

Article

Visualising the Relevance of Climate Change for Spatial Planning by the Example of Serbia

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Featured Application: As the urgency of climate change intensifies, the need for effective spatial planning becomes paramount. This article explores techniques in visualization that empower planners to tackle climate-related challenges and estimate whether balance between state of the art, mitigation measures and adaptation measures is achieved.

Abstract: After decades of rising awareness and undertaken actions, climate change is still one of several focal global challenges. Additionally, the latest report by researchers at the International Panel for Climate Change indicates that the crisis has deepened. With its comprehensive nature, spatial planning is one of the management tools responsible for dealing with climate change and combating its effects. Land use definition is the foundation on which we build mitigation and adaptation systems. It is a complex process that involves (or should involve) a range of stakeholders—experts, politicians, the civil sector, and citizens—in which the clear transmission of messages to stakeholders regarding the state of the art and planned actions is significant. The use of visualisation tools is one of the important ways to achieve this. This research aims to present a set of visualisation tools, applying them in analysis and decision making in the field of spatial planning with regard to climate change. We combined content analysis, colour-graded classification, and the spider method applied to the example of Serbia. The results showed that application of the suggested visualisation methods in combination with regular planning tools (maps) facilitates an understanding of the problem and its presentation to other stakeholders. In the case of Serbia, visualisation tools have shown that adaptation measures prevail over mitigation measures and that the effects of climate change addressed in spatial-planning documents do not significantly match the most challenging effects as perceived from the citizens' perspective. These are aspects that should be corrected in the next generation of planning documents. The suggested visualisation tools are replicable, with slight adjustments to a specific case, to any other region in the world.

Keywords: climate change; spatial planning; content analysis; mitigation measures; adaptation measures; visualisation tools; Serbia



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1. Introduction

Long-term shifts in temperature and weather patterns, recognized as *climate change*, have a strong impact around the globe. Scientists first acknowledged rising global temperatures [1], subsequently accompanied by extreme weather events (floods, heat waves, droughts, cyclones, and wildfires), which can have huge negative impacts on human health and lives, animals, plants, ecosystems, and built infrastructure [2].

There are several theories about the causes of global warming. The most commonly accepted theory by scientists and international organisations/institutions is called anthropogenic (man-made) global warming, which is reflected in Article 1 of the Framework Convention on Climate Change (UNFCCC) as part of the Intergovernmental Panel on Climate Change (IPCC) Glossary: “a change of climate which is attributed directly or

indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods” [3]. Reflections on the connection between human activities and climate change started at the end of the 19th century, when Swedish researcher Svante Arrhenius developed the idea that the use of fossil fuels adds CO₂ to the atmosphere, thus altering some parameters of climate conditions [1,4]. This important hypothesis was rather neglected till the 1950s, when researchers started to test it with technically improved methods [5]. The results indicated that the hypothesis was correct, and measurements in the following decades showed a constant rise in temperature and CO₂ concentration in the atmosphere [6–8]. However, the World Meteorological Organization (WMO) had more serious concerns at the end of the 1970s, warning that an increase in CO₂ in the atmosphere could be the cause of global warming [2].

It took another decade before WMO and the United Nations Environment Programme (UNEP) managed to establish the IPCC in 1988 as a United Nations (UN) body to advance knowledge on climate change. The result was the creation of responsible and suitable climate policies and constant international negotiations on climate change mitigation and adaptation [9]. Following IPCC efforts, the UN proclaimed taking “urgent action to combat climate change and its impacts” [8] as one of the sustainable development goals in 2015 [10]. Showing their awareness about climate change issues and in order to put solutions in practice, 196 parties ratified the Paris Agreement—a legally binding international treaty on climate change, which was adopted at the Conference of Parties (COP21) in Paris in 2015 and entered into force in 2016 [8].

The global temperature in Europe is rising. Serbia belongs to the group of countries where the number of cold days and nights has decreased, while the number of warm days and nights has increased [11]. Central European countries greatly contribute to the net short-term warming caused by emissions [12]. According to the latest scientific data (*ibid.*), observed trends for Central Europe show significant increases in the intensity and frequency of hot extremes and significant decreases in the intensity and frequency of cold extremes. There is significant intensification of heavy precipitation, days with thunderstorms have an increasing trend along with an increase in river floods, while drought trends remain unchanged. It is very likely that these man-influenced trends will continue. The frequency of heat waves will likely increase in all European regions, and heat stress due to both high temperatures and humidity will affect morbidity, mortality, and labour capacity (*ibid.*).

Data presented in the Second National Communication of the Republic of Serbia under the UN Framework Convention on Climate Change [13] show that there has been a significant increase in daily mean temperatures since 1960, as well as in daily maximum and daily minimum temperatures (with an average 0.3 °C increase per decade). The Republic of Serbia has experienced an increased number of episodes with heavy precipitation. The major changes have been in rising temperature trends, coupled with extremely high temperatures and extended warm periods. Climate change scenarios for the time horizon 2040–2070–2100 predict a plausible temperature rise and precipitation decrease, along with a reduction in frost days and an increase in summer days (*ibid.*). If they are realised, these estimates will have numerous negative effects on many sectors, especially hydrology and water resources, forestry, agriculture, and healthcare.

Spatial planning, owing to its multidisciplinary nature, is recognized as a key element in dealing with climate change, referring to both mitigation and adaptation [14,15]. It is considered to be a framework that plays a crucial role in linking mitigation and adaptation to climate change [16,17], as well as reconciling various elements of built-up space and environment in which interventions are required [18]. The latest prognoses of climate change trends indicate that it will have serious negative impacts on humanity and consequently create challenges in the field of spatial planning, particularly in aspects of land use regulation, urban design, planning engineering measures, and adaptation/mitigation infrastructure which play a crucial role in coping with future challenges [11,19,20].

At the city level, it has been proved that engaged spatial planning reduces the severity of the heat island effect [18], while on a more general scale, it will be the key to solving challenges such as population displacement caused by climate change impact [11]. Although the history of spatial planning is very long, decision-makers in Europe have only recently started to consider it a tool in combating the negative effects of climate change [21], but still not as much as they should or could [22,23]. Some case studies have been conducted to analyse and assess the impact of spatial planning on climate resilience (e.g., [21,22]). There are also a few international initiatives that emphasize the role of spatial planning instruments in coping with climate change, such as the CLISP—Climate Change Adaptation by Spatial Planning in the Alpine Space Project [24] or OECD Climate Change in the European Alps—Adapting Winter Tourism and Natural Hazards Management publication [25].

The results of the literature search on the topic of visualization methods in spatial planning related to climate change did not indicate that researchers have addressed this issue. From experience, as well as a review of existing plans analysed in this work, it has been shown that, apart from maps, other visualization tools for representing or analysing climate change issues are not in use.

Maps, as a means of visualisation, have always been part of spatial planning. Geographically represented visualisation has been greatly improved and popularized with the introduction of Geographical Informational Systems (GIS) [26]. But, maps are not the only tool for visual communication with stakeholders. Namely, the development and popularization of technology have brought many new opportunities and tools to visualise urban and spatial planning measures and concepts [27,28]. Currently, the use of virtual reality and augmented reality are new trends with growing relevance for planning and public participation processes [29,30]. All these methods that are closely related to the use of technology and visualisation became indispensable during the COVID-19 pandemic because it was the only way to include stakeholders in the planning process [31].

This research aims to suggest a set of visualisation tools in analysis and decision making in the spatial planning process with regard to climate change. Spatial planning (spatial plans) is understood here to be a management tool to deal with the global challenge of climate change effects and awareness. The tools were applied to the example of Serbia, i.e., its spatial-planning documents on the national and regional level. The suggested tools have an internationally applicable value since, with slight adjustments, they can be applied in any other territorial context. The Data and Methods chapter will present more details on the chosen tools and research process, followed by the Results chapter, where the presented tools will be applied to the example of Serbia's spatial-planning documents. A broader context for understanding the suggested tools and results will be given in the Discussion chapter. Finally, the Conclusions chapter will give a quick overview of the main messages, the applicability of the suggested visualisation methods, and potential improvements for future research.

2. Data and Methods

This research is built around two main pillars: one addresses spatial planning as a tool to deal with climate change, and the other addresses the methodology of visual analysis and presents the role of spatial planning in dealing with climate change effects. In this regard, this research combines several methods in order to visualise relations between climate change and spatial planning. We use Serbia only as an example because the suggested visualisation methodology can be applied in the context of any country or even at the international, regional and local level.

2.1. Data Collection Methods

The Law on Planning and Construction (2023) [32] defines four types of spatial plans in Serbia: (1) spatial plans for the Republic of Serbia, (2) regional spatial plans, (3) spatial plans for special-purpose areas, and (4) spatial plans for local self-governing units. The spatial plan for the Republic of Serbia, as an overarching strategic document, provides

strategic guidelines for regional and other spatial plans at lower planning levels. The whole territory of Serbia is encompassed by regional plans as well as local plans. The relationship between climate change and spatial planning is analysed here through the current set of national and regional documents, i.e., the national spatial plan, all nine regional plans, and some additional planning documents that accompany them such as strategic environmental assessment (SEA) and implementation plans: the Spatial Plan of the Republic of Serbia (2010) [33] and its SEA (2010) [34], and Implementation Program (2011) [35]; the Regional Spatial Plan for Južno Pomoravlje (2010) [36]; the Regional Spatial Plan for the Administrative Area of the City of Belgrade (2011) [37]; the Regional Spatial Plan for the Autonomous Region of Vojvodina (2011) [38], with its Implementation Program (2013) [39]; the Regional Spatial Plan for Timočka Krajina (2011) [40] and its Implementation Program (2015) [41]; the Regional Spatial Plan for Nišavski, Toplički, and Pirotski Districts (2013) [42]; the Regional Spatial Plan for Zlatiborski and Moravički Districts (2013) [43]; the Regional Spatial Plan for Šumadijski, Pomoravski, Raški, and Rasinski Districts (2014) [44]; the Regional Spatial Plan for Podunavski and Braničevski Districts (2015) [45]; and the Regional Spatial Plan for Kolubarski and Mačvanski Districts (2015) [46].

2.2. Data Analysis and Visualisation Methods

Content analysis is a tool for determining the presence of certain words, themes, or concepts within qualitative data (i.e., spatial-planning documents) [47,48]; Content analysis enables researchers to analyse and quantify the presence and frequency of selected terms, thus interpreting their relevance. It is commonly used in social sciences and the context of climate change e.g., [49,50], although not in the field of spatial planning, which is the intention of this paper. We used content analysis with the aim of developing a visual method to present it.

Therefore, we used information visualisation methods in order to communicate in a graphical, interactive, and understandable way, since 90% of the information transmitted to the brain is visual [51,52]. Until recently, research in social sciences posed fundamental challenges to the application of visualisation techniques [53]. However, in the field of spatial planning, it has been acknowledged since the very beginning that visual communication, featuring significantly more graphic constituents than text, has an indispensable role in providing the necessary information. A review analysis by Shen et al. [54] showed that most common visualisation methods are based on lines, plots, maps, parallel coordinates, and radial coordinates. Based on a comparative assessment of some of the most popular visualisation methods (presented in Table 1), we further elaborated our content analysis findings through a *colour-graded classification* and the *spider* method as the simplest, most readable, affordable, and fastest to produce.

Charts (line charts, bar charts, pie charts, and histograms) are one of the most common visualisation methods that are simple and fast to produce and which do not require basic software and skills, but are rather easy to read and understand. Diverse types of charts correspond to different needs. A line chart displays data points connected by straight lines, illustrating trends and variations over a continuous range. It is effective for showing changes in data over time or across categories. A bar chart represents data using rectangular bars of varying lengths that correspond to the value it represents, making it easy to compare values among different categories. A histogram represents the distribution of a dataset. It consists of bars where the width represents intervals and the height represents the frequency or count of data points within each interval. It is commonly used in statistical analysis to show the frequency distribution of continuous data. Finally, a pie chart represents data in a circular graph, divided into slices to illustrate the proportion of each category relative to the whole. It is effective for displaying the composition of a whole and showing the relationship of parts to the whole.

Table 1. Comparison of selected information visualisation methods.

Visualisation Method	Simplicity and Speed of Production	Affordability (Software, Skilled Workforce)	Clarity and Readability	Comment
Line chart, bar chart, histogram, pie chart	++	+	+	Simple and fast production, requires basic software and skills, rather easy to read and understand.
Colour-graded classification	++	++	++	Very simple and fast to produce; does not require special software nor skills; easy to read.
Cartographic representations/maps	--	--	++	Requires time, software and skills to produce. Easy to read, but not all data can be spatially related; too much information or too many colours can make reading difficult.
Radar chart/spider	+	+	++	Simple and fast to produce; semi-skilled workforce (can be used to visualise the relative strengths and weaknesses of the selected case studies or different scenarios for various chosen factors).
Word cloud	+	+	+	Simple to produce but requires software. Limited clarity/readability, for text summarisation (and analysis).

Source: [55–57]. Note: the symbols “+” and “–” and their multiplication signify the intensity of positive and negative aspects associated with each specific visualisation method.

Maps as cartographic representations are inextricably linked with spatial planning. They are graphical representations of geographic information, providing a visual depiction of spatial relationships and features on the Earth’s surface. They use symbols, colours, and scale to convey information about locations, landscapes, and various spatial attributes. However, their production requires time, costly software and experts with specific skills that require time to develop. They are easy to read, but cannot be applied in the representation of all aspects (measures) of climate change since they do not all have spatial connotations nor are they convenient to present on a map.

A word cloud is mainly used for text summarisation and the analysis of qualitative data (in business and academia); it is simple to produce but requires software and has limited clarity/readability. A word cloud is a visual representation of text data where words are arranged in a graphical manner, and the size of each word is determined by its frequency or importance in the given text. Commonly used words appear larger and more prominent. It is often employed to quickly identify and communicate key themes or topics within a set of textual information. According to Table 1, it is clear that simplicity and speed of production are often opposite to costs (i.e., simple methods are usually not very expensive), while correlation with readability varies.

Colour-graded classification is a simple visual tool developed for this research. Colour-graded classification is a method of categorizing or representing data using a colour spectrum. In this technique, different colours are assigned to different categories or values within a dataset. The variation in colour intensity or hue indicates variations in the underlying data, providing a quick visual understanding of patterns or differences. It is commonly used in maps, charts, and visualizations to enhance the interpretation of information and highlight distinctions within a dataset. In this case, it is a visual representation, resembling a table, where selected measures related to climate change are distributed in four categories according to frequency: (1) dark blue—measures present in all analysed documents (100%); (2) light blue—measures present in the majority of the analysed documents (more than 50%, less than 100%); (3) light red—measures occurring only in some of the analysed documents (above 0%, less than or equal to 50%); and (4) dark red—measures not occurring in the analysed documents (Figure 1). This colour-graded classification lists all the measures tracked via content analysis by order of their occurrence in the analysed spatial plans. The frequency of their occurrence was measured by the number of planning documents addressing each particular measure and by the share of planning documents addressing each particular measure.

No.	Keyword (Measure)	Planning documents addressing keyword in a context of a measure(s)		No.	Keyword (Measure)	Planning documents addressing keyword in a context of a measure(s)		No.	Keyword (Measure)	Planning documents addressing keyword in a context of a measure(s)					
		No.	%			No.	%			No.	%				
1	Landslide "Klizište"	14	100.0	6	Irrigation "Navodnjavaenje", "Irigacija"	13	92.9	24	Bank revetments "Obaloutvrda"	7	50.0	35	Sprinkling (system) "Orošavanje"	0	
2	Afforestation "Pošumljavanje"	14	100.0	7	Education "Edukacija"	13	92.9	25	Retention "Retenzija"	6	42.9	36	Correcting the course of the river "Ispravljanje rečnog toka"	0	
3	Biomass "Biomasa"	14	100.0	8	Dam "Bran"	12	85.7	26	Rehabilitation of buildings "Sanacija objekata"	6	42.9	37	Sand bag dyke "Zečji nasip"	0	
4	Landfill "Deponije"	14	100.0	9	Water reservoir "(Vodo)akumulacija"	12	85.7	27	Insurance "Osiguranje"	6	42.9	38	Terrain slope "Nagib terena"	0	
5	Waste water "Otpadne vode"	14	100.0	10	River bed "Rečno korito"	12	85.7	28	Meteorological station "Meteorološka stanica"	6	42.9				
				11	Establishing new prot. areas "Proglašenje novih zašt. područja"	12	85.7	29	Warning system "Uzbunjivanje"	4	28.6				
				12	Notification "Obaveštavanje"	12	85.7	30	Electric drive, Electric power "Električni pogon"	3	21.4				
				13	Embankment "Nasip"	11	78.6	31	Drop by drop "Kap po kap"	3	21.4				
				14	Drainage "Odvodnjavaenje", "drenaža"	11	78.6	32	Financial support "Finansijska podrška"	3	21.4				
				15	Channel "Kanal"	11	78.6	33	Hall "Grad"	2	14.3				
				16	Plan (combating drought, weather disasters, fires, climate change, etc.) "Plan"	11	78.6	34	Anti-hail "Protivgradni"	1	7.1				
				17	Credit "Kredit"	11	78.6								
				18	Farmers cooperative "Zemljoradnička zadruga"	11	78.6								
				19	Monitoring "Monitoring"	11	78.6								
				20	Climate change "Klimatske promene"	11	78.6								
				21	Greenhouse "Plastenik"	9	64.3								
				22	Strategy, strategic "Strategija", "strateški"	8	57.1								
				23	Civil protection "Civilna zaštita"	8	57.1								

Figure 1. Colour-graded classification of keywords (addressed measures) by frequency. (dark blue—the highest frequency, dark red—the lowest frequency).

The *spider method*, based on radial coordinates and radar charts, or the practice of displaying data in a circular pattern, is an increasingly common technique in information visualisation research. It is a graphical method of displaying multivariate data in the form of a two-dimensional chart with three or more quantitative variables represented on axes radiating from a central point. It uses connected lines to illustrate data points, helping

to visualize patterns and comparisons across multiple variables simultaneously. Each axis represents a different variable, and data points are plotted where these axes intersect. Radar charts are useful for displaying and comparing data distribution patterns. This visualisation tool is characteristic for comparative scenario studies in decision-making processes [58]. It has already been applied by researchers in the field of spatial planning in Serbia e.g., [59–61], although not in the visualisation of the relationship between climate change and spatial planning. The essence of the method is to transform unrelated variables (e.g., population density, employment rate) into standardized spider values, and scale the axes from zero (interior) to ten (outer edge) so that a higher score represents better performance. Our research included only related variables (all presenting the occurrence frequency of the measures); hence, absolute values were used instead of standardized spider values. As in the spider tool with standardized values, occurrence frequency in the analysed spatial-planning documents rises in the graph with distance from the graph interior.

2.3. Research Design

Visualisation methods have been part of extensive research because their application “clarifies the complexity of the models [and] . . . creates an overview and transparency” ([62] p. 1). Some researchers chose visualisation to increase the expressiveness and attractiveness of overall environmental issues [63,64], urban planning, and carbon emissions [65], etc. In urban and spatial planning, visualisation has gone beyond its role as a tool for researchers and experts and has become a requirement in decision-making processes when addressing citizens and other stakeholders [31,66]. Therefore, the research design presented in this paper can have relevant applicability beyond this paper and the example of Serbia.

For content analysis, the focus of this research dictated that one of the concepts and keywords to look for was “climate change”. Based on this, we selected 38 keywords that were traced and observed in the context of climate change, i.e., in the form of a measure proclaimed by the analysed planning document. The keywords were selected based on climate change measures and concepts recognized in the previously conducted study by Pantić et al. [61]. In that study, citizens were asked to enumerate all the climate change measures they were familiar with. Since the nature of some enumerated measures does not pertain to the field of spatial planning (e.g., the selection of crop type, changes of field work schedules), we chose not to consider those measures in the selection of keywords and concepts. The list of 38 keywords (measures) is presented in Figure 1. To trace the selected keywords in the documents, we used the command “find” in digital versions of the analysed planning documents (Word or PDF files) and subsequently checked the context in which the keyword was used. If the context referred to climate change and represented a proclaimed measure, we considered it a positive result and used it in the next step of the analysis.

In the next step, we used binary analysis and frequency grading. A matrix was created where spatial-planning documents intersect keywords. If the keyword was used in the document in the context of climate change measures, this was indicated with a “1”; if the keyword was not found, this was indicated with a “0”. In our document analysis, the keywords we sought served as indicators, guiding us to specific sections within the documents. After identifying each keyword, we meticulously examined the context in which it was employed, assessing whether it pertained to climate change measures. This process not only allowed us to confirm climate-change-related content but also to scrutinize different sections of the text and potentially identify new keywords that enriched our analytical framework. Part of the matrix is shown in Table 2 as an example. Table 2 also illustrates that “TOTAL” represents the frequency of keywords throughout the analysed documents, not in terms of the frequency of occurrence in individual documents but the number of documents in which they appear. Figure 1 is the outcome and the first visual representation in the analysis. It shows the relevance of certain measures to spatial planning

in Serbia in four categories, based on the number/percentage of plans in which measures occur in the climate change context.

Table 2. Measures addressing climate change—example of the matrix for binary analysis and frequency grading.

		Anti-Hail “Protivgradni”	Hail “Grad”	Bank Revetments “Obaloutvrda”	...
1	Spatial Plan of the Republic of Serbia 2010–2020	1	1	1	...
2	Strategic Environmental Impact Assessment for the SPRS 2010–2020	0	0	0	...
3	Implementation Program for the SPRS 2010–2020	0	0	0	...

	TOTAL	1	2	7	...

The next task was to simplify represent the results. To achieve that, we distributed the 38 keywords into categories, with each corresponding to a different climate change effect. The climate change effects we selected based on the relevant literature review e.g., [31,67–71], typical for the territory of Serbia, are the following: drought, floods, hail/storms, heat waves, landslides, and premature snow melting. The distribution of keywords, hence, measures, is displayed in Table 3. Some keywords/measures were considered in several categories (e.g., 2—afforestation, 11—establishing new protection areas) since they influence multiple aspects, i.e., climate change effects.

Table 3. Classification of keywords (measures) by climate change effect.

Climate Change Effect	Keywords (Measures) (Ordinal Numbers in Figure 1)
Drought	2, 5, 6, 7, 8, 9, 11, 12, 15, 16, 17, 18, 19, 20, 22, 23, 25, 27, 28, 29, 31, 32, 35
Floods	1, 2, 7, 8, 9, 10, 11, 12, 14, 13, 15, 16, 17, 18, 19, 20, 22, 23, 24, 26, 27, 28, 29, 32, 36, 37, 38
Hail/Storms	7, 11, 12, 16, 17, 18, 19, 20, 21, 22, 23, 26, 27, 28, 29, 32, 33, 34
Heat waves	2, 3, 6, 7, 8, 9, 12, 11, 15, 16, 17, 18, 19, 20, 21, 22, 23, 25, 28, 29, 30, 31, 32, 35
Landslides	1, 2, 7, 8, 9, 10, 11, 12, 13, 16, 19, 20, 22, 23, 24, 26, 27, 28, 29, 32, 38
Premature snow melting	2, 3, 5, 7, 9, 11, 16, 19, 20, 22, 25, 28, 30, 38

Only then was it possible to proceed with the quantification of the appearance of each effect for each planning document (Figure 2). This was performed by summing up the number of keywords addressed in each plan per each climate change effect, as shown in Figure 2. The result is a matrix that shows how many aspects of dealing with climate change were addressed in each analysed plan in relation to each climate change effect separately. Additionally, the matrix allows for comparisons between plans and between extents to which climate change effects are addressed (“Total per plan” and “Total per effect” in Figure 2). Parallel to the matrix, we applied the spider visualisation method that targets the presentation of climate change effects in spatial planning, i.e., the spatial planning of Serbia (Figure 2).

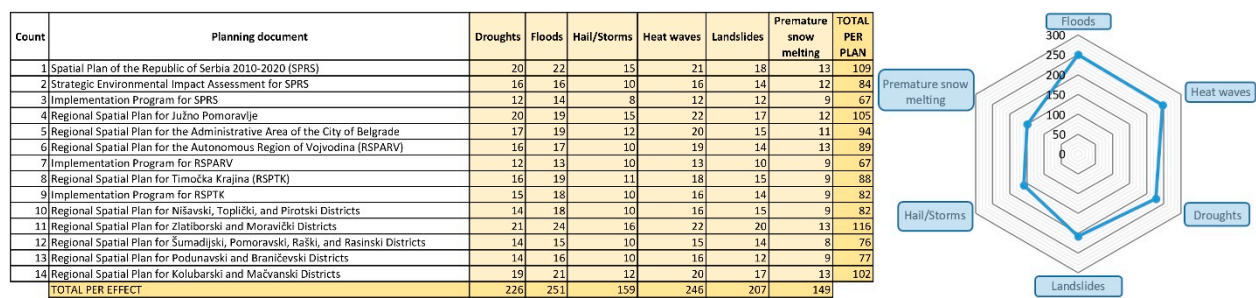


Figure 2. Addressing climate change effects in spatial-planning documents.

As maps are a consistent part of spatial plans where measures related to climate change can be potentially presented, we added a map analysis to the analysis of spatial plans. The focus was on infrastructural, conceptual, and territorial elements (river dams, erosional endangered areas, protection zones, etc.). In addition to the fact that such an analysis indicates the involvement of specific plans in climate change, these examples contribute to the general interpretation of mapping as a standard visualisation method in spatial planning.

Therefore, this study proposes a methodology for the visual evaluation of the extent to which climate change is tackled in spatial-planning documents using the example of Serbia, while noting its applicability in any other international, national, regional, or local context.

3. Results

This section presents the results of the planning document analysis, i.e., the presence of climate change themes and climate change measures in the spatial planning of Serbia. The results are interpreted descriptively and visually using combined visual methods.

The Spatial Plan of the Republic of Serbia 2010–2020, as the overarching planning act, included the topic of climate change in Serbia’s spatial planning with the introduction of an independent section titled “Effects of Climate Change”. The Regional Spatial Plan for the Administrative Area of the City of Belgrade (2011) [37] followed this example identically. Other analysed plans, however, did not treat climate change issues through a separate chapter; rather, climate change effects and climate change-related measures were addressed in sections about agricultural development, environmental protection, energy consumption, and others.

Some keywords (i.e., measures) in Figure 1 can be interpreted as measures directly triggered by climate change concerns, such as education and increased awareness, calls for specific plans to combat drought, weather disasters, fires, etc., the use of biomass, and the introduction of infrastructure for electric vehicles. According to Figure 1, only a few measures are integrated in all analysed documents: landslide regulation, afforestation, the intensification of biomass use, the treatment of landfills in a sanitary manner (modernisation), and wastewater treatment. On the other hand, there are measures that none of the spatial-planning documents prescribed, such as sprinkling systems in agriculture or for urban green infrastructure maintenance, the correction of the course of rivers, sandbag dykes, or the correction of terrain slopes to mitigate erosion and other effects of heavy precipitation, storms, and floods. The same colour-graded classification of measures indicates that the number of vastly prescribed measures is slightly larger than those omitted in spatial-planning documents. The majority of measures (light blue) are contained in most of the analysed documents and there are measures (light red) whose presence should be improved in the new generation of spatial plans in Serbia.

Figure 2 shows how the most relevant climate change effects are addressed in the analysed plans in Serbia. The final row (total per effect) and the accompanying spider graph show that the most addressed climate change effect is flooding, followed by heat waves and droughts to a significant extent, and less significantly by landslides, hail storms, and premature snow melting. The final column (total per plan) shows how the extent of

the reaction towards climate change effects is distributed over the analysed documents, i.e., that the Regional Spatial Plan for Zlatiborski and Moravički Districts has the best coverage and that the implementation programs are not as engaged with climate change effects as the plans themselves. Besides the mentioned regional spatial plan, the Spatial Plan of the Republic of Serbia has good coverage of all climate change effects. Various types of documents serve distinct purposes, and as a result, it may seem unnecessary for all of them to uniformly address climate change. Nevertheless, identifying omissions in the table can signal aspects that warrant potential consideration.

Out of ten analysed spatial plans, eight include maps on which some climate change-related measures are presented. It appears that their relation to climate change issues is more auxiliary than explicit, which can also be concluded from the map titles, e.g., a map of hazards, a map of tourism and environmental protection, a map of infrastructure, etc. Also, on their maps, the Regional Plan for Južno Pomoravlje, the Regional Spatial Plan for Timočka Krajina, and the Regional Spatial Plan for Šumadijski, Pomoravski, Raški, and Rasinski Districts present only zones of living environment according to four quality categories, which might also be related to climate change effects, but this cannot be clearly read from the maps. The elements related to climate change on the maps of the remaining spatial plans are most often water-management infrastructure—dams, the regulation of river beds, and channels; highlighting environmental impairment categories; and locations/areas exposed or at risk of exposure to erosion processes and landslides. The most prominent example would be the Regional Spatial Plan of Nišavski, Toplički and Pirotski Districts (2013), with an accompanying map of tourism and environmental protection, which shows erosion, potential flooding areas, riverbed regulation activities, and an infrastructure map, which shows water-management infrastructure and planned dams (Figure 3).

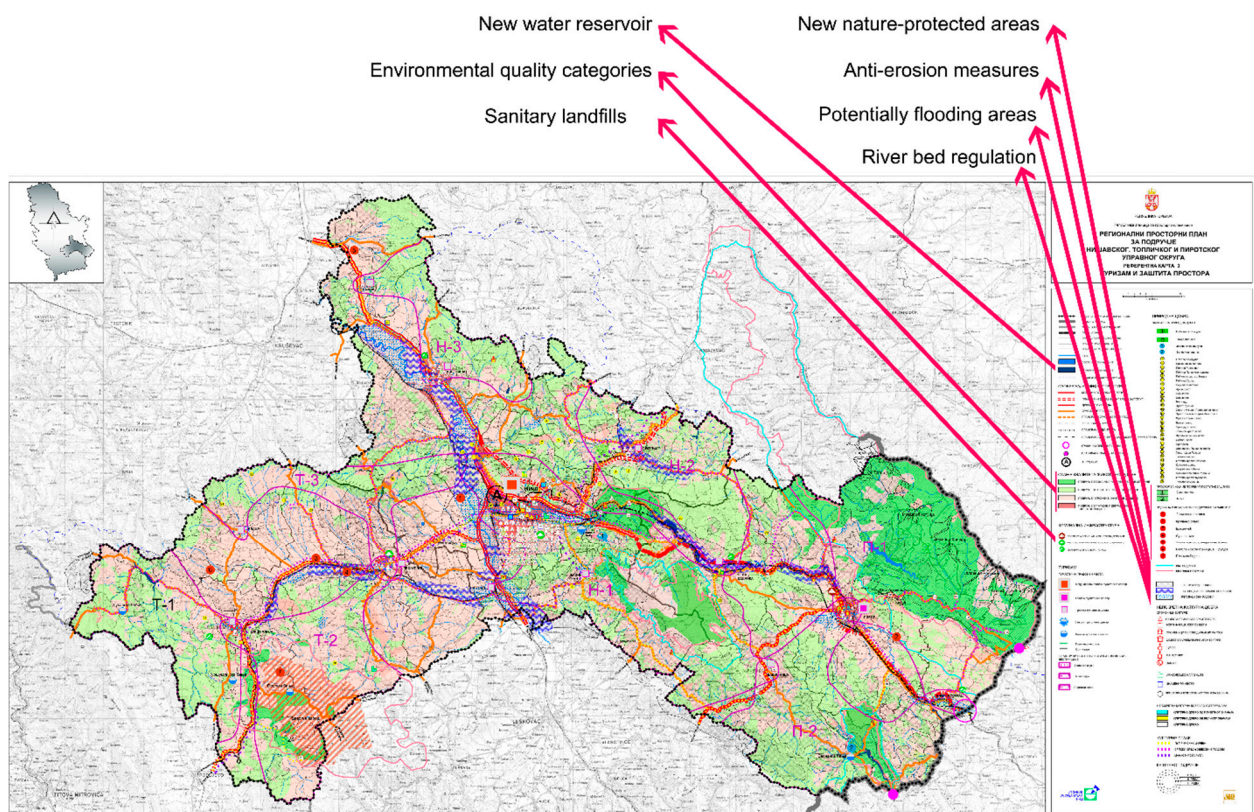


Figure 3. Map as an example of presenting climate change measures. Source: prepared based on the internal IAUS database, ©JP Zavod za urbanizam Niš & IAUS.

4. Discussion

Our analysis shows that most of the measures to combat climate change effects in Serbia have been circumstantial so far. The regulation of riverbeds, care of channels, irrigation-drainage systems, etc. were part of the spatial planning setup before climate change took the global spotlight. But, over time, their significance increased with the occurrence of new environmental problems. Döll [72] stresses the increasing significance of irrigation systems from the perspective of global climate change trends, Van Binh et al. [73] indicate the close relationship between climate change and changes in riverbeds, and Doelman et al. [74] investigate and prove the high importance of afforestation in climate change mitigation. All these are “traditional” measures in spatial planning in Serbia, which are beneficial in the context of climate change.

Climate change measures are differentiated as mitigation and adaptation measures, where the former are in charge of reducing and stabilizing the levels of heat-trapping greenhouse gases in the atmosphere, prevalingly CO₂, and the latter are adjustments in response to climate change effects [75,76]. By observing the list of measures in Figure 1, we can conclude where the adjustment is regarding the analysed plans. The reduction of CO₂ is one of the globally accepted aspects in the combat against climate change [2]; however, adaptation measures (preventing the intensity of climate change impact: irrigation system, dams, water reservoirs, etc.) in Serbia’s spatial plans are more frequent than mitigation measures (preventing the intensity of climate change itself: afforestation, biomass as an energy production resource, education, etc.). This is in contrast to the 28 cases of EU cities analysed by Reckien et al. [77]: almost 70% of the analysed cities have mitigation plans and less than 30% have adaptation plans. Serbia’s spatial-planning documents more often prescribe traditional anti-pollution measures (afforestation, sanitary landfills, proclaiming protected areas, etc.), but the analysis has showed that they have also introduced new categories in land use—reserving land for power supply stations for e-vehicles, wastewater facilities and energy production from biomass. New measures that are not related to specific locations or land but still refer to climate change include educating the population on this topic.

Colour-graded categorisation allows the beneficiaries an easy and quick overview of the measures that are missing and the actions that should be considered in the creation of future spatial planning and other types of documents. Garrigos-Simon et al. [78], who applied science mapping and the visualisation of similarities to visualise results regarding content analyses on the topic of sustainability, share the same attitude. In their view, visualisation helps professionals and researchers understand the examined problem. The tabulation and application of the spider tool visually facilitates comprehension of the potential gap between climate change effects and selected measures. The analysis of the table behind the spider (Table 3) also has value in understanding which measures have multiple impacts, which is convenient in the processes of prioritizing measures: those that impact several and the most crucial climate change effects are to be given priority over others that have only a limited impact.

With regard to their readability, the tools suggested in this paper use up to four colours, i.e., a maximum of two colours in two shades each. This approach eases readability for the viewers because, as Mitchell [79] advocates, using more than seven colours (on a map) can make it difficult to recognize subjects with closely aligned values. Maps are also a relevant means of communicating messages. Even though this research only shows the role of maps in spatial planning in Serbia, it indicates that maps are one of the visualisation tools that help professionals and stakeholders involved in decision making to realise which aspects of combating climate change have been included in a set of solutions and which have been omitted. The rapid increase in geographical information systems (GIS) is one of the signs that mapping different topics improves planning [80–82], implementation, and monitoring processes and that the interactive perspective of GIS is the next step that mapping climate change measures should take in Serbia and elsewhere. Since synthesis maps with an abundance of subjects are the most common characteristic of maps in spatial

planning, the application of the suggested methods tends to increase readability, which is relevant for experts' understanding and even more for non-professional stakeholders [83].

What we see from the cross-check of Table 3 and Figure 2 is that measures that address educating the population and other stakeholders about climate change, establish new protection areas, deal with wastewater treatment, create planning and strategic documents for extreme weather events, and monitor climate change-related parameters by introducing new meteorological stations and instruments would have an impact on all climate change effects—floods, droughts, hail storms, heat waves, landslides and premature snow melting. Five types of interventions—afforestation, building dams, establishing notification and warning systems, organizing civil protection, and financial support to farmers for the introduction of protection systems (e.g., anti-hail nets, drainage systems) or reimbursement in the case of damage due to extreme weather events—tackle five out of six climate change effects. They also have diverse impacts on different fields of climate change effects. Drainage systems, correcting river courses, sandbag dykes, and alterations of terrain slopes are measures influencing only one climate change effect—flooding. However, selecting priority measures should be made with caution because, for example, floods are the most common effect of climate change in Serbia [61] (Pantić et al. 2022); hence, it would not be wise to disregard them.

Survey results collected by Pantić et al. [61] (2022) indicate that citizens in the rural areas of Serbia suffer the most from (1) drought, (2) flooding, and (3) hail, and less from (4) heat waves, (5) landslides, and (6) premature snow melting. This gradation does not completely coincide with the gradation of climate change-effect measures incorporated in the analysed spatial plans, and the differences indicate aspects that are changing. According to Figure 2, floods are considered more comprehensively in spatial-planning documents than drought, and hail is only considered after heat waves and landslides. If we compare the Spatial Plan of the Republic of Serbia for 2010–2020 with the new one for the period of 2021–2035 [84], which is in the adoption process, we will see that the presence of climate change measures is strengthened in the new document (Figure 4), although their prioritization per effect remains the same. The least considered effect in the plans of both generations is the premature melting of snow, which is in contrast to the efforts of Alpine countries to socio-economically adapt to climate change—looking for a solution to prevent avalanches or prolong the skiing season [25] (Agrawala 2007). The reason behind this might be the fact that the majority of households in Serbia still depend prevalently on agriculture instead of tourism. Therefore, premature snow melting is not considered to be a particular threat to the economy or health.

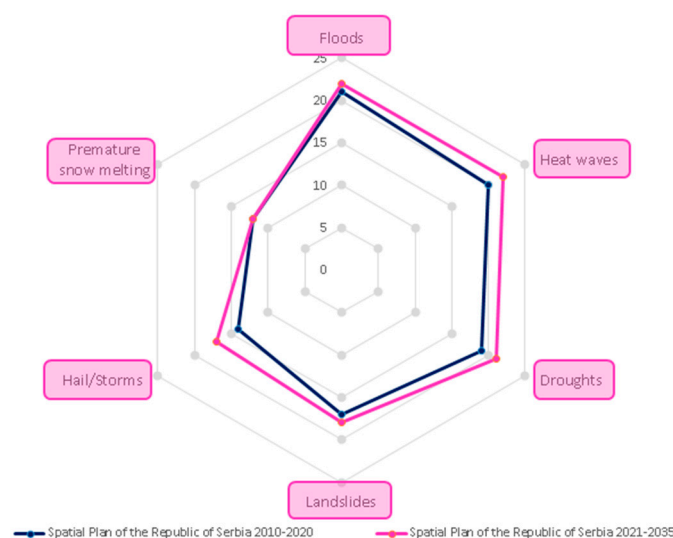


Figure 4. Comparison of the spatial plans of the Republic of Serbia.

Furthermore, applying the recommended visualisation methods to Serbia's spatial-planning documents has revealed a noticeable increase in awareness regarding climate change mitigation over the analysed period (2010 to 2023). A review of the keywords and measures addressing climate change in these planning documents indicates significant progress. Most of the measures (as shown in Figure 1) have been part of the spatial-planning discipline in Serbia for some time, including afforestation, dam and reservoir construction, retentions, landfills, and waste collection. While these measures predate the significant emergence of climate change concerns, they are now receiving heightened attention in spatial-planning documents. Notably, only four measures are consistently present in all analysed spatial-planning documents, highlighting the potential for introducing new measures to further improve these documents.

According to the Law on Planning and Construction (2023) [32], there is no obligation to address climate change in Serbia's spatial planning system. Therefore, their integration depends greatly on the awareness of experts and decision-makers, as well as initiatives coming from citizens in the early public viewing of a plan. According to the analysed spatial-planning documents, the extent to which climate change was addressed depended on the spatial-plan coordinators, since the plans with independent chapters on climate change were led by the same spatial-plan coordinators. This is why raising awareness of this topic is relevant, not only for professionals, but also for teachers [85], the media [86], citizens [87], and all other stakeholders [88]. Sending a clear message is relevant in communication, and the visualisation suggested here can play an important role in communications between professionals and final users as a non-technical, easily understandable tool.

It is important to stress that public opinion is not always based on facts and can be influenced by the media and politicians, including climate change issues [89]. Therefore, the role of visualising results is to facilitate an understanding of the state of the art and the future we want in all phases and by all stakeholders [31]. The role of visualisation techniques and methods became more significant during the COVID-19 pandemic when communication and participation were possible only online, i.e., using technology [26,90]. The visualisation methods suggested in this research are applicable not only to screen groups of spatial-planning documents but also at the level of each plan individually. Most important, they can be applied already in the drafting phase, so that corrections in defining final measures can be conducted on time. Their implementation does not have to be limited to the field of spatial planning either because they are also suitable for other decision-making opportunities.

The novelty of this paper is the introduction of new visualisation tools in spatial planning and evaluating the appropriateness of responses to climate change defined in spatial plans. These suggested visualisation tools implicitly demonstrate their effectiveness in enhancing stakeholder communication.

5. Conclusions

The research presented in this paper contributes significantly to the existing body of international empirical evidence concerning the capacity of spatial planning to facilitate climate change through adequate measures. Along with the analysis of climate change measures proposed in current spatial-planning documents in Serbia, this research has employed two information visualisation techniques to enhance our understanding of these measures from multiple perspectives.

The findings of this study underscore the potential role of visualisation as a tool in evaluation and decision-making processes related to climate change and its adverse impacts. These visualisation techniques serve to simplify complex information, fostering effective communication with all stakeholders involved in the planning process. The visualisations utilized here enable the recognition of climate change measures, assess the extent to which they are incorporated into the existing spatial planning framework, and identify which climate change impacts are receiving the most attention. As a result, the emphasis on

specific climate change effects can be compared with and adjusted in response to the main climate change aspects and issues (e.g., floods, hail, and drought).

The visualisation methods discussed in this research, such as colour-graded classification, spider diagrams, and maps, can be readily adapted for application in various national and international contexts. The simplicity of colour-graded classification and spider diagrams facilitates clear and accessible communication between professionals and the general public in planning processes, including public participation, which increases the feasibility of the plans and the appropriateness of measures to the real problems which citizens face. Once the climate change measures are identified, they can be easily categorized as adaptation, mitigation, or a combination of both, offering insight into whether there is a need to strike a better balance between these two approaches. It is important to note that when applying the suggested visualisation methods in other cases, the selection of keywords for content analysis and the climate change effects considered should be adapted to suit the ever-evolving measures addressing climate change and the region-specific effects. The advantage of implementing the suggested visualisation methods is that they do not require substantial resources in terms of technology, expertise, and time. They are also not limited in terms of generalizability because they can be easily adapted to different regions or contexts with distinct climate challenges. The findings might not be universally applicable, especially for regions facing unique climate challenges, thus emphasizing the need for context-specific approaches and adaptations.

A limitation of this approach lies in the fact that analysed measures cannot always be compared to real local issues. This would require additional data collection, which might be demanding should it involve a non-standardized step in the creation of a spatial plan. In addition, it is important to acknowledge that certain limitations may arise regarding the potential omission of key words in the content analysis. Therefore, there is a possibility that we omitted some climate change measures in the analysed documents, believing that they did not affect the results. In addition, it is important to acknowledge that certain limitations may arise regarding the potential omission of key words in the content analysis. Therefore, there is a possibility that we omitted some climate change measures in the analysed documents, believing that they did not affect the results. By addressing these limitations and following these recommendations, future studies can further enhance the use of visualisation techniques in climate change planning and adapt them to meet the unique challenges faced by different regions.

In conclusion, we strongly recommend the integration of visualisation techniques in the decision-making process, as they have demonstrated their effectiveness in this study. While the combination of methods presented here is a valuable starting point, it is important to recognize that the field of visualisation offers a wide array of tools and methods that can contribute to a more comprehensive understanding of various aspects related to climate change planning. As we continue to address the pressing issue of climate change, the dynamic nature of this field should encourage ongoing innovation and the exploration of visualisation techniques to support effective spatial planning for climate change mitigation and adaptation. Our recommendations for the authors of future studies are to conduct further research to validate the effectiveness of visualisation techniques in different regions and under various climate change scenarios. This will help establish the generalizability of the approach. An interdisciplinary collaboration, i.e., the encouragement of collaboration between experts in climate science, spatial planning, and data visualisation, would ensure that the chosen visualisation methods are tailored to address the specific needs of each stakeholder. Practitioners are encouraged to apply, test, and explore similar methods to involve the public and stakeholders in the design and interpretation of visualisations. This can enhance transparency and help mitigate subjectivity concerns.

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and S.M.; Investigation: M.P., T.M. and S.M.; Writing—original draft preparation: M.P.; Visualisation: M.P. and T.M.; Writing—review and editing: M.P., T.M. and S.M.; Funding acquisition: S.M.; Resources: M.P., T.M. and S.M.; Supervision: M.P.; Data curation: M.P.; Software: M.P. and T.M. All authors have read and agreed to the published version of the manuscript.

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