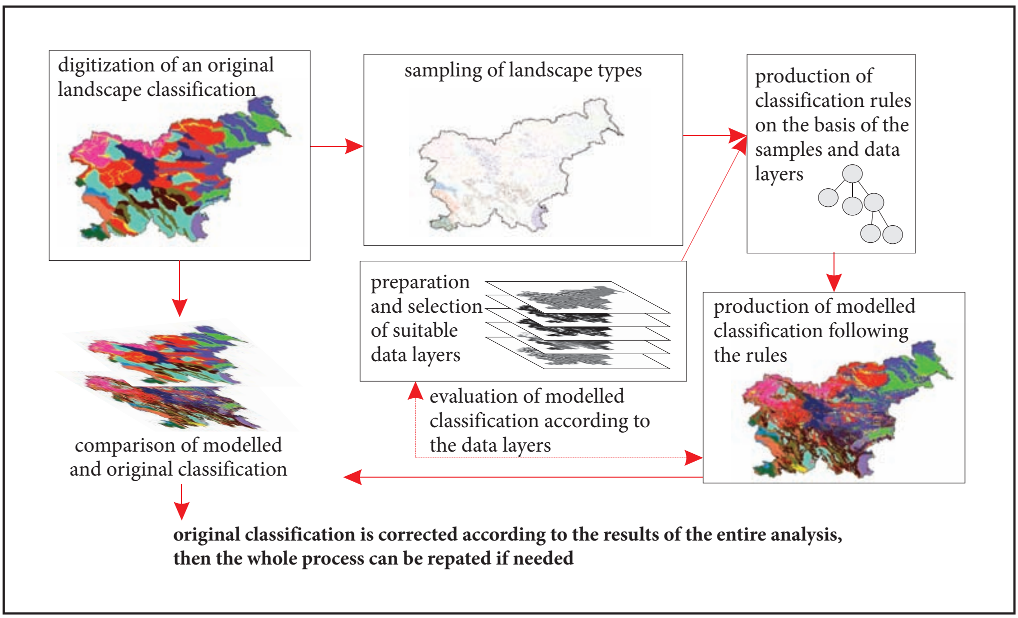

Figure 55: Producing the modeled landscape classification.

vector modeling, thus significantly reducing unnecessary data and determining the smallest homogeneous units that encompass the most similar raster cells.

The proposed methodological steps are not only useful for the area of Slovenia, but also suitable for other countries or regions.

Improving landscape macrotypologies would be beneficial for developing fundamental research in geography as well as for greater application of research findings in agriculture, regional planning, preserving the countryside, settlement, planning proper land use, landscape ecology, and preserving Slovenia's natural and cultural heritage.

With this conclusion of the article, we want to demonstrate how science – albeit at a more theoretical level, such as the creation of landscape typologies – can solve the problems of ordinary people through modern methods. After all, helping people should be one of the basic tasks of science. The authors would like our text on macrotypologies and microtypologies to serve as a small contribution to this.

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