Vulnerability Levels and Adaptive Capacities to Heatwaves of Citizens in Belgrade, Serbia

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ABSTRACT

Climate observations show that Serbia has been experiencing an increase in mean temperatures and frequency of heatwaves, in part due to its high population growth and unsustainable urbanisation. The goal of this research was to establish the heatwave level of vulnerability in Belgrade municipalities and determine citizens' adaptive capacities.

The MOVE framework was used to determine vulnerability, and an online survey was carried out to gather data on adaptive capacities. Very high vulnerability was found in the municipalities of Palilula, Zemun and New Belgrade. The survey was in accordance with the ArcGIS-generated vulnerability map. It showed a high adaptation capacity of the low-vulnerability, high-income respondents living in the central municipalities of Old Town and Vračar. Results show that adaptation capacity is highly determined by income and social inclusion levels. This research can serve as a good basis for defining city-level measures to reduce the consequences of heatwave effects in Belgrade.

Keywords:

Balkan, ArcGIS, survey, exposure, susceptibility, lack of resilience

Word count: 11 624

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And where is the beginning?

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1. INTRODUCTION

The Intergovernmental Panel on Climate Change (IPCC) defined climate change as a change in the state of the climate that can be identified by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer (IPCC, 2007a). It refers to any change in climate over time, whether due to natural variability or as a result of anthropogenic activities (Sané et al., 2015). Copernicus, the global climate data store, confirmed that 2023 was the warmest calendar year in global temperature data records going back to the 1850s. The steady temperature increases resulted in the global average temperature in 2023 being 14.98°C, 0.17°C higher than the previous highest annual value in 2016 (Copernicus, 2023). Further, the World Meteorological Organization report on the state of the global climate in 2023 reported that the last 10 years were the warmest on record (WMO, 2024).

One of the impacts of rising temperatures is the increased likelihood of the occurrence of heatwaves with more severity, higher frequency and longer duration (IPCC, 2023). Heatwaves are often defined as prolonged periods of abnormally hot weather relative to the expected conditions at a given time and place (Perkins-Kirkpatrick & Gibson, 2017). These extreme events are of great concern as they can inflict devastating impacts on human health, ecosystems, agriculture and the economy (Di Blasi et al., 2023; García-León et al., 2021; Margolis, 2021; Polazzo et al., 2022). Record-setting temperatures in Europe adversely affected human health and well-being, illustrated by increased mortality during heatwaves in several countries (García-León et al., 2021). Europe has experienced several heatwave events since 2000 (2003, 2006, 2007, 2010, 2014, 2015 and 2018), with the summer of 2003 being remembered as the 'summer of the century' when a heatwave event resulted in up to 70,000 deaths in Europe (Margolis, 2021). The impacts of heatwaves upon human beings are first experienced in cities (Ward et al., 2016). Urban areas are particularly affected by heat events due to the high degree of sealing, building structure, relatively low proportion of green spaces, and an altered water balance (Mohammad Harmay & Choi, 2022). This means that around 73% of people in Europe, who are living in urban areas are potentially highly vulnerable (Royé et al., 2020).

Available scientific evidence, showed the likeliness of extreme heatwaves increasing in the future (IPCC, 2019). This is further confirmed by Forzieri et al. (2017) a study based on data analysis to forecast future risks from weather-related extreme events. It assumes that by the year 2100, two-thirds of the European population could be affected by weather extremes (Forzieri et al., 2017). The Urban Climate Change Research Network's Second Assessment Report on Climate Change in Cities placed the average annual temperature increase trend per decade between 0.1°C and 0.5°C in the period from 1961 to

2010 in European cities (Reischl et al., 2018). It is estimated that the temperature will rise between 1.3°C and 3°C in the middle of the 21st century (2040–2070) and between 1.7°C and 4.9°C at the end (2070–2100). Climate adaptation is considered a priority theme identified in the UN's Sustainable Development Goals, the Urban Agenda for the EU, and is a specific target of the Paris Agreement.

The need and relevance to assessing vulnerability to climate change and natural hazards are based on the assumption that the severity of the impacts of extreme climate events depends strongly on the level of vulnerability to these events, making the concept of vulnerability fundamental to human-environment research (Laranjeira et al., 2021). Research on vulnerability to natural hazards has made significant progress over the last decades. The primary focus of research has been on enhancing the precision of climate information and hazard data (Birkmann et al., 2022). Numerous global vulnerability indexes have emerged over time, utilizing diverse indicators. A precise assessment of these indexes can enhance comprehension of the relation between climate extremes and impacted entities. Such analysis can offer valuable insights into policymaking and decision-making (Birkmann et al., 2022). According to Wolf & McGregor, (2013) and Wilhelmi & Hayden, (2010), city-scale spatial information on heat vulnerability could add great value to urban development decision processes and adaptation strategies.

Observations of climate conditions in Serbia indicated that since the 1980s, Serbia has experienced a rapid increase in mean temperatures and the frequency of heatwaves, which are trending upwards (Digital Climate Atlas, 2023). Analyses of heatwaves in Serbia have been performed using several different approaches, and all of them showed a growing trend in maximum temperature (Unkasevic & Tosic, 2009; Unkašević & Tošić, 2013) and heatwaves (Malinović-Milićević, 2013; Malinović-Milićević & Radovanovic, 2016; Unkašević & Tošić, 2011). However, the literature review showed a lack of up-to-date, city-scale research about heatwaves in Belgrade. Given the fact that Belgrade is the capital and most populated city in Serbia which has, in the last decade, undergone intense urbanisation, the purpose of this thesis is to gather information about the level of vulnerability of Belgrade municipalities to heatwaves and to give an insight into the Belgrade's citizens' adaptation capacities to heatwaves. As the city further develops, characterizing urban vulnerability and adaptive capacity among the residents will help identify strategies for heat hazard mitigation and climate adaptation (Hayden et al., 2017).

In this regard, particular emphasis was given to the two research questions:

1) ***To what level are Belgrade municipalities vulnerable to heatwaves?***
2) ***What are the adaptive capacities of Belgrade citizens to heatwaves on an individual level?***

By answering these questions, the thesis provided insight into the link between heatwaves in urbanised areas and citizens' adaptation capacities to them. The results helped identify the most vulnerable areas needing swift assessment and the most vulnerable population groups yielding special attention as guidance towards successful future adaptation measures.

2. THEORETICAL BACKGROUND

2.1. Heatwave definitions

According to the IPCC, global warming will intensify temperature extremes in the 21st century (Masson-Delmotte, 2022). Heatwaves are considered one of the main phenomena of global climate change, related to intense temperature increases (Lee et al., 2011). There are various definitions of a heatwave depending on regional contexts. A definition, on which this thesis is based, is employed by the IPCC (IPCC; 2023a): "a period of abnormally hot weather, often defined regarding a relative temperature threshold, lasting from 2 days to months." The Austrian definition defines a national threshold when a daily maximum of 27°C is exceeded on three successive days (Reischl et al., 2018). Given that Serbia lacks a predefined heatwave threshold and given that both Belgrade and Austria fall within a moderately continental climate zone, this study adopts the 27°C temperature threshold for its analysis.

2.2. Consequences of heat waves to human health

Even though heatwaves are understood as meteorological events, their significance and influence could not be adequately presented without presenting the various consequences they pose on the human body (figure 1).

As a way to respond to heat stress, the human body employs two main mechanisms: redistributing blood flow to the skin to enhance heat transfer and sweating to remove body heat (Ebi et al., 2021). While these responses help regulate core temperature, they can impact individuals differently, especially those with pre-existing medical conditions. Increased blood flow to the skin during heat stress, places greater demand on the heart. This can strain the cardiovascular system, particularly in individuals with existing heart conditions (Boyette & Manna, 2024). Further, sweat production during heat stress can lead to dehydration (Ebi et al., 2021). Dehydration can also contribute to acute kidney injury and chronic kidney disease, particularly problematic for outdoor workers in hot regions (Glaser et al., 2016). Heatwaves are also associated with air stagnation, thereby aggravating respiratory diseases in urban areas (Jay et al., 2021). Heat-related lung damage, compounded by pre-existing respiratory conditions and air pollution, is a significant cause of mortality and morbidity. Excessive human morbidity and mortality rates are often caused by prolonged exposure to extreme temperatures during the day and reduced heat recovery during the night (Buzan & Huber, 2020). An attribution study of heat-related mortality in Paris and London for summer 2003 was conducted and it was found that anthropogenic influences increased the risk of heat-related mortality by ∼70% and ∼20% in Paris and London, respectively (Mitchell et al., 2016). The European population is rapidly ageing, and the ongoing and predicted changes in age structure challenge urban areas (Martín & Paneque, 2022). In heat-related vulnerability assessments, the elderly are identified as especially prone to suffer from heat stress because of weak thermoregulatory mechanisms and compounded factors such as chronic diseases and side effects of medications (Martín & Paneque, 2022). In addition, comorbidities such as overweight, obesity, subsequent cardiovascular diseases and other health problems such as type II diabetes are also increasing in the EU (Marques et al., 2018).

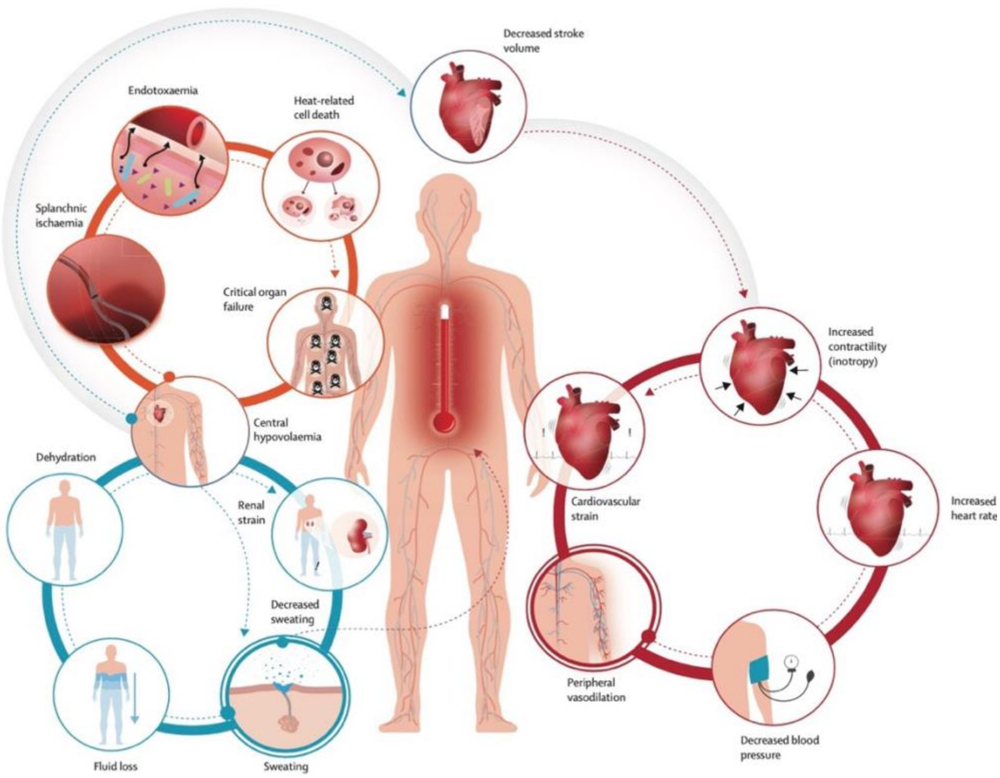

Figure 1: Illustration of the physiological pathways of human heat strain (Ebi et al., 2021).

Heatwaves can concur with other hazards or drivers in the form of compound events with cumulative impacts. Examples of heatwave-compounded hazards include high humidity, drought, air pollution or wildfires (Bansal et al., 2023; Li et al., 2020; Mukherjee & Mishra, 2021; Zhang et al., 2020). These compound events can lead to strong perturbations of the global carbon cycle, and disproportionate socioeconomic impacts in highly-populated areas and major breadbasket regions (Bastos et al., 2020; Kornhuber et al., 2020). To some extent, heatwaves have an inherent compound nature since their drivers interact at multiple spatiotemporal scales and intervene in other climate-related hazards. During the European mega-heatwave that affected western Europe, the heatwave was accompanied by an intense European drought, devastating wildfires, record-breaking Mediterranean mega heatwaves and high death tolls in many European countries, including Spain, Portugal and the UK (Barriopedro et al., 2023). Thus, it is essential to deepen our comprehension of heatwaves and their reactions to climate change in order to evaluate and forecast related risks effectively and to bolster preparedness for forthcoming events.

2.3. Urban Heat Island Effect

Alterations to the natural environment associated with urban activity mean that climate variability in urban landscapes is more complex than in peri-urban and rural areas (Barriopedro et al., 2023). Statistics showed that we are experiencing the largest wave of urban growth in history, with 55% of the world's population (4.2 billion people) currently living in urban areas, a expected to rise to 70% by 2050 (Callaghan et al., 2021). Due to the urbanization processes that lead to the extension of an impervious surface which can modify the meteorological conditions, aerodynamic properties, hydrological process, and surface morphology (Barriopedro et al., 2023), urban areas are certainly more exposed and vulnerable to the negative effects of climate change (figure 2). Increasing urbanization has increased the vulnerability of European cities to heatwaves (Bhattacharjee et al., 2019). Growth and concentration of population in cities, and an ageing population contributed to a further increase in the vulnerability of cities to climate change. Most heatwave phenomena occur in regions with heavy population density and higher urban developments that have hotter surface conditions due to land cover alterations and high anthropogenic heat (Stewart & Oke, 2012).

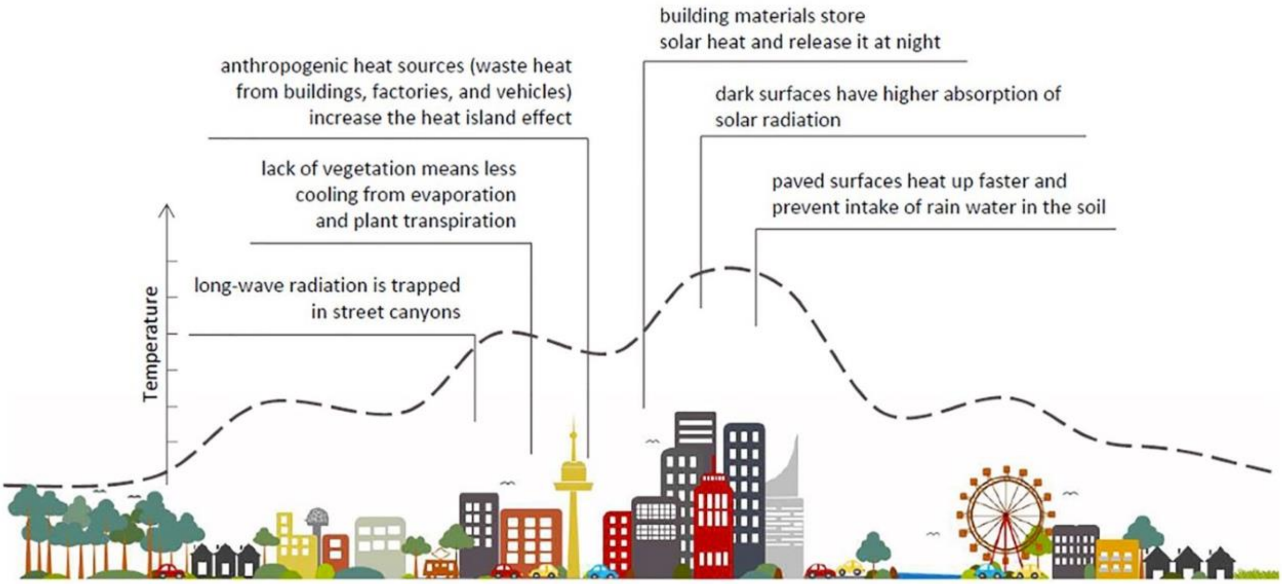

Figure 2: Schematic illustration of the factors that contribute to the urban heat island (UHI) effect (Barriopedro et al., 2023).

A high percentage of concrete surfaces together with a low percentage of green areas increase the land surface temperature (LST) in urban areas due to low evapotranspiration and soil moisture rate (Mohammad Harmay & Choi, 2022). The higher LST in urban areas compared to their surrounding areas results in the Urban Heat Island effect (UHI), which has become a rising issue in recent years (Huang & Wang, 2019; Mohammad Harmay et al., 2021). One of the main topics usually studied to characterise the urban climate is the extreme temperatures in cities due to the formation of the UHI effect first discussed back in the 1940s (Reischl et al., 2018). It is defined as the relative warmth of a city compared to the surrounding rural areas, it is associated with changes in runoff, effects on heat retention, and changes in surface albedo (IPCC, 2014b) which intensifies the vulnerability of cities to extreme heat. Cities are particularly affected because urban structures allow heat to accumulate during the day resulting in higher temperatures at night (20–25°C or more) (Reischl et al., 2018). This phenomenon appears in almost every urban area, no matter whether the specific city is small or large, or whether it is situated in a warm or cold climate (Stewart & Oke, 2012). The UHI effect presents planning challenges due to the continuing processes of climate change and urbanisation (Rizwan et al., 2008).

One major effect of UHIs is the increase in human discomfort, especially in the inner cities well documented by urban heat stress studies (Arifwidodo & Chandrasiri, 2020; Callaghan et al., 2021; Szewczyk et al., 2021). Thus, strategies of mitigation and adaptation particularly through urban planning are needed, especially considering that more than half of the world's population lives in comparatively small areas of densely concentrated urban cores (Ward et al., 2016).

2.4. Urbanism in Belgrade

After World War II, the political division of Europe transformed many pre-war kingdoms into new communist countries. This was also the case for Serbia (then part of Yugoslavia), an undeveloped agrarian country (Mihaylov & Ilchenko, 2022). Its development towards a modern communist country was marked by three guiding principles: industrialisation, electrification and urbanisation (Đorđević, 1961). Reconstruction plans were developed for Belgrade, the intention was to create the capital of the new state, a symbol of Yugoslavian unity, as a model socialist city (Kulić, 2014). In line with the socialist city model, the central area of Belgrade was developed as a grid layout consisting of major roads and large city blocks measuring approximately 400 x 600 meters. These blocks feature multi-story residential buildings with open spaces primarily designated for parking, and limited green areas. Much of the housing was constructed rapidly and inexpensively to accommodate the substantial influx of rural migrants (Mihaylov & Ilchenko, 2022). Presently, urban blocks dating back to the communist era have remained largely unchanged, comprising the predominant architectural landscape of Belgrade (Vesković & Jovanović, 2018). This is especially problematic as one of the determinants concerning indoor overheating potential is the construction years of buildings people live in or occupy (Reischl et al., 2018). Buildings that were constructed during the post-war era are not as resistant to temperature changes during heatwaves as buildings constructed during the late 19th and early 20th centuries with larger rooms and higher ceilings that are thermally insulated or can be adapted more easily than older ones (Reischl et al., 2018).

Since the post-socialist transformation began, catching up with modern European capitals has been a constant goal of Belgrade city development (Ana Pajvanči, 2019). Due to the slow post-socialist transformation in Serbia during the 1990s (Vuletić, 2005), it was after 2000 that Belgrade's urban policy began to fit into a wider global trend of ‘city entrepreneurialism’ with the ambition to reproduce patterns of development related to city restoration and touristification while facing increasing challenges related to under-developed traffic and utility infrastructure (Pajvanči, 2019). With the concentration of attractive facilities in central city locations, inherited socio-spatial inequalities from both pre-socialist and socialist periods have been reinforced. Expensive development in the city centre resulted in a low-income population moving toward the city edges in less expensive municipalities. Other forms of inequities are seen in unequal green cover areas. The city contains some large green areas like Košutnjak forest and Zvezdara forest; however, their accessibility differs across the city and is particularly low in the densely built-up inner-city areas even though it is significantly more expensive to live in the centre.

It is estimated that only 31% of Belgrade’s territory is considered a “green” area, which is low compared to the European average of 42% (EEA, 2022). Additionally, since the 90s there has been a lowering of green areas by 13%, while infrastructural developments have increased by 33% (Stokic, 2022). As an important reduction of urban outdoor overheating potential is the open and green space area in a city (Reyes-Riveros et al., 2021), it is important to identify which districts in Belgrade might be particularly at risk due to their relatively limited open and green space areas.

3. THEORETICAL FRAMEWORK

3.1. Concept of vulnerability

The concept of vulnerability is used for assessing the social construction of risk, by determining to what extent an entity will be affected in a place where they are spatially located (Kablan et al., 2017). The vulnerability definition that this thesis is based on is employed by IPCC. According to the IPCC, vulnerability is defined as “the degree to which a system is susceptible to and unable to cope with, adverse effects of climate change, including climate variability and extremes” (Solomon et al., 2007; IPCC 2007, WGII, G; Stocker et al., 2014). Furthermore, the IPCC’s special report on the impacts of global warming of 1.5°C defines vulnerability as “the propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt.” (IPCC, 2019:560).

3.2. The MOVE Framework

Method for the Improvement of Vulnerability in Europe (The MOVE) framework was developed as an all-encompassing vulnerability framework, that provides improved insight into the multi-faceted nature of vulnerability (Birkmann et al., 2013). It is considered a multidimensional, comprehensive, systematic framework for vulnerability assessment (European Commission, 2013). As a part of the MOVE project, sponsored by the European Commission, conducted from 2008 to 2011 the MOVE framework was developed to improve vulnerability assessment in Europe.

It underlines that hazards are of natural or socio-natural origin while vulnerability in its multi-faceted nature is mainly linked to social conditions and processes (Birkmann et al., 2013). Key factors of the MOVE framework defining the vulnerability are exposure of an entity to a hazard, the susceptibility of the exposed entity and its lack of resilience (Figure 3).

1. Exposure refers to how much an entity is within the geographical range of a hazardous event. It has a spatial and temporal aspect and encompasses both the physical aspects of social systems, such as infrastructure, as well as the human elements, like livelihoods, economies and cultures, that are spatially bound to specific resources and practices which may be at risk (Kablan et al., 2017).

2. Susceptibility represents the tendency of entities, whether social or ecological, to experience harm. In order to gain a full picture, it analyses the physical, technical, environmental, social, cultural, and institutional sides of vulnerability (Lianxiao & Morimoto, 2019).

3. A lack of resilience refers to the constraints related to accessing and utilizing entities' resources to address a recognized hazard. This encompasses activities such as reducing risks before an event, coping during the event, and responding after the event. In contrast to adaptive capacities, these abilities primarily centre on the entities capability to endure when confronted with a hazard affecting the system or the exposed element (Birkmann et al., 2013).

Hazards and vulnerability are interconnected and result in risk with potential economic, social and environmental impacts (figure 3).

Adaptation deals with the ability of a system to learn from past disasters and to change existing practices for potential future changes and mitigation of vulnerability index. The adaptation box (figure 3) is concerned with vulnerability intervention by reducing the exposure and susceptibility of the system. Compared to the key factor 'lack of resilience', which refers to existing capacities the, concept of resilience improvement includes learning and future reorganization processes and therefore is positioned as a sub-component of the adaptation box (Birkmann et al., 2013).

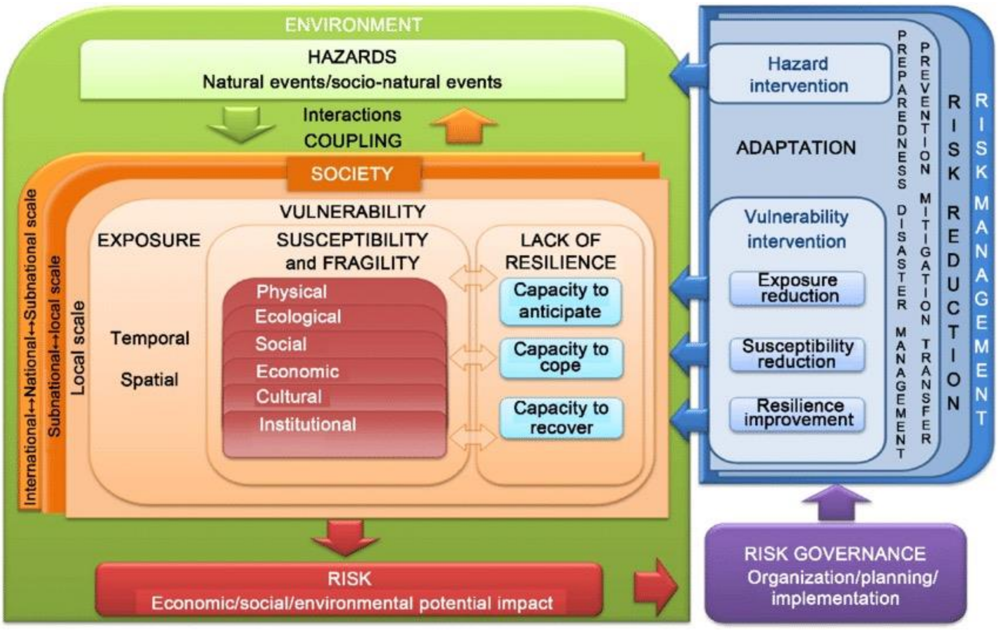

Figure 3: The MOVE framework of natural Hazards: Framing vulnerability, risk and societal responses (Birkmann et al., 2013).

This framework emphasizes the significance of considering multiple thematic dimensions when evaluating vulnerability in the context of natural and socio-natural hazards (Birkmann et al., 2013). In the case of the study area, heat extremes are not solely attributed to elevated temperatures but rather to a combination of rapid urbanisation and the presence of settlements with limited to minimal green spaces, which exacerbate risks associated with natural hazards.

3.3. Indicator selection

Based on the definitions of the MOVE framework, literature review and available data, relevant indicators were identified to characterize the three components of vulnerability (figure 3): exposure, susceptibility and lack of resilience. The indicators used and the compound indicators developed were then assessed and spatially represented through the application of the GIS ArcMap.

Table 1: Indicators of Vulnerability used to assess the vulnerability levels of each municipality in Belgrade.

Indicator of Vulnerability	*Data Set*	*Data Source*
Exposure	Population Density per city district	Statistical Office of the Republic of Serbia
	Average temperature in July 2022 per city district	Klimerko - https://klimerko.org/ OpenMeteo - https://open-meteo.com
Susceptibility	Percentage of older than 65 years per city district	Statistical Office of the Republic of Serbia
	Unemployment rates per city district	Statistical Office of the Republic of Serbia
Lack of resilience	Percentage of greenery per city district	OpenStreetMap
	Percentage of people living alone per city district	Determined as a 10%, 20% and 30% scenario

Exposure can be determined as the number of people per city district differently exposed to extreme temperatures due to the urban heat exposure effect which worsens the intensity of the hazard (Birkmann et al., 2013). According to the data availability, exposure was calculated using equation (1), by multiplying the number of habitants per city district (I) with the temperature of each district (T).

1. $E = IT$ (Depietri et al., 2013)

According to the literature review, the elderly, the unemployed and immigrants are considered to be the most susceptible groups to suffer harm in the case of extreme heat events (Malmquist et al., 2022). Based on these findings and the availability of the data, the following indicators were chosen as representative: the percentage of the population per city district older than 65 years (El) and the percentage of unemployed per city district (U) as a proxy for low income. The composite indicator of susceptibility (S) is obtained, according to equation (2).

2. S= 1/ 2 El + 1/2 U (Depietri et al., 2013)

Lack of resilience (LoR) is calculated as a compound indicator of two single indicators. During a heatwave, the majority of deaths generally occur amongst the elderly who live alone as they are less able to promptly recognize, seek help and be assisted in case of malaise (Lianxiao & Morimoto, 2019). Therefore, it can be assumed that the percentage of elderly living alone per city district (Ela) is a proxy for the lack of coping capacity of the population. However, due to the lack of official data on the percentage of the elderly living alone, a scenario of 10%, 20% and 30% was calculated. A "proof of concept" assumption that was adopted was a middle value of 20%. This was because calculations for 10%, 20% and 30%, showed that the results increase proportionally, meaning that only absolute values are changing but the symbology of the map display is not altering. The second indicator is green areas as they are crucial for minimizing heat extreme effects (Jay et al., 2021). The percentage of the surface of Belgrade covered by greenery per city district (Cf) is used as a proxy, thus city districts with a low percentage of greenery indicate a high lack of resilience. The composite indicator for LoR is then calculated according to equation (3).

3. LoR= 1/2 Ela + 1/2 (1 – Cf) (Depietri et al., 2013)

Finally, the vulnerability (V) index to heatwaves in each Belgrade municipality is calculated by aggregating the composite indicators of the three components through equation (4).

4. V= E [(S + LoR) / 2] (Depietri et al., 2013)

For the spatial representation and mapping of the single and composite indicators shown in figures 6-9, the values obtained were grouped into five classes using the quantile method, a predefined function of ArcGIS. With this method, each class contains an equal number of features, thus all classes differ in their value ranges. To facilitate comparison, the qualitative labels “very high, high, medium, low, very low” are used in the legends.

3.4. Adaptation

IPCC defines adaptation to climate change as the process of the adjustment of natural and social systems to present or expected natural hazards and their aims to reduce negative impacts and exploit potential benefits (IPCC 2019). Adaptation is a common component of vulnerability and resilience assessments (Martín & Paneque, 2022), it presents the potential of the affected entities to adapt to climate change, its associated events, and resulting consequences (IPCC, 2019). It is usually concerned with the long-term strategies and approaches that can also take resources into account which are not yet available (Laranjeira et al., 2021; Vogel & O'Brien, 2004). In the environmental literature, adaptation measures are further defined as manifestations of adaptive capacity (Smit & Wandel, 2006). Measures of adaptive capacities are rather strategic and also include the prediction of potential future risks (Birkmann, 2008; Birkmann et al., 2013; Vogel & O'Brien, 2004). Additionally, research on adaptive capacity contributes to vulnerability research, which, in broad terms, examines the nature and structure of a society's ability to prepare for and recover from natural hazards (Hayden et al., 2017).

Therefore, under the MOVE Framework, the exposure, susceptibility and lack of resilience were used to determine the vulnerability level to the heatwaves of municipalities in Belgrade. Additionally, adaptation was measured as adaptive capacity.

4. MATERIALS AND METHODS

4.1. Study area

Belgrade is the capital and the largest city in Serbia. It has an urban area of 3,223 km^2. The city is located at the confluence of the Sava and Danube rivers and on the southern edge of the lowland Pannonian Basin and the northern edge of the Balkan Peninsula. The geographic coordinates of Belgrade span from approximately 44°06'N and 20°23'E in the north to about 44°16'N and 20°18'E in the south.

The administrative organization of the territory encompasses 17 municipalities (figure 4). Most of the municipalities are situated in the Šumadija region, on the southern side of the Danube and Sava rivers. Three municipalities Zemun, Novi Beograd, and Surčin are on the northern bank of the Sava in the Syrmia region and the municipality of Palilula, spanning the Danube, is in both the Šumadija and Banat regions.

The city has gone through considerable population growth, expansion of residential and commercial areas and sealing of undeveloped spaces. Belgrade has approximately 1,681,405 inhabitants (25% of the total Serbian population) (Statistical Office of the Republic of Serbia, 2022). A higher percentage are female 51.4% compared to 48.6% that are male (Statistical Office of the Republic of Serbia, 2022).

Overall, 20.28% of the total inhabitants are 65 years or older, with the percentage expected to grow. There is an unemployment rate of 9% (Statistical Office of the Republic of Serbia, 2022).

According to the Köppen-Geiger climate classification, Belgrade belongs to a Cfa climate, characterized as a temperate warm climate with a rather uniform annual distribution of precipitation, as well as a warmer summer (Beck et al., 2018). In Belgrade, the mean monthly air temperature in January amounts to 0.6°C, while the mean monthly air temperature in July is 22.7°C (Nenković-Riznić & Djukic, 2022). Due to intense urbanism, temperatures in Belgrade's city centre are on average, 8°C higher than in surrounding areas (Digital Climate Atlas, 2023). An additional temperature increase of 2.9°C is expected to occur by 2100 under the 4.5 RCP scenario and an increase of 3.6°C under the 8.5 RCP scenario (Digital Climate Atlas, 2023).

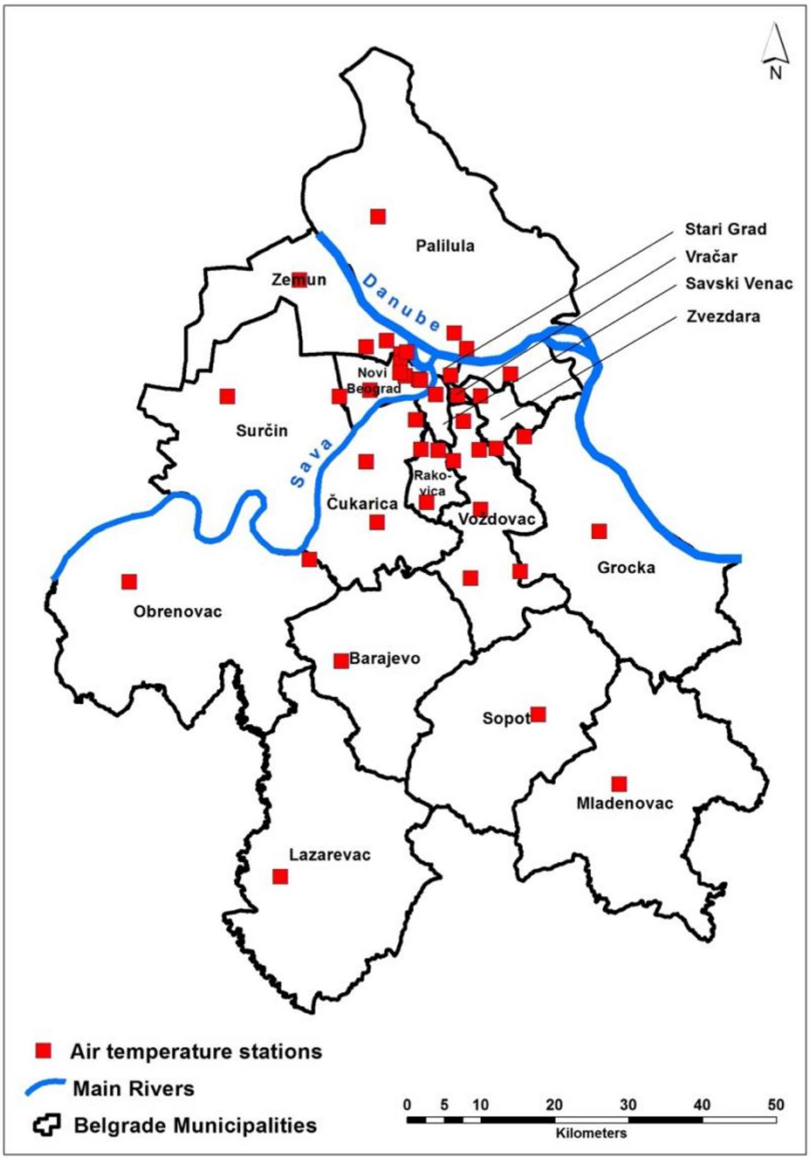

Figure 4: Map of 17 municipalities in Belgrade, together with the location of the air temperature stations used to gather temperature data.

4.2. Data source

For the quantitative part of the study, three main data sets were used: socio-economic data regarding the Belgrade population, temperature data, and green land cover data. Socio-economic data, precisely the number of people in every municipality, the number of people older than 65 years and unemployed people for each municipality were obtained from the Statistical Office of the Republic of Serbia, for the year 2022 (last obtained results).

Based on data from "The International Disaster Database," (CRED, n.d.) the most recent heatwaves in Serbia were documented in 2022. Consequently, temperature data were collected for the hottest months of the year, June, July and August, and the average temperature for each month was computed. The month with the highest average temperatures, which was July, was selected for the analysis (Figure A1). Data were gathered from the national website – Klimerko and the international meteorological website- OpenMeteo (figure 4).

The publicly available data from OpenStreetMap were used to gather information about the percentage of green areas. The data used include all green areas (pastures, meadows, forests, parks...). Using ArcGIS, the data were merged into one layer and then exported at the municipality level. This way, I had the possibility of calculating the area of green areas per municipality. For the administrative subdivision of Belgrade, the 17 municipalities were used (figure 4).

4.3. Survey sampling

Adaptation capacities data needed for the adaptation analysis were obtained by means of an anonymous online survey of Belgrade citizens. Questions for determining the perception of Belgrade citizens to extreme heat during summer months were formulated based on the literature reviews and similar studies obtained in European cities (Hayden et al., 2017; Laranjeira et al., 2021). The questionnaire was made and analysed using Google Forms. Responses were collected by sharing questionnaires on social media, Facebook pages related to each municipality, WhatsApp and Facebook groups associated with environmental problems that I am a member of.

The survey was conducted in all 17 Belgrade municipalities. The questioner sought to understand Belgrade's residents' adaptive capacity to extreme heat including knowledge, attitudes, and practices; participants' social capital; and their access to adaptation resources. The survey consisted of closed-ended and 1 open-ended questions. Closed-ended questions were used to generate quantitative data, while open-ended questions helped contextualize closed-ended responses and allowed respondents to describe views in greater depth. Questions were divided into 7 thematic sections to ease the result analysis. The questionnaire started with socio-demographic questions and continued with questions concerning climate change perception, heat risk perception, living situation and environment, heat stress and health, social capital and finally adaptation to heat stress. The survey was done following ethical guidelines, I took a measure of stating in the last question that the responses will be used in the research and asking if responders agree with that. To ensure that everyone can participate, the original questionnaire was done in Serbian. To gain the full picture I took a trip to the 4 biggest retirement homes in Belgrade for a face-to-face survey and shared questions to students from various universities. After two months total of 410 questionnaires were completed. Results were analysed using Google Forms and Excel.

5. RESULTS

5.1. Vulnerability assessment to heatwaves

In this section, results obtained through the spatial analysis for all single and composite indicators used for the calculation of the final map of vulnerability are presented and described.

5.1.1. Exposure

The spatial distribution of exposure to heatwaves was based on the temperature map (figure A1), and the population map (figure A2). The exposure map (figure 5) showed that the very high effect is concentrated in the central city municipalities of Zemun and New Belgrade and Palilula. Further, a high effect was identified in the municipalities of Zvezdara, Čukarica and Voždovac a densely populated area. Medium effect was found in the municipalities of Grocka, Obrenovac and Rakovica. Low exposure effect was identified in Old Town, Mladenovac and Lazarevac. While very low exposure was found in Savski Venac, Barajevo, Sopot and Surčin.

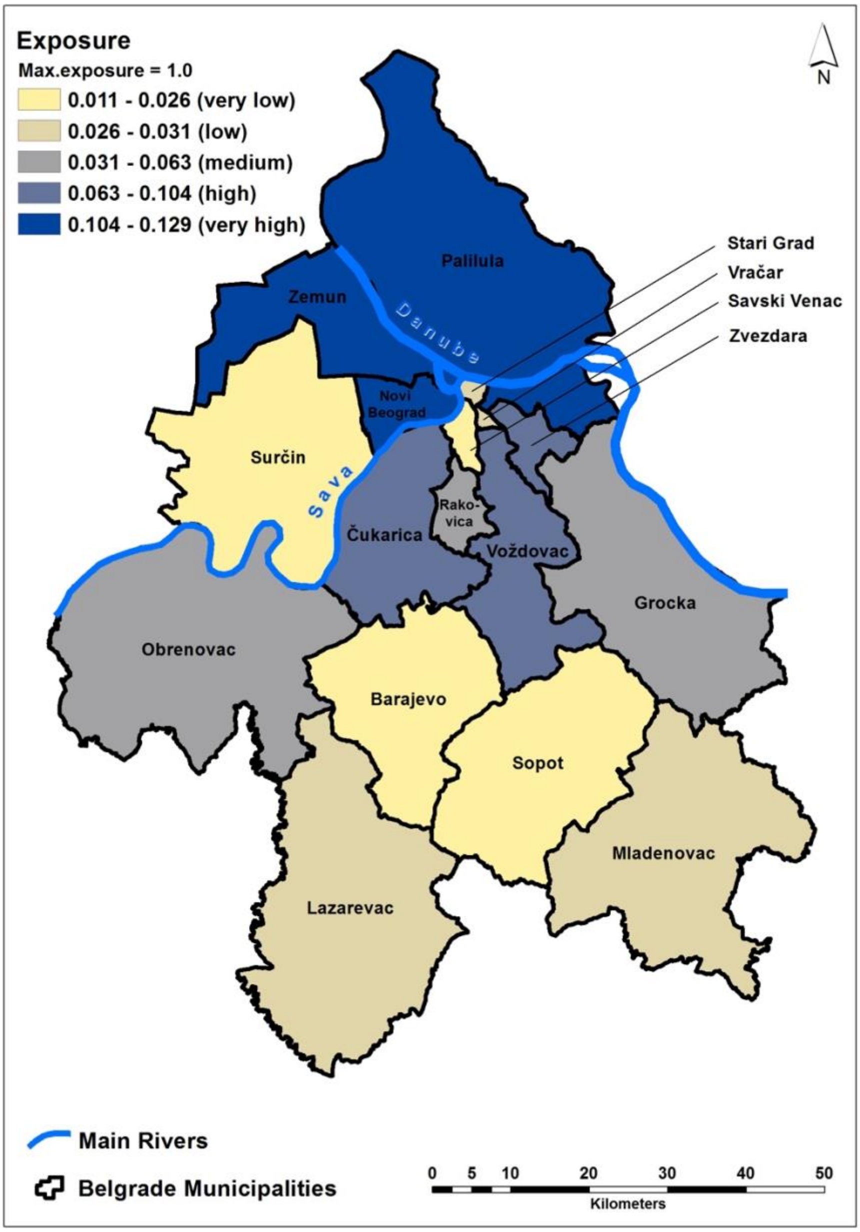

Figure 5: Map of exposure of Belgrade municipalities to heatwaves.

5.1.2. Susceptibility

For susceptibility calculation, two indicators, unemployed (Figure A3) and elderly- older than 65 years (Figure A4) were measured and spatially represented. The susceptibility map (figure 6) showed very high susceptibility in the southern part of the city in the municipalities of Barajevo, Sopot and Mladenovac. High susceptibility hot spots are situated in Obrenovac, Grocka and Savski Venac. The medium susceptibility rate was found in Zemun, Surčin, Čukarica, New Belgrade, Old Town and Lazarevac. Low susceptibility was identified in Rakovica, Voždovac and Vračar. Very low susceptibility was reported at Palilula and Zvezdara.

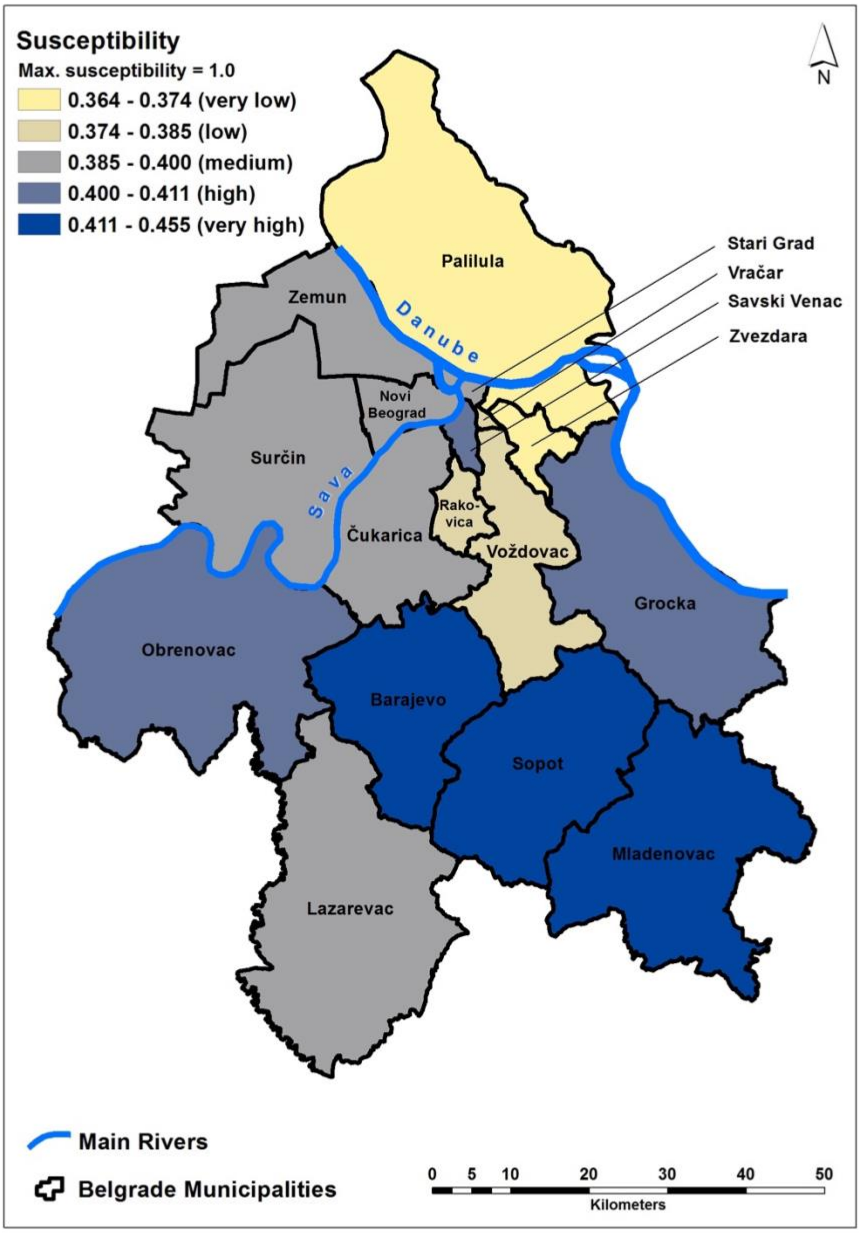

Figure 6: Map of susceptibility of Belgrade municipalities to heatwaves.

5.1.3. Lack of Resilience (LoR)

For the calculation of the lack of resilience (figure 7), two indicators were used: elderly people living alone (Figure A5) and the lack of green areas per city district (Figure A6). A very high level of LoR was registered in the municipalities of Zemun, Old Town and Vračar, while a high level was recorded in the municipalities of Novi Beograd, Obrenovac and Grocka. A medium degree of LoR was registered in the suburban municipalities of Surčin and Mladenovac, as well as in the central zone of the city in the municipality of Savski Venac. A low degree of LoR was measured in the municipalities of Lazarevac, Sopot, Čukarica and Palilula. While a very low degree of LoR was registered in the municipalities of Barajevo, Voždovac, Rakovica and Zvezdara.

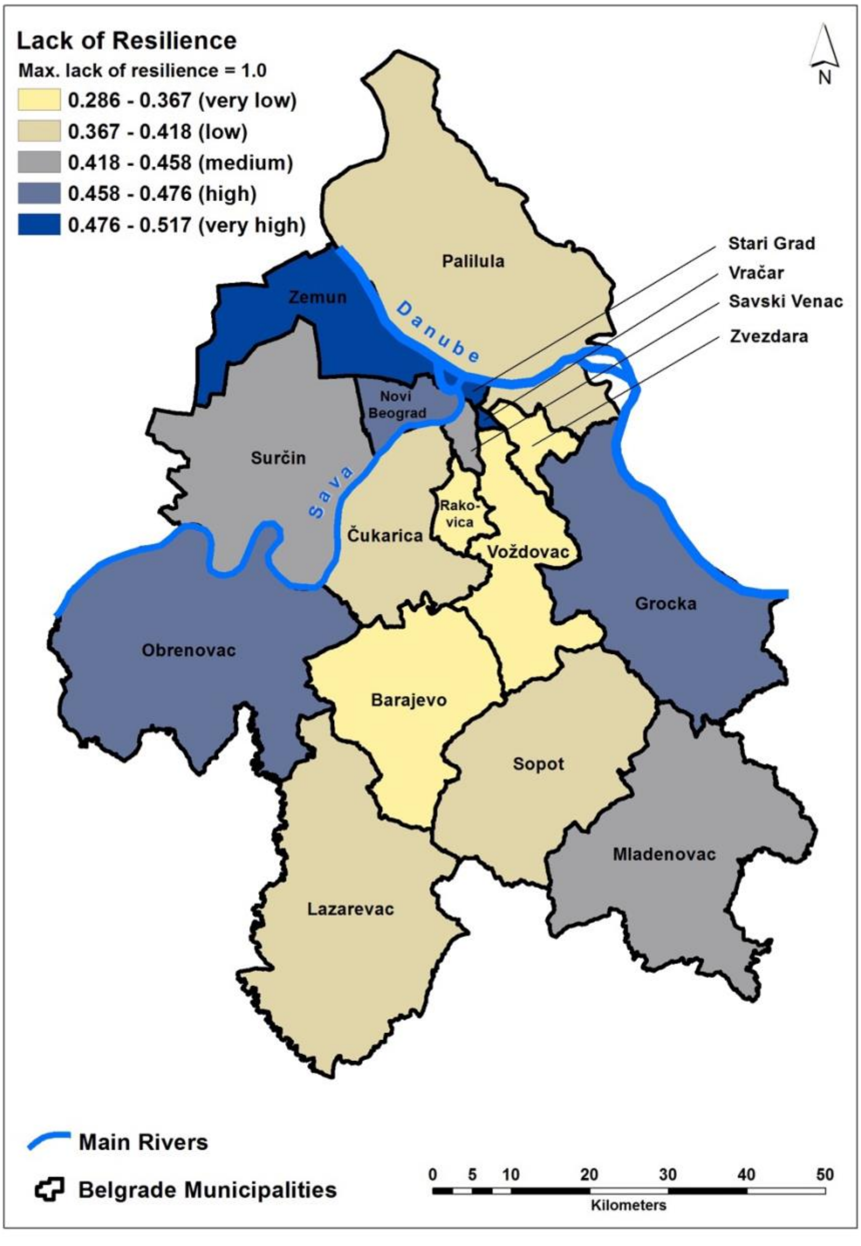

Figure 7: Map of lack of resilience of Belgrade municipalities to heatwaves.

5.1.4. Vulnerability

Very high vulnerability indices were registered in the municipalities of Zemun, New Belgrade and Palilula. A high level was registered in the municipalities of Čukarica, Zvezdara and Voždovac. The results indicate a medium vulnerability level in the municipalities of Obrenovac, Rakovica and Grocka. A low vulnerability level was recorded in the central municipalities of Old Town and Vračar, as well as in the suburban municipalities of Lazarevac and Mladenovac. Then, a very low level of vulnerability was recorded in the suburban municipalities of Savski Venac, Surčin, Barajevo and Sopot (figure 8).

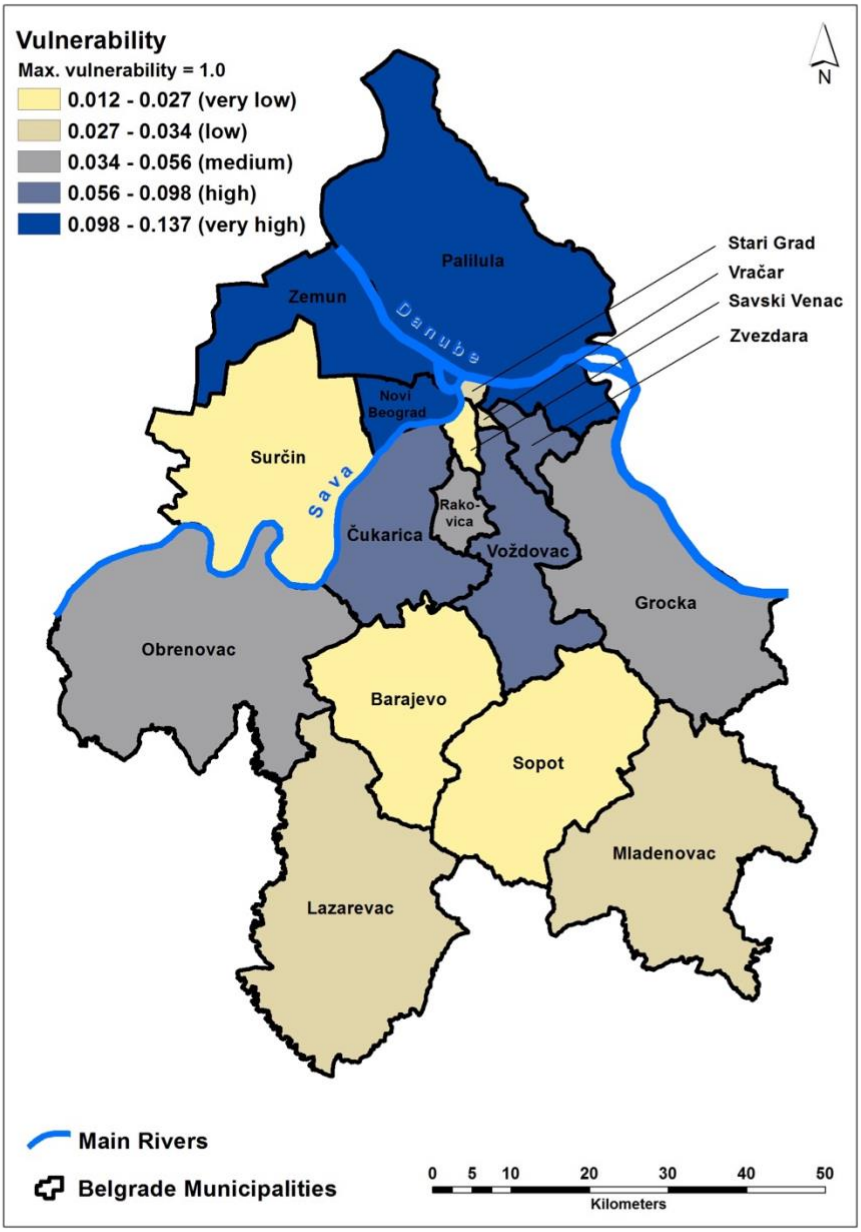

Figure 8: Map of the vulnerability levels of Belgrade municipalities to heatwaves.

The results indicated the great importance of studying the impact of heat on the degree of vulnerability of the population. Namely, the representation of the results in thematic maps is a fundamental added value to the analysis in three ways: (I) vulnerability indices are spatialized, adding a geographical dimension to the results and showing that different parts of the city correspond to different levels of vulnerability (II) it can drastically improve the communication and understanding of the results for a wider group of stakeholders, and (III) it provided an information layer that can be matched with other geo-referenced data. Finally, special attention was paid to ensure that the maps were readable for colourblind individuals by using the Civids colour ramp.

5.2. Results from the online survey

Extremely high temperatures, especially during the summer months, pose the question of to which extent and how heat affects the everyday lives of humans. For that reason, the examined survey analysed the adaptation capacities to the extreme heat of Belgrade's citizens. The population sample presented here represents a demographically broad range of urban residents in Belgrade.

5.2.1. Socio-demographic structures

The survey was answered by 410 respondents in total, with 215 females and 195 males. Most of the respondents, 222 exactly, were in the 18-34 age group, there were 85 respondents in the 35- 64 age group and 103 older than 65 years.

Other socio-demographic data are systematically represented in a table given in the appendix, Table A3.

5.2.2. Citizens' risk perception of the heatwaves

About 97.3% of respondents believed that climate change exists. Around 97.5% of the respondents believed that climate change is a problem and that it is noticeable in Belgrade. Furthermore, 86.9% thought that climate change affected their everyday life. When asked which natural hazards already pose a personal threat, around 8.3% stated that they already see a personal risk in heat waves, 18.1% see heatwaves as a future problem and as many as 72.9% perceive heat waves as a current and future problem (figure 9). In addition, most households are convinced that floods 21.7% and heavy rain 23.4% pose a personal risk now and in the future. Cold spells are mentioned less often, with less than 5% seeing them as a personal risk.

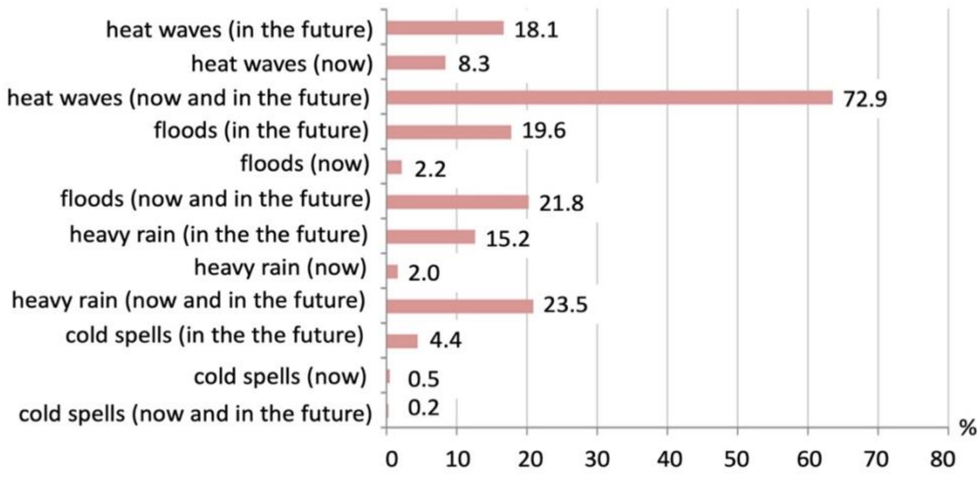

Figure 9: Do you think that proposed climate change-induced natural hazards pose a threat in Belgrade?

Regarding the questions related to temperatures in Belgrade and heat stress, 93.9% considered that temperatures in Belgrade are extremely high during summer months, 50.5% considered temperatures higher than 40°C to be extreme and 49.5% see 30-40°C as extreme. 92.9% considered extremely high temperatures to be a disturbance to their everyday life functioning. Public transport (78%) and the inner-city area (52.7%) were identified as hotspots of perceived heat stress. 41% reported high heat-stress during short walks to the store, pharmacy or restaurant (figure 10). A lower percentage, 14.1% and 18.5% are experiencing it in their own homes and workplace.

Figure 10: Where do you experience the highest heat stress?

5.2.3. Use of green spaces and housing situation

To questions related to housing situations and the use of green areas the highest percentage, 62.2% reported living in an apartment, 25.4% are living in a house and 12.4% are living in student accommodations and homes for the elderly. A high percentage, 70.7% reported that they experienced unbearable heat in their homes. A significant number of respondents (53.4%) indicated that their house or apartment has access to a 'green' balcony or patio, 38.8% had access to their garden, and 38.5% reported having a park or vast green area close by (figure 11). Air conditioning in the vehicle was reported by 34.9% of respondents, while 82.2% reported having cooling systems in the living space, resulting in 70.2% of respondents pointing out that they have increased electricity bills during the summer months.

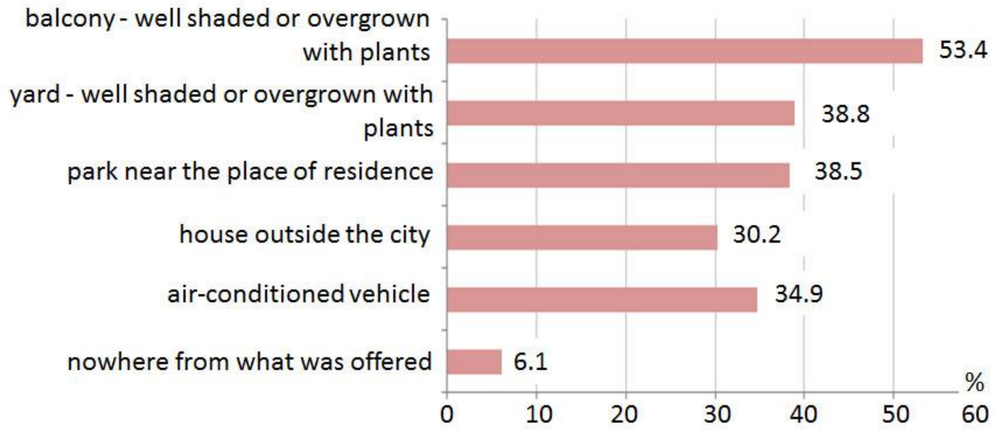

Figure 11: During unusually high temperatures do you have access to:

5.2.4. Heat health risk nexus

Approximately 45% of the respondents stated that they often suffered from dizziness, headaches and increased thirst when exposed to extreme heat (figure 12). Nausea was mentioned by 28.5% and exhaustion by 36.6%. As a symptom frequently occurring during heat events, lower concentration and sleeping problems were reported at around 29.8% and 32.7% respectively. During extreme heat, 29.3% reported to have cardiovascular issues. In Belgrade, 74.4% of chronic disease respondents stated to have increased problems during higher temperatures. Due to the heat extremes, 30.5% stated that they had been admitted to the hospital.

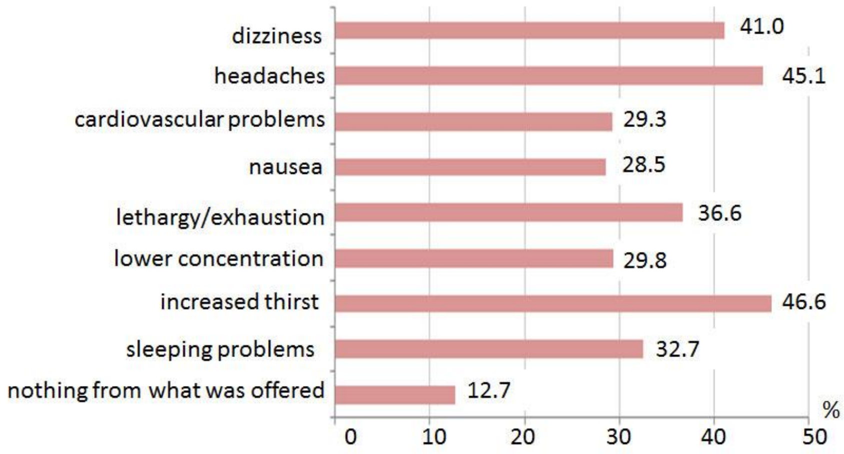

Figure 12: Do you experience any heat-related health problems during the summer months?

5.2.5. Social capital

The analysis of the data showed a highly significant positive relation between people with intensive and regular contact with people in their neighbourhood and the willingness to offer help in their neighbourhood. When asked if they have relatives or neighbours visiting during heat extremes, 65% reported that people are coming to visit. At the same time, the data suggest that people having regular contact with their neighbours are more likely to believe that they can generally rely on help from their neighbours. An even higher number, 90% reported that they have members of their family or neighbourhood that can be a quick help during extreme heat if needed.

5.2.6. Adaptation to heat stress

Figure 13 showed the results regarding the willingness to implement measures to prevent heat stress. Results regarding the willingness to implement measures to prevent heat stress showed that 48.2% of citizens are willing to create additional shading, while 57.5% of respondents choose the climate-adapted design of their garden, balcony, or courtyard with plants or water elements. Furthermore, 35.7% chose an adaptation of personal habits, and 20.8% of the interviewees stated that they are willing to move to a climate-adapted neighbourhood.

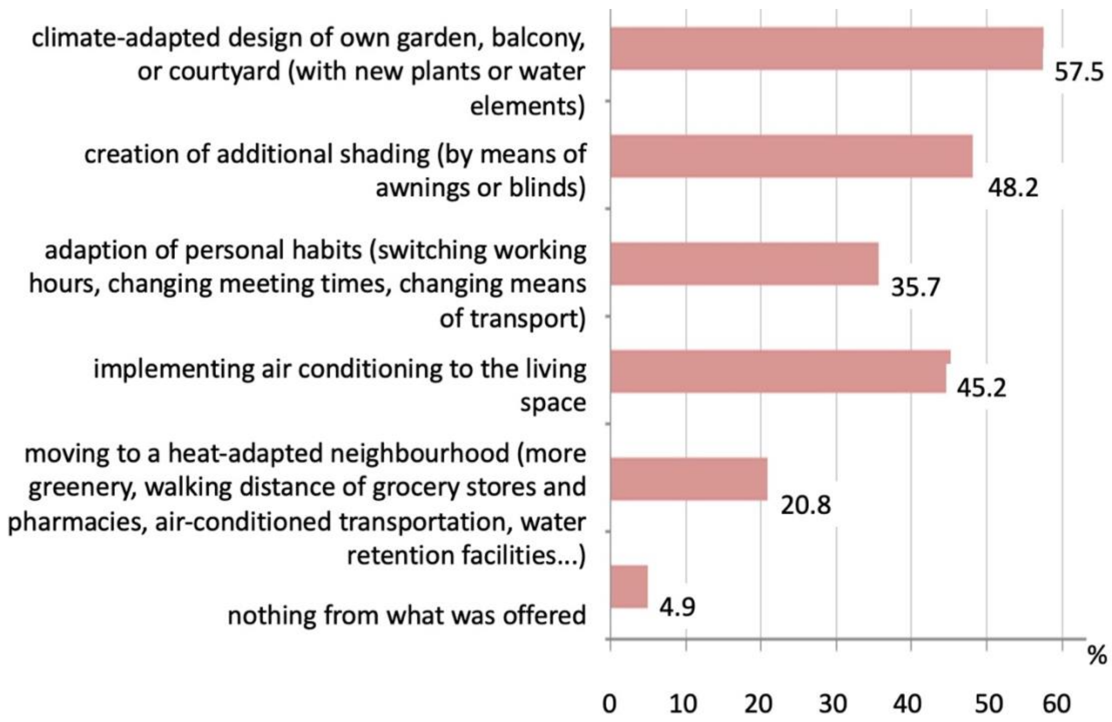

Figure 13: Which of the protection measures would you be willing to implement during extreme heatwaves?

When asked what proposed alternatives could aid in mitigating heat extreme temperatures (Figure 14). The highest percentage, 79.8% and 74.6% choose better maintenance and expansion of public gardens, parks and other green areas and increased number of trees and greenery in densely populated municipalities. 45.9% believed that an increased number of water facilities is important for minimizing heat extremes.

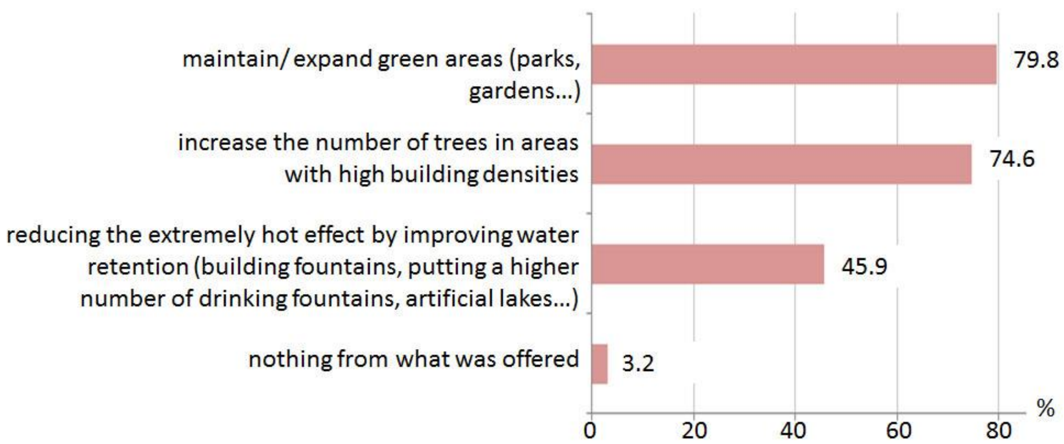

Figure 14: Which of the following do you think would have the highest impact on the extreme heat exposure reduction?

The last question was an open-ended question asking about personal beliefs and ideas about what the City Administration can do to increase the adaptation capacity of the city to the extreme heat. The survey showed that the majority of people believed that primary adaptation measures should be increased greenery and water bodies. Additionally, citizens are expecting improved air conditioning in public transport. Other ideas are proposing stopping outdoor physical labour when temperatures are unbearable, increasing water drinking facilities, and improving urbanization plans that incorporate mitigation measures for heatwaves and other natural hazards. Some of the answers stated that there is a lot that the government can do but it feels like they are doing nothing.

6. DISCUSSION

This section provides a discussion of the information obtained from the literature review, generated maps (figure 5-8 and Appendix, Figures A1-A6) and an online survey undertaken. The discussion is divided based on the two research questions stated in the introduction and identified limitations to the thesis.

6.1. Vulnerability levels to heatwaves of Belgrade municipalities

6.1.1. Exposure

A significant degree of exposure was recorded in the central municipalities of Voždovac, Zvezdara, and New Belgrade due to the domination of high-rise building blocks, resulting in increased population density, elevated average surface temperatures, and limited green spaces. This observation aligned with existing literature indicating that urbanisation, higher population concentration, and reduced greenery result in higher temperatures (Nimac et al., 2022). The presence of green areas is known to lower the heat stress (Wong et al., 2021). Surprisingly, despite the presence of forested areas in Zemun, Čukarica, and Palilula, these municipalities exhibited a high level of exposure. This can be because concrete surfaces store heat and cause the surface temperature to increase, thus the prevalence of concrete surfaces has a greater impact on exposure than the presence of green spaces (Bozdogan Sert et al., 2021). Possible adaptation measures are lying in utilizing green infrastructures. Green infrastructure, encompassing green roofs, green facades and parkland expansion has been regarded as an effective adaptation strategy (Besir & Cuce, 2018). Significant temperature decrease was recorded in urban areas of Graz and Berlin after the implementation of green roofs on concrete building blocks (Hoeben & Posch, 2021; Knaus & Haase, 2020). Further research generated for Hungary, suggests that green roofs can significantly lower heat-induced mortality rates by lowering indoor temperatures (Marvuglia et al., 2020).

The moderate level of exposure observed in Grocka and Obrenovac may stem from their distance from the city centre and medium population density. However, recent urban development has led to increased temperatures, particularly notable in Obrenovac, potentially intensified by the operation of the Nikola Tesla thermal power plant, known for its air pollution emissions (Smid et al., 2019). Confirming the fact that outdoor air pollution sources can further elevate temperatures (Eguiluz-Gracia et al., 2020). One of the adaptation measures that is already being planned is the implementation of desulfurization plants, in which the technological procedure of sulphur dioxide removal from flue gases is carried out, thus lowering emissions (RERI, 2023). As an alternative measure, the area could benefit from reducing extreme temperatures by adding water bodies, like in the study by Sützl et al. (2022) where the city of Zurich was used to prove the clear cooling effects of water bodies.

Despite high temperatures in central municipalities like Vračar, Old Town and Savski Venac, low exposure was recorded, possibly due to high real estate prices limiting population density. Peri-urban areas like Mladenovac, Surčin and Lazarevac, characterized by lower population density and more greenery, also exhibited low exposure. Confirming that the presence of green belts can mitigate exposure when concrete surfaces are limited (Wong et al., 2021). Hsu et al. (2021) stated that the effect of heat stress is lower in rural areas. That is why when moving away from the city centre towards Barajevo, Sopot, and Surčin, exposure decreases significantly due to lower population density and the presence of more rural areas.

6.1.2. Susceptibility

One of the determinants of citizens' susceptibility to heatwaves is dependent on income levels as it usually determines the ability to implement heat regulation systems (Murage et al., 2020). Nijman & Wei (2020) argue that the higher unemployment thus lower income levels are characteristics of the municipalities on the outskirts of the town compared to the central districts. The observation of very high susceptibility in the southern municipalities of Barajevo, Sopot, and Mladenovac aligns with expectations, given their distance from the city centre, high unemployment rates, and predominance of elderly residents. Similarly, outer municipalities like Obrenovac and Grocka exhibit high susceptibility, likely due to lower living standards and elevated unemployment rates. To increase the adaptation capacities of poorer communities Sun et al. (2021) developed a methodology to evaluate the effectiveness of passive cooling measures to improve residential building heat resilience. Results show that roof insulation and solar-control window films appear to be promising solutions for reducing heat gains and improving indoor comfort levels, for both grid-connected and off-grid scenarios (Sun et al., 2021). Governmental subsidies for the installation of these measures can greatly contribute to the sustainable building design and energy conservation efforts of Belgrade's municipalities while increasing adaptation measures for vulnerable communities. In contrast, Savski Venac, situated centrally, boasts a high employment rate. However, due to its predominantly elderly population, and the fact that the elderly are the most sensitive (Wong et al., 2021), it is characterized by heightened susceptibility.

Medium susceptibility is evident in numerous municipalities, influenced by their proximity to the city centre and demographic structures. For instance, Zemun and Surčin, easily accessible and with a younger population, exhibit medium unemployment rates. New Belgrade and Čukarica, close to the city centre, feature middle-aged citizens with stable employment. Old Town, with a significant elderly population, is an expensive district which boasts low unemployment rates. Since tolerance to heat is largely dependent on the aerobic fitness level, one can expect an increased adaptation potential in a younger population (Foster et al., 2020). Lazarevac, even though it is located on the city's outskirts, is characterized by medium susceptibility, potentially due to its predominantly younger population. Additionally, Rakovica and Voždovac, surrounding the city centre, show low susceptibility due to their youthful populations and minimal unemployment rates. Municipalities recording very low susceptibility, such as Palilula and Zvezdara, are distinguished by their youthful populations, minimal unemployment rates and high percentage of greenery. Vračar, known for its affluent residents, despite its elderly demographic, showcases low susceptibility.

The results indicated that susceptibility to heat waves depends on multiple intertwined factors. For example, while Vračar might be expected to exhibit high susceptibility due to its elderly population, its high standard of living likely fosters better heat adaptation potential and thus lower sensitivity. A possible adaptation measure increasing the adaptation potential of elderly people is connected to their social status. Namely, during heat stress events, there is a lack of social connections identified in the elderly population which leads to isolation and loss of activities (Fransson et al., 2023). Baquero & Forcada (2022) researched the thermal comfort of the elderly in the Mediterranean, the research concluded that the development of cooled indoor spaces used as a meeting point can aid in the adaptation of the most vulnerable group.

6.1.3. Lack of Resilience (LoR)

Elderly individuals living alone are considered a group with limited prompt assistance capacity during hazards (Fransson et al., 2023). In Belgrade, they are primarily concentrated on the western side of the city, in Zemun, New Belgrade, and Čukarica. Zemun and New Belgrade exhibit high percentages of green area deficiency, agreeing with a very high and high LoR. Conversely, Čukarica benefits from the Košutnjak forest's green ring, resulting in a lower LoR. Good isolation and temperature-oriented construction can aid in lowering heat-induced consequences (Reischl et al., 2018). The older areas of Belgrade, such as the Vračar and Old Town, were not constructed following up-to-date construction since they were built decades ago (Santiago Lema-Burgos, 2020), further, they lack green areas and are populated by an older demographic thus displaying very high LoR.

Research showed that people with increased social connections have greater adaptation capacities than people in isolation (Kafeety et al., 2020). Surčin and Mladenovac, despite low green area percentages, demonstrate medium LoR attributed to higher rates of multigenerational families thus lower rates of elderly individuals living alone. Additionally, Barajevo and Sopot, characterized by multigenerational households and ample green spaces, exhibit low LoR. Grocka and Obrenovac have deficient greenery, high unemployment rates, and lower living standards, resulting in high LoR. However, confirming the fact that income level is an important determinant of resilience (Murage et al., 2020), Rakovica and Palilula have significant populations of elderly individuals living alone, however, there is a low unemployment rate, resulting in low LoR. Lazarevac and Mladenovac, located on the city outskirts, feature lower percentages of elderly living alone and medium green coverage, translating to low and medium LoR, respectively. Zvezdara, with its notable elderly population, benefits from the urban forest's green ring, offering cooler environments and healthier surroundings, resulting in very low LoR. Savski Venac, situated in the city centre, presents very low percentages of elderly living alone but a slight green space deficit, contributing to a medium LoR.

The generated LoR map showed that the linkage of green cover per city district to resilience deficiency underscores the importance of environmental components in coping with hazards.

6.1.4. Vulnerability

As a result of the combination of the three composite indicators, the highest vulnerability level to heatwaves in Belgrade was determined in the central districts on the western side of the river Sava in municipalities Zemun and New Belgrade and in Palilula. Additionally, a high vulnerability level was found in Čukarica, Voždovac and Zvezdara. Generated maps show a high accordance between exposure and vulnerability. Namely, the municipality of Palilula is characterized by very high exposure, but a low lack of resilience and susceptibility, however, the vulnerability level is in accordance with exposure showing a very high level. Additionally, municipalities of Barajevo, Sopot and Mladenovac show very low and low vulnerability and exposure, however a very high susceptibility. Similar results were found in the work of Welle et al. (2014) where the results of vulnerability assessment in Cologne Germany for heatwaves and floods show that the exposure factor has a big influence on the overall vulnerability of the city. This is because the exposure was multiplied by the equal-weighted sum of susceptibility and lack of resilience. Different weights for each factor of vulnerability could also be used based for instance on expert judgments or stakeholder opinions (Welle et al., 2014).

Due to its high living standards and lower population density very low and low vulnerabilities were identified in the central districts of Stari Grad, Savski Venac and Vračar. The medium level was reported on the outskirts of Obrenovac and Grocka and in the more central district of Rakovica. The vulnerability map (figure 8) showed that the districts with lower living standards on the outskirts of the city like Lazarevac and Surčin; have very low and low vulnerability levels. On the other hand, municipalities at the centre of the city with higher population density and higher living standards but a much lower percentage of green areas are characterized by very high and high vulnerability levels. This corresponds to the fact that greenery is crucial to heat mitigation by showing that a high degree of vulnerability affecting the wealthy districts is mostly due to the lack of greenery, thus the importance of greenery during urban planning is of essential importance for future projects (Wong et al., 2021).

The presented multidimensional assessment of vulnerability to heatwaves confirmed that the older, unregulated urbanised municipalities particularly observable in municipalities located along the northern bank of the Danube, like Zemun, New Belgrade and Palilula, yield high exposure and vulnerability and play a big role in shaping the city's heat vulnerability (Santiago Lema-Burgos, 2020). This confirmed the conclusion by Depietri et al. (2013) that future, climate-oriented, improvements in the management of not intensely urbanised peri-urban areas are crucial for lowering the vulnerability as well as strengthening the resilience of the urban population. These assessments provide insights into vulnerability to various stressors, emphasising the importance of targeted interventions to enhance resilience across different city areas.

The analysis underscores that urbanisation, concrete surfaces, population concentration, and lack of greenery are primary influencers of heatwave vulnerability. This echoes findings conducted by Nimac et al. (2022) in Zagreb, Croatia, and Smid et al. (2019) across European cities. Further, it suggests that Belgrade, like other metropolies, will become increasingly vulnerable to extreme heat in the coming decades. Up to this point, the results give information about where it is relevant to implement adaptation strategies in the city.

6.2. Adaptive capacities of Belgrade citizens to heatwaves on an individual level

6.2.1. Socio-demographics and its influences on individual adaptive capacities

A survey on the individual level provided new insights into the linkages between general socio-economic vulnerability and the adaptive capacities of citizens to adapt to heat stress in urban areas (Hayden et al., 2017; Laranjeira et al., 2021). Studies conducted by Hayden et al. (2017) and Voelkel et al. (2018) concentrated on examining the connections among socio-demographic factors, perceived heat stress, and individual adaptive capacities. Voelkel et al. (2018) emphasized that heat exposure and adaptive capacity are closely linked to socio-demographic variations. According to their research, specific social segments within a population, such as low-income groups, tend to have lower adaptive capacities. Further, they experience disproportionately high temperatures and have limited access to shelters from extreme heat (Voelkel et al., 2018). The conducted online survey showed accordance with the generated susceptibility map (figure 6). Namely, the highest susceptibility was found in Barajevo, Sopot and Mladenovac, where online survey showed a very high percentage of people living in lower-income groups, 84%, 81,8% and 62,6% respectively. Mou (2023) mentioned the positive relation between income level and education level, stating that in most cases higher education results in higher income. In that regard, municipalities where respondents fit in higher education levels like Vračar and Old Town also choose higher income resulting in increased heatwave adaptation capacities and thus lower vulnerability (figure 8). On the other hand, a statement by Voelkel et al. (2018) that people with lower income have limited access to shelter from extreme heat confirmed the fact that predominantly people from low-income municipalities with lower levels of education like Barajevo, Grocka and Sopot report their workplaces as heat hotspots. People with lower levels of education usually tend to have jobs in the domain of outdoor physical labour (Foster et al., 2020). Thus high susceptibility in these municipalities follows the statement that people doing physical labour are, on a daily basis, more exposed to heatwaves (Foster et al., 2020).

Further, Martín & Paneque, (2022) mention age as an important indicator of susceptibility. Results show that there is 76% of the elderly in Barajevo, 56% in Mladenovac, 62% in Grocka and Surcin and 45,5% in Sopot, all of these municipalities are characterised by very high and high susceptibility (figure 6). Additionally, analysis of the demographics and heatwaves showed that women, as a population, are less able to adapt to imposed heat stress (Kumar et al., 2022). The conducted survey and Statistical Office of the Republic of Serbia (2022) showed that Belgrade is a city with a predominantly female population thus resulting in overall higher city vulnerability.

The findings from the household survey on heat stress carried out in Belgrade confirmed the significance of vulnerability indicators such as sex, socioeconomic status, age and education level in adaptability to heat stress. Additionally, fresh perspectives emerged regarding individual risk perception and adaptive abilities, which are also interconnected with factors like age, income, and social connections.

6.2.2. Risk perception of the heatwaves in connection to adaptation capacity

Individual risk perception to climate change and heat stress influences adaptation decisions and the willingness to adapt. Whether adaptation to experienced or future events takes place depends on the extent to which a personal risk is perceived at present or in terms of future climate change (Laranjeira et al., 2021). Thus, the identification of environment-related hazards and extreme events that are classified as direct or potential threats is a reasonable step when analyzing individual adaptation to climatic events (Howe et al., 2019). The survey captured attitudes towards climate change. Following the trend from other European countries like Germany, Italy, and Croatia (Antronico et al., 2020; Nimac et al., 2022; Venghaus et al., 2022) almost all respondents believe that climate change exists. Additionally, responders believe that climate change is a problem and that it is noticeable in Belgrade, and a significant majority pointed out that it greatly affects their everyday lives. Interestingly, the respondents see a higher personal risk of all of the proposed natural hazards in the future than at present. This aligns with the perception of the people in the European city of Ludwigsburg (Laranjeira et al., 2021) and with the study conducted by Antronico et al. (2020) that observed a general tendency of citizens to see weather-related issues as temporally distant events, unworthy of great concern, despite being aware of their existence. This mindset can affect general efficiency of adaptation actions as it aligns with the theory formulated by Bubeck et al. (2012), which suggests that individuals take action to reduce their vulnerability only when they perceive themselves to be highly exposed (Antronico et al., 2020).

Literature suggests that experiences with intense heat in one's own living space contribute to an increased risk perception (Sandholz et al., 2021). Therefore, respondents from the municipalities with the highest vulnerability (figure 8) and exposure (figure 5) like Palilula, Zemun and New Belgrade choose their own apartment as the highest heat stress hotspot. Additionally, the data analysis uncovers, that the threat of heat stress is not limited solely to residential areas. In accordance with the work conducted in Bonn by Sandholz et al. (2021), respondents also experience significant heat stress in public transport and near the city centre. Public transport was especially highlighted in municipalities like Zemun, New Belgrade, and Čukarica where the survey showed, that most of the responders are currently enrolled in universities, they especially highlighted the importance of public transport climate adaptation. Agreeing with the research by Laranjeira et al. (2021) which stated that city centres are especially seen as areas of high heat stress, areas around the city centre were considered another hotspot, with over 52.7% of respondents.

6.2.3. Use of green spaces and housing situation as adaptation capacity

To get a full picture of adaptation capacities, the living situation of the respondents was analysed (Sandholz et al., 2021). Literature shows that people living in houses generally experience lower heat stress compared to people living in apartments (Farahani et al., 2024). In Belgrade, the survey showed a higher percentage of people living in apartments thus resulting in higher overall vulnerability. Additionally, the survey showed that citizens from peri-urban municipalities with a lower vulnerability (figure 8) like Barajevo, Sopot, Lazarevac, Mladenovac and Surčn are predominantly living in houses which confirms the low vulnerability level.

Hayden et al., (2017) findings suggest that income significantly impacts the household adaptive capacities, predominately as it usually determines the ability to implement heat regulation systems. Air conditioning (AC) is considered the most efficient measure of home heat adaptation (Jay et al., 2021). Most of the responders, 82,2%, confirmed the presence of the AC in their homes. However, even though it is so widely used, the use of AC needs to be critically revisited. Research indicates that the widespread adoption of air conditioning systems among citizens contributes to increased energy consumption and subsequently higher greenhouse gas emissions, particularly in urban settings (Jay et al., 2021). Furthermore, the direct heat discharge from AC units elevates temperatures in their immediate vicinity, exacerbating UHI effects (Viguié et al., 2020). On average, the time spent under high heat stress conditions in the streets is increased by about 20 min per day because of AC (Viguié et al., 2020). Thus, even though it is an efficient solution for households that can afford it, AC makes the situation worse for households who cannot or do not want to adopt it. Survey results show that the percentage lacking AC is in relation to income, type of living space and municipalities. Namely, AC is predominantly lacking in houses in low-income municipalities like Sopot, Mladenovac and Lazarevac. Additionally, AC is also lacking in the population that chooses student accommodation, confirming the statements that university students are increasingly affected by heatwaves due to their living situation (Cedeño Laurent et al., 2018; Wolkoff et al., 2021). Further, confirming the survey research conducted by Randazzo et al. (2020), people who have AC implemented are experiencing increases in their electricity bills during the summer months. Possible adaptation measures can be seen in the implementation of sustainable facades. The research by Alsaad et al. (2022) about the simulations of the urban microclimate in Stuttgart, Germany, revealed that the facade greening led to enhanced thermal comfort both outdoors and indoors, having a favourable influence on the microclimate within the simulated area, along with a minor distant effect.

Literature showed that parks and gardens can serve as important retreat areas during extreme heat events (Wong et al., 2021). The survey showed that this is especially true for the citizens that are lacking private gardens or balconies for whom publicly accessible green and recreational areas are important heat adaption measures. As the implementation of green areas is of crucial importance for lowering the UHI effect, the proposed central strategy in the climate change adaptation plans of both Paris and its surroundings involved a significant urban reconfiguration policy aimed at incorporating numerous parks and green spaces (Viguié et al., 2020).

6.2.4. Social capital as adaptation capacity

The results of the household survey confirmed the research by Carmen et al. (2022) that individual risk perception and the existence of social capital can be seen as dimensions of adaptive capacity or at least as factors influencing it. In particular, research done in Germany by Osberghaus et al. (2023) showed that social contact among neighbours is a factor in increasing adaptive capacities and coping mechanisms. The analysis of the survey data showed that people having regular contact with their neighbours are more likely to believe that they can generally rely on help from their neighbours. This suggests that people who are well-integrated in their neighbourhood are more likely to expect rapid help in an immediate emergency within their living environment. LoR map (figure 7) showed agreement with the survey answers. Among municipalities like Barajevo, Sopot, Mladenovac and Obrenovac where a higher percentage of elderly was detected (Figure A4), lower LoR was seen in the municipalities like Barajevo and Sopot where the surveyed elderly respondents chose the positive social factor answers. In this regard, Voelkel et al. (2018) emphasized the importance of cultural sensitivity and inclusion and proposed additional adaptation measures of effectively distributing cooling centres in areas where the greatest burden befalls vulnerable elderly populations. A great example of the implementation of this measure was found in Seoul, where indoor cooling centres for elderly people are the primary adaptation, with about 3000 centres managed during the summer (Park et al., 2021).

6.2.5. Health-related adaptation drawbacks

Another factor that determines adaptive capacities and vulnerability is the recognition and conscious acknowledgement of heat-related health issues (Laranjeira et al., 2021). In accordance with a survey conducted by Itani et al. (2020), the data show that specific symptoms occur with varying frequency within different age groups. According to the survey, the younger population seem to suffer more frequently from sleeping and concentration problems than the elderly. However, the ageing population states a high prevalence of diabetes and cardiovascular and respiratory diseases. This is not a surprise given that cardiovascular diseases ranked first in terms of the number of deaths in Serbia (Vasic et al., 2022). People suffering from such pre-existing health problems are more likely to be harmed in case of extreme heat events and thus have lower adaptation capacities (Borchers Arriagada et al., 2020). In Belgrade, a significant number (74%) of pre-chronic patients stated to have increased problems during higher temperatures, the literature showed that these types of patients typically result in an increased rate of hospital admissions (Millyard et al., 2020). In this regard, the importance of increasing hospital adaptive capacity during heatwaves can be observed in the study by Brooks et al. (2023). Namely, England's 2019 heatwaves caused significant health services staff disruption. Facilities and equipment and hospital staff experienced difficulty in managing heat risks in hospitals. The study suggests that priority should be given to increasing adaptive capacities through workforce development, and strategic long-term planning, as well as to improving health system resilience to current and future heat-health risks.

6.2.6. Readiness to adapt and Adaptation abilities

The survey asked about measures the respondents have already implemented or plan to implement to protect themselves against heatwaves. In addition, the survey also explored what people would do in the future if the occurrence and intensity of heat stress remained the same or intensified. Results are in accordance with the research conducted in Ludwigsburg (Laranjeira et al., 2021) indicating a prevalence of willingness to implement measures that are associated with a slight or minor change in lifestyle or linked to rather low monetary expenditure, such as the creation of additional shading, climate-adapted design of their garden, balcony, or courtyard with plants or water elements. A significant number of respondents are also ready to adapt personal habits such as choice of working hours, meeting points, or means of transport and the installation of an AC system as a possible option for the future. On the contrary, measures which are associated with major changes in everyday life or increased monetary expenditure such as, for example, moving to a place with a more suitable climate have rarely been implemented or planned to be implemented by the respondents.

Readiness to adapt affected vulnerability levels, namely, the vulnerability was lowest (figure 8) in high-income municipalities like Vracar, Old Town, and Savki Venac which are predominated by the elderly (Figure A4) that are usually considered to be at the highest risk from the urban heat. However, their relatively lower vulnerability was the result of higher readiness to adapt due to better housing conditions and a high potential to adapt their behaviour to heat, as they are usually retired or no longer part of the working population with potentially fixed working hours.

The research gave insights into the connections between individual socio-demographic characteristics and various forms of adaptive capacities, along with specific adaptation measures. By undertaking these analyses, the goal was to identify the social groups toward which specific adaptation measures or policies could be primarily directed, fairly addressing the needs and interests of Belgrade's residents.

6.3. Limitations

The proposed framework provides multidimensional insights into the vulnerability levels of Belgrade municipalities. However, in its current form, the study has some limitations concerning data collection and analysis. Compared to frameworks used in vulnerability research in the study done by Paranunzio et al. (2021) or Yu et al. (2021), which have more descriptive, precise indicators like % of houses needing repair, % of people having family doctors, or % of people not owning a car... The MOVE framework does not depend on those in-depth indicators. Thus, for countries, like Serbia, lacking in-depth statistical information on a national level, this is a valuable framework to gather an overall picture. For that reason, this thesis had to incorporate a framework for which statistical data could be obtained.

Additionally, it is crucial to highlight that in the application of the MOVE framework presented in the paper, all indicators utilized carry equal weight. Altering the weighting of these indicators could alter the impact of the outcome of vulnerability assessments. This is especially pertinent in the context of exposure calculation, as a district with few people and high temperatures might have the same exposure as a district with many people and lower temperatures. Maragno et al. (2020) and Welle et al. (2014) propose a solution by stating that the decision of which indicator (in this context, temperature or population number), has greater weight could be determined by the importance they have for the decision-making or policy-making body, thus the decision to assign greater significance, and consequently greater weight, to certain elements constitutes a political decision that necessitates thorough discussion and deliberation.

Due to the time frame for completing the thesis, research was done during the winter months of February and March. This may give a slightly altered picture of the survey results, than if the research was done during summer months when people are experiencing increased temperatures. Additionally, the thesis does not encompass all of the Belgrade citizens, and the results are characterized by an uneven distribution of citizens across the municipalities. The majority of the respondents are from the central parts while there is a lack of respondents from the outskirts of the city, which could lead to some unintentional biases.

7. CONCLUSION

The lack of data and information to support the city-scale adaptation processes is often mentioned as a factor that is hampering successful adaptation decision-making. Thus, this thesis provided new insights into the vulnerability levels of Belgrade municipalities and the adaptive capacity of its citizens to heatwaves. It was concluded that in the city of Belgrade, both vulnerability and adaption capacity are highly determined by citizens' income levels, levels of greenery in the municipality and population density. Interestingly, compared to other studies that highlight age as a crucial vulnerability determinant results showed that in Belgrade age is not a crucial determinant. Namely, in high-income municipalities with predominantly elderly populations vulnerability levels are lower than in municipalities with lower-income younger populations. On the other hand, lower-income municipalities with a higher level of greenery and lower urbanisation levels are characterised by lower vulnerability levels compared to higher-income, lower-greenery municipalities. Additionally, even though they are characterized as predominantly middle-income municipalities with substantial greenery percentages, highly populated municipalities with higher urbanisation rates show higher vulnerability levels.

The obtained results gave an overall look at the current city-scale situation and can serve as a wake-up call for prompt action. They offered valuable information about which municipalities are highly vulnerable (Palilula, Zemun and New Belgrade) and should be a primary goal of future policy measures and to which population groups' (low-income, socially excluded groups) future adaptation strategies should primarily be aimed for successful heatwave effect adaptation.

The findings of this thesis underscored the significance of vulnerability research as an initial phase in identifying crucial points within the city that require a prompt, solution-oriented approach. Nevertheless, this study does not delve into comprehending the criteria guiding the decision-making process. The formulation of adaptation strategies is heavily influenced by political, social, and economic factors, which play a pivotal role in shaping decision-making processes. However, these crucial factors were not integrated into the methodology. Therefore, it is important to address these aspects in future research endeavours. Furthermore, for a successful future adaptation strategy, it could be important to analyze heat load change in future climate conditions. Therefore, this study could be followed up with one that will consider climate projections and expected urbanisation scenarios.

Moreover, this thesis offered valuable insights for comparative studies, should the methodology be replicated in other cities. Since the survey aimed at generating data which is easy to replicate by asking closed-ended questions, the proposed survey-based methodology to analyze individual adaptive capacities can also easily be transferred and replicated in other cities. In this regard, it would be interesting to see which individual adaptive measures are likely to be implemented in dependency of different political, economic, and cultural backgrounds and conditions in different countries.

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9. APPENDIX

9.1. Table A1. Temperature in July 2022 and identified heatwaves throughout the month.

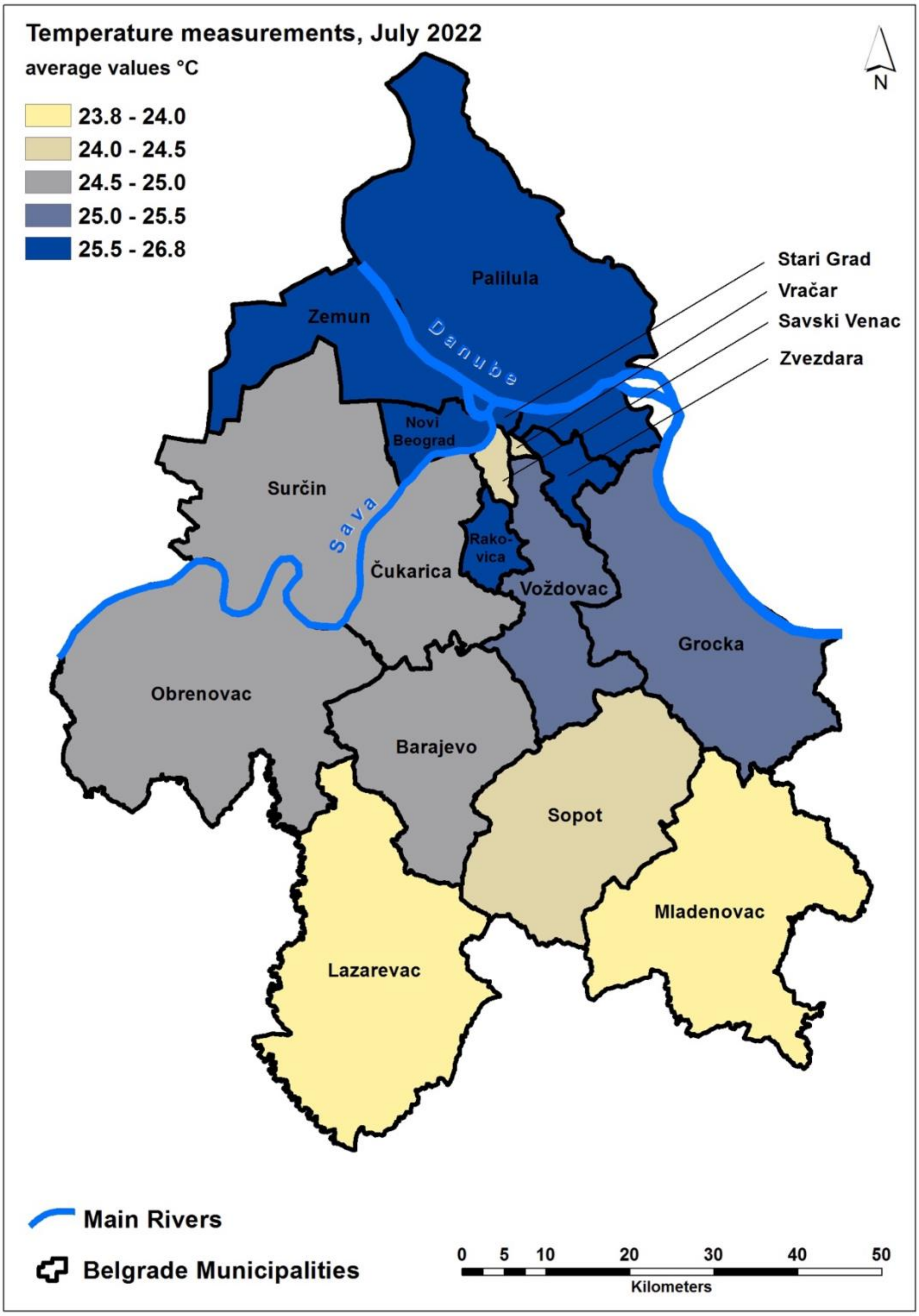
R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE	AF	AG
16.7.	17.7.	18.7.	19.7.	20.7.	21.7.	22.7.	23.7.	24.7.	25.7.	26.7.	27.7.	28.7.	29.7.	30.7.	31.7.
26	25	26	28	29	30	31	34	28	29	30	27	26	29	26	23
24	23	24	25	27	28	29	32	27	28	29	27	24	28	24	21
26	25	24	25	27	29	29	31	30	29	29	29	28	29	28	26
22	22	22	24	25	27	27	29	26	26	27	25	24	26	24	22
26	25	25	27	29	31	31	33	31	29	31	29	26	29	28	25
26	25	25	27	29	30	31	33	29	29	30	27	26	27		
22	20	20	22	24	26	26	29	24	25	25	23	23	26	23	20
24	23	23	25	26	28	29	31	27	27	28	26	25	27	25	22
22	21	21	24	25	27	28	29	26	26	27	24	23	26	23	22
25	24	26	26	28	28	28	29	28	28	28	26	25	27	26	23
25	26	27	30	32	34	35	35	34	34	33	32	29	31	29	30
25	25	25	26	27	29	30	31	29	29	29	27	27	28	27	25
22	22	23	25	27	29	29	30	28	28	28	26	25	27	25	24
23	22	22	23	24	27	27	28	26	26	28	25	25	26	25	22
26	25	24	26	28	29	30	32	29	28	29	27	26	29	27	24
23	22	22	24	25	28	28	30	27	27	28	25	25	27	24	23
25	26	26	27	29	31	31	32	31	30	30	28	27	30	28	26
28	28	27	28	29	31	31	33	30	30	31	29	29	31	31	29
25	25	25	26	28	29	30	31	30	29	30	28	27	29	28	25
24	24	24	25	27	29	30	31	29	28	29	27	26	28	27	24
24	24	25	26	27	28	29	30	29	29	29	27	25	27	27	26
25	25	24	25	27	28	28	29	26	27	28	25	24	27	24	23
	25	22				27	28	25	25	25	23	22	24	23	
21	21	21	23	25	26	27	29	25	26	26	25	22	26	24	20
23	24	24	25	26	28	29	30	28	27	28	26	25	27	27	24
25	26	26	28	29	31	31	33	31	30	31	29	26	30	28	26
26	27	27	26	27	27	27	28	28	28	28	28	28	27	28	28
22	22	21	24	25	27	27	30	27	27	27	25	24	26	24	22
24	23	23	24	25	27						28	25	27	27	25
23	23	22	24	25	27	27	29	27	27	28	26	25	26	25	23
22															
23	23	22	24	26	28	28	30	27	27	28	25	23	26	25	21
23	22	22	25	25	28	28	30	27	27	28	26	25	27	24	23
22	24	23	24	23	30	28	31	28	27	29	26	24	27	27	24
22	21	21	23	24	27	27	28	27	26	27	26	24	27	24	22
24	24	25	27	30	31	32	33	29	30	30	27	25	27	25	24
22	22	22	23	25	27	28	30	26	26	27	25	24	26	23	22
23	22	21	23	24	27	27	29	26	26	27	25	23	26	24	23
23	22	22	24	26	27	28	30	27	26	27	25	24	26	23	22
24	23	24	25	27	28	29	31	28	28	29	27	24	27	27	24
23	22	22	23	25	26	27	29	27	26	27	25	24	26	24	23
28	28	27	30	32	34	35	35	34	34	33	32	29	31	31	30

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
Gisid	Name	1.7.	2.7.	3.7.	4.7.	5.7.	6.7.	7.7.	8.7.	9.7.	10.7.	11.7.	12.7.	13.7.	14.7.	15.7.
0	Klimerko VL GZBV Beograd	33	27	23	28	29	23	25	21	21	20	19	21	23	28	29
0	Descon Klimerko	31	26	28	30	27	22	24	20	20	19	17	19	21	25	28
1	Klimerko Miljakovac	32	29	30	31	29	26	26	25	24	24	22	22	24	26	28
1	Rakovica_Meteo	28	25	26	27	27	22	22	20	20	20	18	19	21	24	26
2	Klimerko SF GZBV Beograd	34	28	31	32	30	25	26	23	23	22	21	23	25	28	30
2	Klimerko Avala	33	27	30	31	30	23	25	21	21	20	19	20	23	27	29
2	Klimerko Jajinci	29	23	26	27	25	20	20	17	17	17	15	17	19	24	24
2	Klimerko Kumodraz 2	29	26	27	29	26	22	23	20	20	18	17	18	21	24	27
2	Vozdovac_Meteo	28	25	26	27	27	22	21	20	20	19	17	18	20	24	26
2	Klimerko Pmjavor							26	22	22	21	19	21	24	26	27
3	Klimerko VD GZBV Beograd	34	32	34	33	33	29	31	26	25	28	27	28	30	33	32
3	ViÅ¡njiÄkobanjski Klimerko	31	28	29	30	29	26	26	25	23	23	22	23	24	26	27
3	Klimerko - Kotez	31	27	29	29	28	23	25	21	20	21	20	21	23	27	27
3	Palilula_Meteo	28	27	27	28	27	23	22	21	21	20	18	19	21	24	25
4	Klimerko Hilandarska	32	27	28	30	27	23	24	22	22	20	19	20	22	26	29
5	Savski Venac_Meteo	28	26	27	28	27	23	22	21	21	20	18	19	21	24	26
6	Klimerko BJ GZBV Novi Beograd	33	29	31	32	29	26	26	24	24	24	23	23	25	28	29
6	Klimerko Blok61	33	30	30	31	30	27	28	26	24	25	24	24	26	29	30
6	NBGD Blok 28	32	28	30	31	29	25	26	24	23	23	22	23	25	27	29
6	Novi Beograd Blok 22	32	28	30	31	28	24	24	22	22	21	20	21	23	27	27
6	Fanki Manki Klimerko	31	28	29	29	30	25	26	23	22	23	22	23	24	26	28
6	Descon Klimerko blok 21	29	25	28	28	24	23	24	21	21	19	18	19	21	25	28
6	Omladinskih Brigada - Blok 38					26	21	18	20	21	19	17	18	21		
7	Klimerko Altina	31	24	27	28	26	21	22	19	18	17	16	17	19	24	26
7	Descon Klimerko Batajnica	31	27	29	30	27	23	24	22	21	21	19	20	22	26	27
7	Klimerko Retenzija	28	25	31	32	30	26	27	24	23	23	22	23	25	28	30
7	Peaceax Klimerko									23	24	23	23	23	25	27
8	Vračar_Meteo	28	26	27	28	27	22	22	21	21	20	18	19	21	24	26
9	Fanki Manki Ledine	32	28	28	29	27	25	24	23	23	22	21	21	22	24	25
9	Surcin_Meteo	28	26	27	28	27	23	23	21	21	20	18	19	21	24	26
10	Klimerko - SremÄica	35	29	32	33	31	26	26	23	24	23	18	22	24	28	30
10	Descon Klimerko - Filmski grad	30	25	27	28	26	21	22	20	19	19	17	19	21	24	27
10	Klimerko 2.0 Rudjer 1	29	25	27	28	26	22	23	20	20	19	17	19	21	25	27
10	Cukarica_Meteo	29	26	27	28	27	23	22	21	21	20	18	19	21	25	27
11	Klimerko Siljakovac	25	25	27	29	27	22	23	20	20	21	19	20	21	25	25
12	Klimerko Rajkovac GZBV	29	25	27	27	24	22	22	21	20	20	17	18	20	24	27
13	Klimerko MT GZBV Beograd	31	27	30	30	29	24	25	22	22	22	20	22	24	28	29
13	Grocka_Meteo	28	26	27	28	27	22	22	21	20	20	18	19	21	24	26
14	Lazarevac_Meteo	28	26	26	27	26	23	22	20	21	20	18	19	21	24	26
15	Sopot_Meteo	28	26	27	27	27	22	22	20	20	19	18	19	20	24	26
16	Mala Mostanica SAMAR	30	26	28	28	28	23	24	21	20	21	19	21	23	26	28
16	Obrenovac_Meteo	28	26	27	27	26	23	23	20	21	21	19	20	22	25	26
		35	32	34	33	33	29	31	26	25	28	27	28	30	33	32

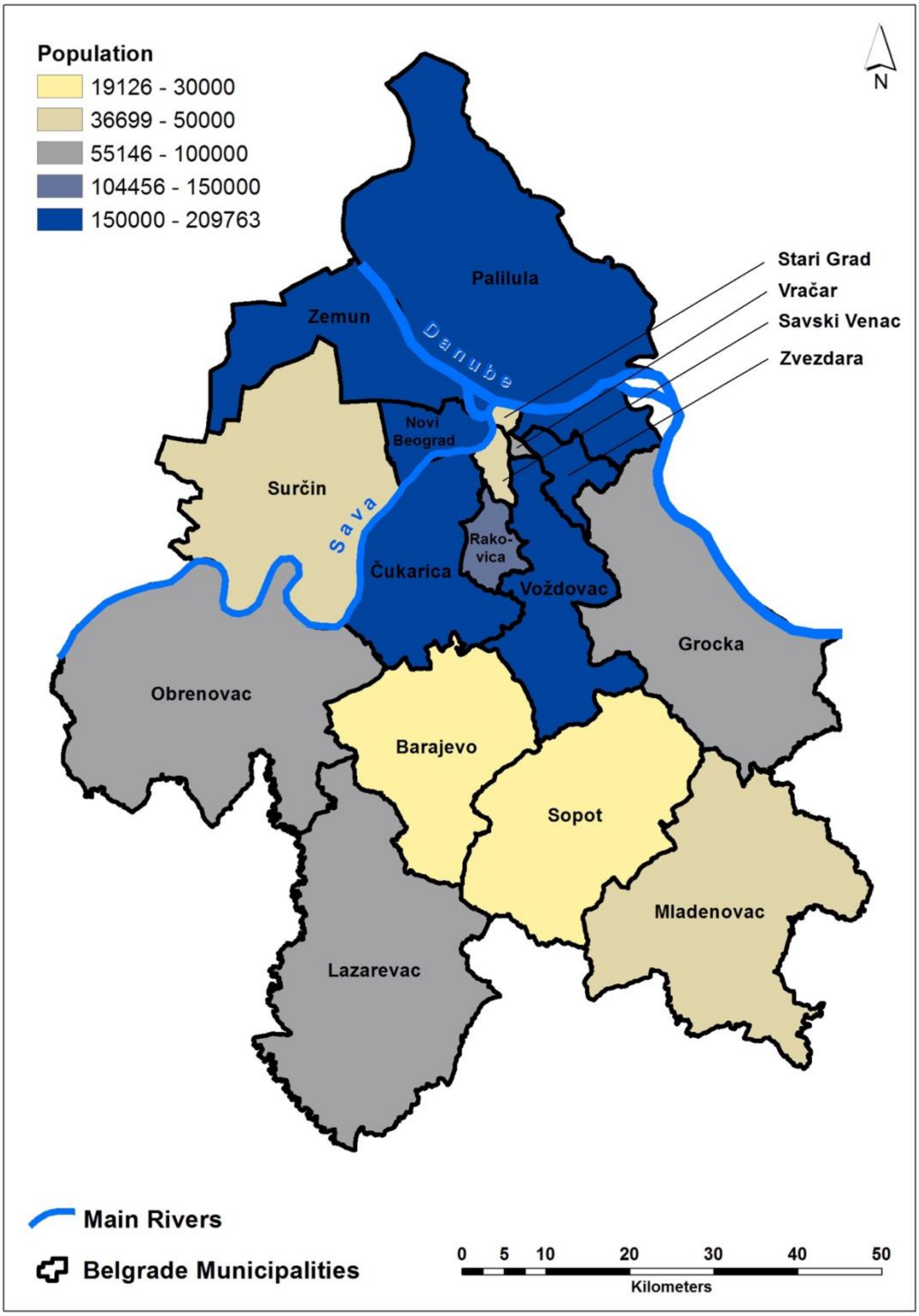
9.2. Table A2. Monthly average temperature calculations for July 2022.

AVERAGE	MIN	MAX	NORMALIZED MEAN
26	19	34	0,4903
25	17	32	0,5376
27	22	32	0,5161
24	18	29	0,5425
28	21	34	0,5087
27	19	33	0,5468
23	15	29	0,5369
25	17	31	0,5438
24	17	29	0,5565
25	19	29	0,6320
31	25	35	0,5677
27	22	31	0,5341
25	20	31	0,4985
24	18	28	0,6194
26	19	32	0,5484
24	18	30	0,5403
28	23	33	0,4839
29	24	33	0,5305
27	22	32	0,5161
26	20	32	0,5161
26	22	31	0,4982
25	18	29	0,6158
23	17	28	0,5000
23	16	31	0,4860
25	19	31	0,5403
28	22	33	0,5132
26	23	28	0,6696
24	18	30	0,5161
25	21	32	0,3706
24	18	29	0,5894
27	18	35	0,5074
23	17	30	0,4615
24	17	30	0,5633
25	18	30	0,5538
25	19	31	0,4758
24	17	29	0,5699
27	20	33	0,5161
24	18	30	0,5081
24	18	29	0,5425
24	18	30	0,5081
26	19	31	0,5430
24	19	29	0,5290
25			
31	25,43502825		
23			

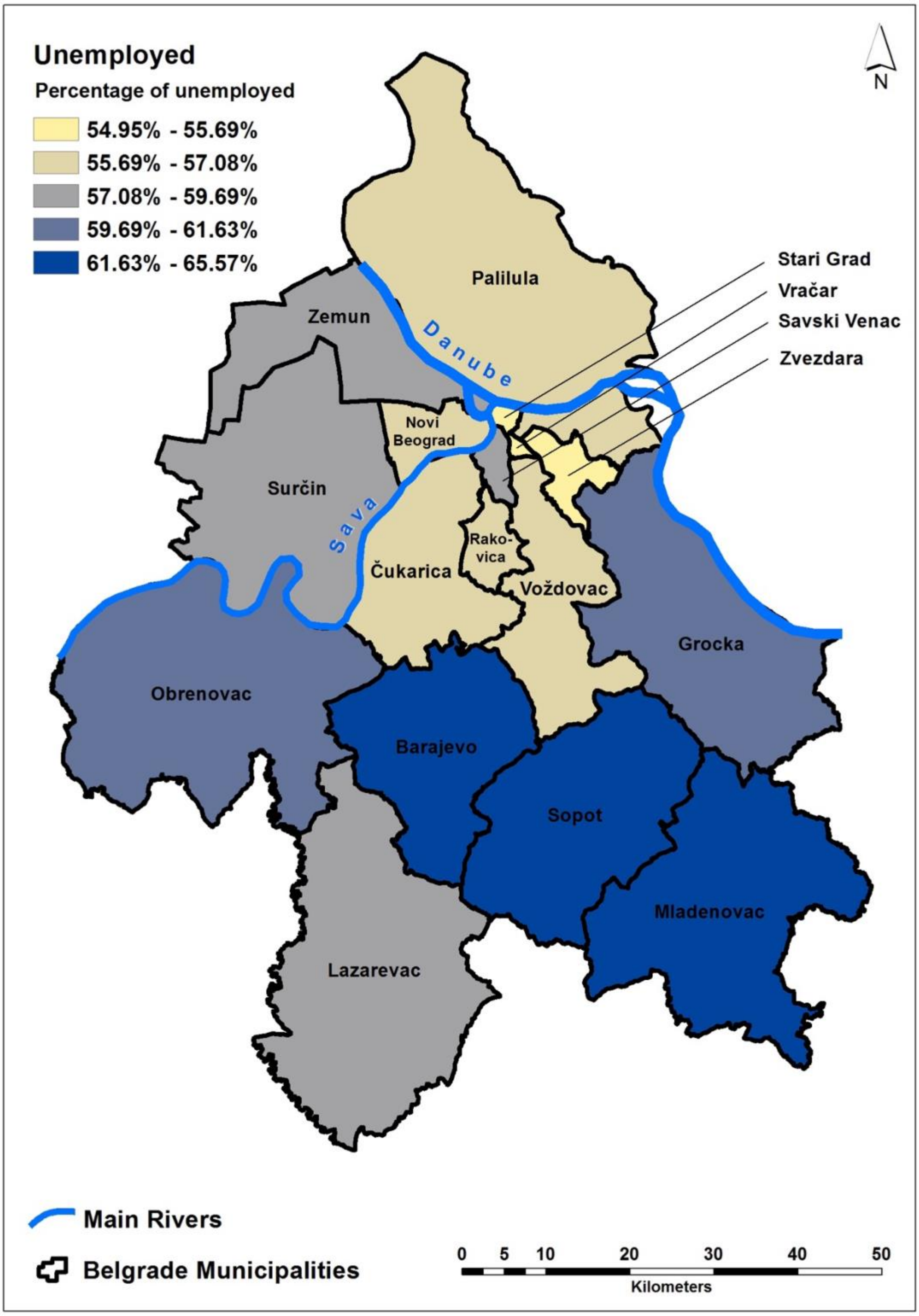
9.3. Figure A1. Average temperature map for July 2022, of Belgrade municipalities.



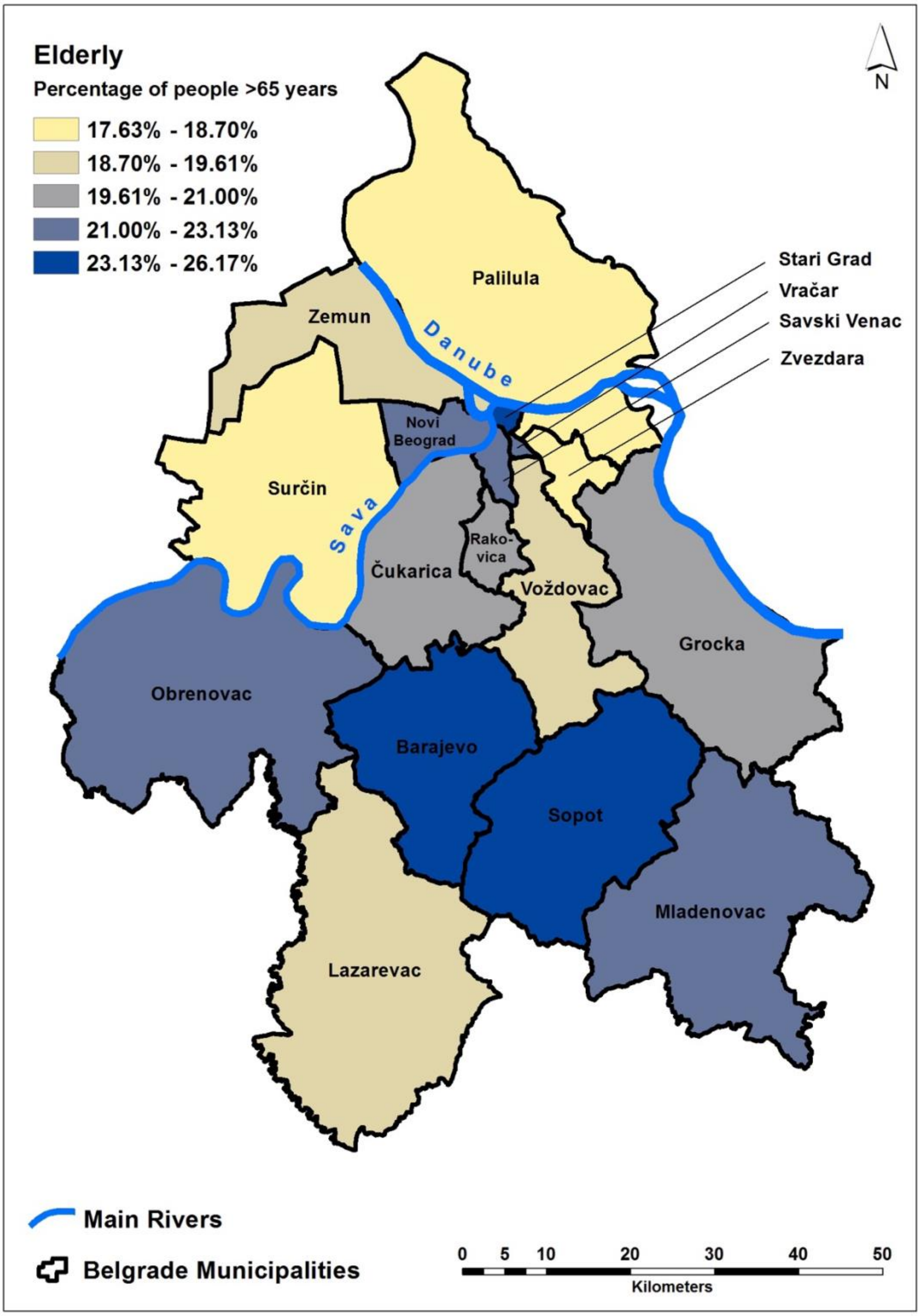
9.4. Figure A2. Population density map of Belgrade municipalities.



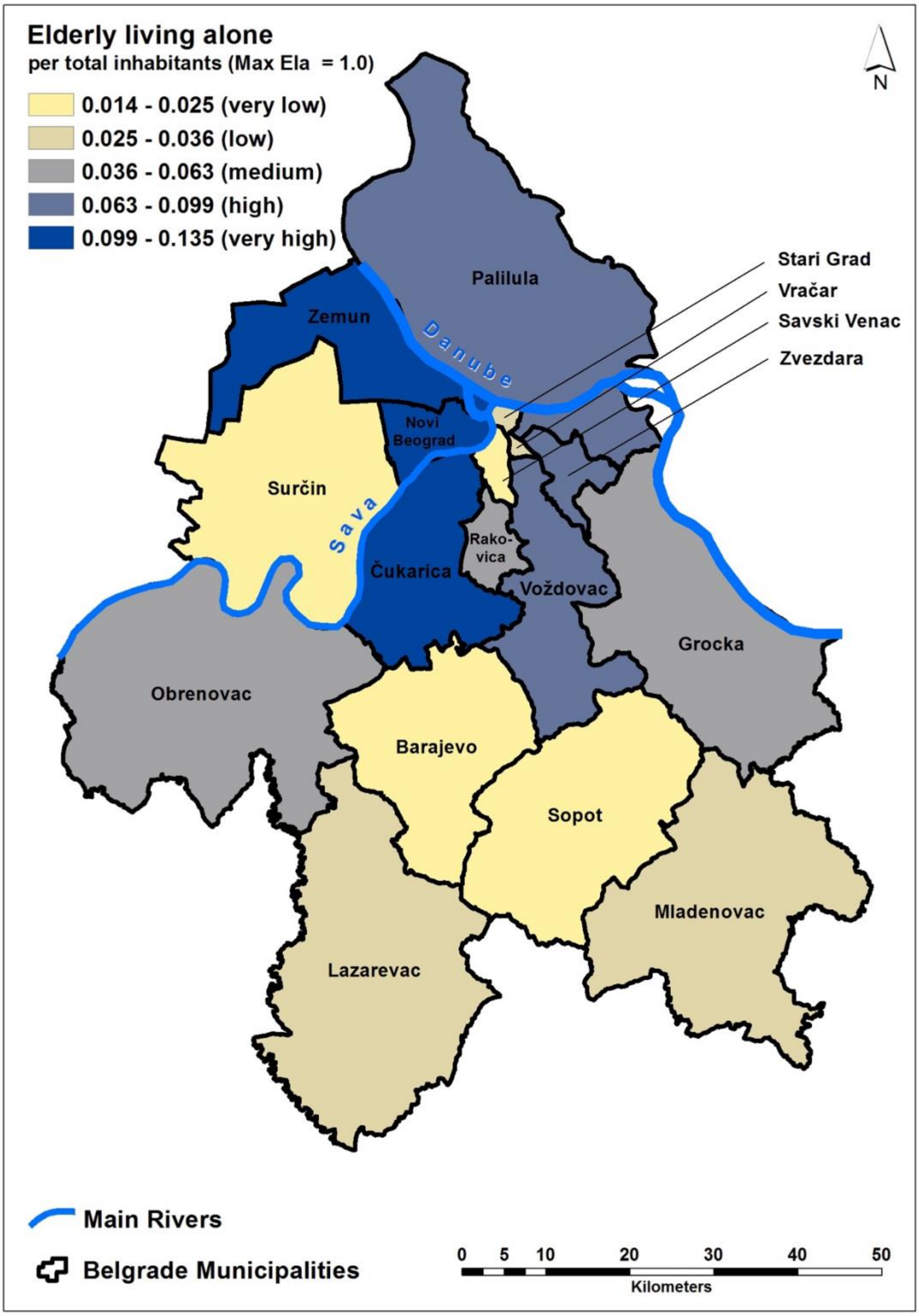
9.5. Figure A3. Unemployment rate distribution map through Belgrade municipalities.



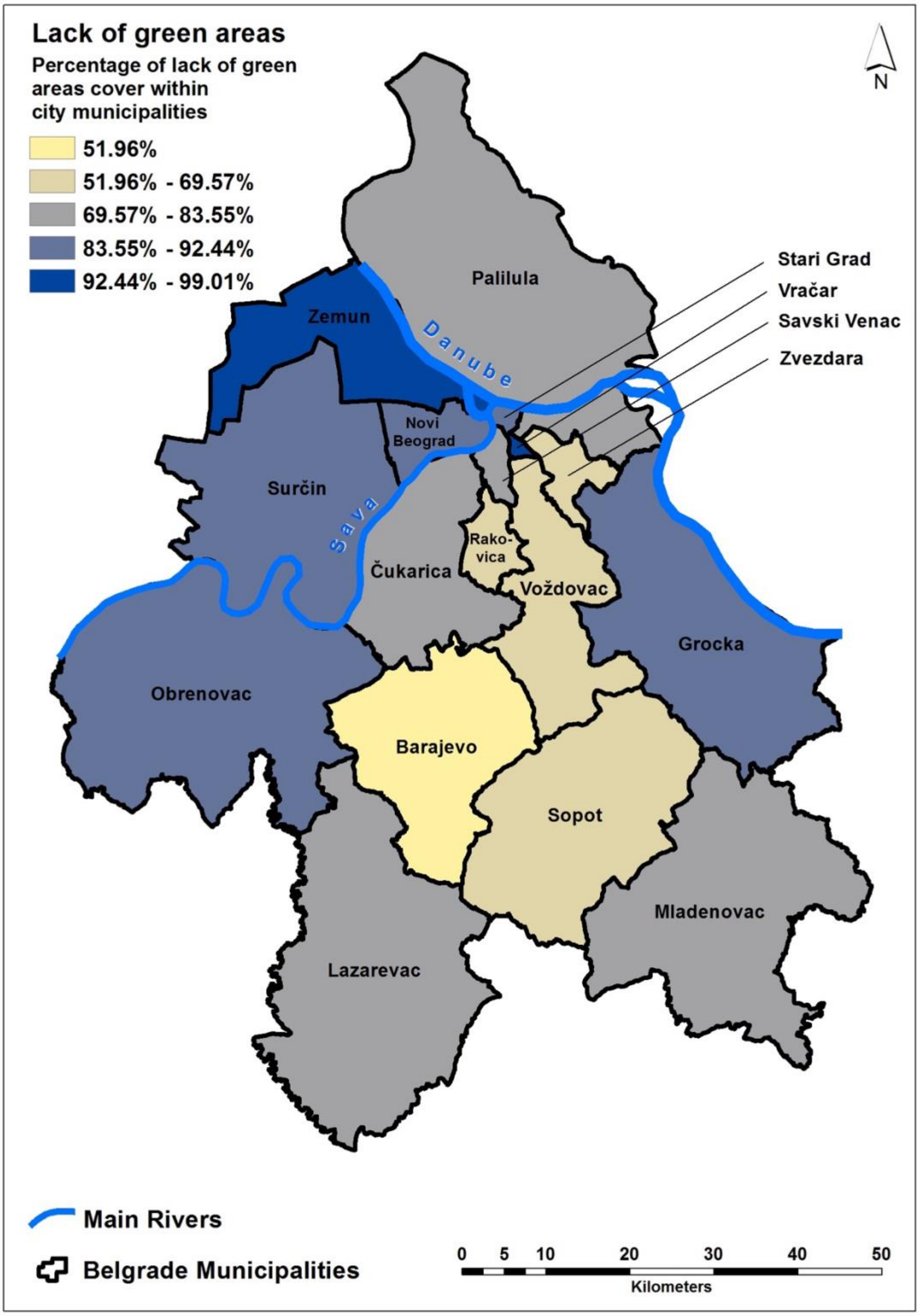
9.6. Figure A4. Map of how the population older than 65 years is distributed through Belgrade municipalities.



9.7. Figure A5. Map of elderly people living alone.



9.8. **Figure A6. Lack of green areas in Belgrade municipalities.**



9.9. Table A3. Socio-demographic data, habits and health status of respondents (N = 410).

Characteristics	Answers	
	n	%
Gender		
Male	195	47.6
Female	215	52.4
Age		
18-34 years old	222	54.1
35 - 64 years old	85	20.7
> 65 years old	103	25.1
Level of education		
elementary school	9	2.2
high school	168	41.0
university degree	156	38.0
master's	56	13.7
PhD level	21	5.1
Duration of living in Belgrade		
< 1*year*	58	14.1
1-5 *years*	65	15.9
6-10 years	45	11.0
> 10 *years*	242	59.0
The Belgrade municipality where you currently live		
Barajevo	25	6.1
Čukarica	40	9.8
Grocka	13	3.2
Lazarevac	13	3.2
Mladenovac	16	3.9
New Belgrade	76	18.5
Obrenovac	5	1.2
Old Town	7	1.7
Palilula	24	5.9
Rakovica	15	3.7
Savski Venac	11	2.7
Sopot	11	2.7
Surčin	8	2.0
Voždovac	21	5.1
Vračar	15	3.7
Zemun	89	21.7
Zvezdara	21	5.1
Do you currently live alone?		
Yes	102	24.9
No	308	75.1
How many other people do you live with?		
1	99	31.0
2	96	30.1
3	93	29.2
more than 4	31	9.7
What is your income level? (RSD)		
don't have a stable income	160	39.0
< 20 000	13	2.5
20 000-50 000	31	7.6
50 000-80 000	84	20.5

80 000-100 000	72	17.6
100 000-150 000	20	4.9
> 150 000	30	7.3

N - Total number of respondents. n - Number of respondents who answered a certain question.