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An ecological study of vulnerability to COVID-19 in Serbia - using Hotspot Analysis for Evidence-Based Population Health Policy

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Abstract

The risk of severe illness or death from COVID-19 is associated with specific demographic characteristics or composition of the population within geographic areas, and the spatial relationship between these areas. The aim of this paper is to identify areas with a higher concentration of population vulnerable to COVID-19, relying on the concept of spatial dependence. Hence, we focus on the share of vulnerable populations using several salient proxy measures at municipality level data for Serbia. The degree of vulnerability at the municipality level was determined by hotspot analysis, specifically the Getis-Ord Gi* statistics. The results indicate heterogeneity in the spatial patterning and typologies of clusters across Serbia. This spatial heterogeneity reveals potentially differing degrees of risk across municipalities. The results can inform decision-makers in the fight against COVID-19 by helping to identify those areas with vulnerable populations that if exposed may stress the local health care system.

Keywords: *COVID-19, population vulnerability, health care system, hotspot analysis, Serbia*

Rezumat. Studiul ecologic al vulnerabilității la COVID-19 in Serbia – utilizarea analizei hot-spot pentru elaborarea unei politici de sănătate ținând cont de caracteristicile populației

Riscul unei boli severe sau de deces datorat COVID-19 este asociat cu anumite caracteristici și structuri demografice ale populației din anumite zone geografice, precum și relațiile spațiale dintre acestea. Lucrarea își propune să identifice zonele cu o concentrare mai mare a populației vulnerabile la Covid-19, plecând de la conceptul de dependență spațială. Prin urmare, ne-am axat pe ponderea populației vulnerabile utilizând câteva măsuri proxy frapante la nivel de municipalitate în Serbia. Gradul de vulnerabilitate la nivelul municipalităților a fost stabilit cu ajutorul analizei hotspot, mai exact statistica Getis-Ord Gi*. Rezultatele obținute indică eterogenitatea distribuției spațiale și a tipologiei de clustere pe teritoriul Serbiei. Această eterogenitate indică un risc potențial diferențiat în cadrul municipalităților. Rezultatele obținute pot fi utile factorilor de decizie în lupta împotriva Covid-19 întrucât pot conduce la identificarea acelor zone cu populații vulnerabile, care dacă sunt expuse pot cauza o presiune considerabilă asupra sistemului sanitar local.

Cuvinte-cheie: *Covid-10, vulnerabilitatea populației, sistemul medical, analiză hot-spot, Serbia*

Introduction

In December 2019, in Wuhan City (Hubei Province, China), a number of patients were diagnosed with pneumonia, but as reported by the WHO China Country Office, the cause was at that time unknown. On January 9, 2020, the China Center for Disease Control and Prevention reported "a new type of coronavirus as the causative agent of this outbreak, coronavirus disease 2019 or COVID-19" (European Centre for Disease Control and Prevention [ECDC], 2020, p. 5). One of the characteristics of the COVID-19 virus is its rapid spread between individuals and associated with population mobility a rapid transmission between geographic areas.

The first case of COVID-19 was officially recorded in Serbia on March 6, 2020, and nine days later, a state of emergency was declared (March 15). But, according to the newest research, the first documented death associated with COVID-19 in Serbia was on February 5, 2020 (Bogdanović et al., 2021). From mid-March, multiple public health measures and guidelines were introduced to help "flatten the curve" and "reduce the pressure on the health care system". The public health measures included lockdowns, physical distancing policies, closing of catering facilities, kindergartens, schools, and universities, reducing the volume of public transport, and promoting working from home. This period is also characterized by the return of a large number of seasonal workers from abroad who performed temporary or seasonal work (Lukić, Predojević-Despić, Janeska, & Lozanoska, 2021). The spatial dimension of COVID-19 has become an integral part of health policy management and governmental decision-making, including both place-specific and countrywide mandatory and recommended travel restrictions and social distancing protocols. Šantić and Antić (2020) argued the initial lockdown (from March 15 to May 6, 2020) was not in line with regional and local inequalities in the number of COVID-19 infections and deaths in Serbia.

More formal use of spatial analytical methods can enable researchers and policymakers to study the spatial dynamics of COVID-19, specifically leveraging concepts of and measures for testing both spatial dependency and spatial clustering (Lessler, Salje, Grabowski, & Cummings, 2016). In theory, sub-national ecological data can help identify some of the spatial associations with COVID-19 rates and thus potential implications for local communities, municipalities, and regions, and the health sector that serves these areas (Rosenkrantz, Schuurman, Bell, & Amram, 2020).

The demographic dimension of COVID-19 refers specifically to the population composition, and that different groups of people have a higher risk of contracting and dying from the consequences of COVID-19. In this context, the elderly and groups of people suffering from specific diseases are at the highest risk of disease and death. Researchers can leverage this demographic reality to identify vulnerable populations and vulnerable places, thereby providing important health management guidelines for reducing the burden and/or slowing down the spread of COVID-19.

The importance of paying attention to research and solving health problems is also indicated by the fact that one of the Millennium Development Goals (MDG 6) is dedicated to the suppression of vicious diseases, as well as one of the Sustainable Development Goals (SDG 3). The goal to be achieved by 2030 is to ensure healthy lives and promote well-being for all at all ages. According to the United Nations (2021), the COVID-19 set back the progress of all 17 goals. It is considered that this pandemic could reverse decades of health improvements. Also, this highlighted the additional weaknesses of each national healthcare system, as well as the need to work further on the SDG17, which implies a stronger global partnership for SDG. This paper is also a contribution to accelerate return to the path of sustainable development by 2030.

The paper concentrates on the identification of municipalities in Serbia that are vulnerable to COVID-19, taking into account age and mortality data on respiratory disease, cancer, and deaths associated with the circulatory system. Fundamental to the approach used here is the concept of spatial dependence and the use of hotspot analysis. The main contribution of this paper is to demonstrate the application of hotspot analysis in the identification of vulnerable areas or regions within Serbia that can inform the allocation of resources to combat COVID-19.

Background and literature review

The impacts of place-specific demographic characteristics on population health have attracted the attention of researchers for many years. About 2400 years ago, Hippocrates, in his treatise Airs, Waters, and Places, stated that the place in which people live shapes their constitutions and habits (as cited in Krieger, 2003). Centuries later, the link between space and the health of the population was revealed in maps (e.g., John Snow Cholera map in 1854) and spatial statistical analysis (Auchincloss, Gebreab, Mair, & Diez Roux, 2012; Cromley & McLafferty, 2011; Kamel Boulos, 2004; Lawson, 2013). The development of geospatial health databases and easier access to spatial analytical tools has enabled the detection of the spatial patterns of infectious diseases, their determinants, and planning for their control or amelioration (Kamel Boulos & Geraghty, 2020; Lović Obradović, Krivošejev, & Yamashkin, 2020).

Vulnerable groups of the population are more susceptible to contracting COVID-19. In order to minimize mortality rates, it is necessary to identify where such groups reside, ensure adequate testing, and treat them (e.g., provision of vaccines or ensuring the supply of oxygen therapy and respirators is adequate) without delay (Amram, Amiri, Lutz, Rajan, & Monsivais, 2020; Chen et al., 2020; ECDC, 2020; Popescu, 2020). Here, the protective measures will be targeted at those requiring increased protection, while fewer restrictions will be directed at the general population (Van Bunnik Bram et al., 2021).

Patients with COVID-19 have different demographic characteristics. In countries, regions, and municipalities, where the share of the elderly population is high, and there is a tendency for higher COVID-19 mortality rates (Liu, Chen, Lin, & Han, 2020). Many early studies have shown that the age structure of the population can be an indicator of the spread and intensity of the pandemic (Dowd et al., 2020). Specifically, older persons infected with COVID-19 had the highest mortality rate (Chen et al., 2020), and studies suggest that the 65 plus and especially 80 plus age groups are at the highest risk from the virus (Naqvi, 2020). Onder, Rezza, and Brusaferro (2020) noted that COVID-19 is more lethal in older patients, and they are a particularly high-risk group, in part because a large number live in long-term care facilities where conditions for the rapid spread of COVID-19 are more favorable (Gardner, States, & Bagley, 2020).

COVID-19 is a respiratory and systemic illness, and research has shown that patients with obstructive pulmonary disease are five times more likely to have severe symptoms due to infection, and they must take special precautions regarding protection against the virus and thus reduce contact with people who are infected (Lippi & Michael Henry, 2020). Furthermore, in case of infection with COVID-19, they approximately have two times higher risk for all-cause mortality (Lee, Son, Han, Park, & Jung, 2021). Oh and Song (2021) outlined the importance of prevention and targeted strategies due to their vulnerability.

Patients suffering from various types of tumors are also vulnerable groups of the population. According to the latest research, patients with cancer have impaired immunity, which makes them more susceptible to infection (Sidaway, 2020). Patients who are receiving systemic anticancer treatments have an increased risk of mortality from COVID-19 and stand as a particularly risky subgroup of cancer patients (Lee, Hu, Chen, Huang, & Hsueh, 2020). The underlying malignancy or anticancer therapy affects the impairment of immunity. It is estimated that these patients are twice as likely to contract COVID-19 compared to a healthy population (Al-Shamsi et al., 2020). As such, scientists proposed specific treatment strategies for patients with cancer during this COVID-19 crisis including, the postponement of adjuvant chemotherapy or elective surgery for stable cancer, and the provision of a special type of protection for patients with cancer or cancer survivors. For patients with cancer infected with SARS-CoV-2, enhanced monitoring and treatment are recommended, especially in older patients or those with other comorbidities (Liang et al., 2020). Targeting cancer patients come to the fore in conditions of a limited supply of vaccines when this population group should have priority (Ribas et al., 2021)

Another category of the population that is vulnerable to COVID-19 is the population with cardiovascular diseases. In addition, other patients with underlying cardiovascular diseases (CVDs) might have an increased risk of death (Huang et al., 2020), and as such these patients require a special kind of treatment in case of infection COVID-19 (Zheng, Mha, & Zhang, 2020). Research by authors from Italy and Spain has confirmed dangerous links between COVID-19 and cardiovascular disease, so they suggest several measures to reduce the risk of infection, as well as the mortality of these patients. Some of them are social distancing, self-isolation, healthy lifestyle habits, regular self-monitoring, etc. (Barison et al., 2020)

The number of COVID-19 cases and deaths varies across space as indicators of social vulnerability related to COVID-19 (Amram et al., 2020; De Souza, Machado, & Do Carmo, 2020; Karaye & Horney, 2020; Lawal & Arokoyu, 2020; Macharia, Joseph, & Okiro, 2020; Snyder & Parks, 2020). The importance of identifying the distribution of vulnerable populations related to COVID-19 is driven by the needs of the local health care systems because this is the front-line in the fight to reduce COVID-19 mortality. As seen in Lombardy, Italy, and most recently across India (April–May, 2021), pressure on the health care system can have catastrophic consequences (Armocida, Formenti, Ussai, Palestra, & Missoni, 2020). Indeed, systemic social inequalities highlight the problems related to health care provision during COVID-19 (Dorsett, 2020). Many COVID-19 data dashboards now report not just on cases and deaths but also hospital capacity. In Serbia, the country of interest in this study, the level of health care system preparedness is "medium to high," having approximately 31 physicians, 61 nurses and midwives, and 57 hospital beds for every 10,000 people (The United Nations Development Programme, 2020).

Methodology

Data

Following the principles of ecological study (Morgenstern, 1995), this study focuses on the groups of the population within the spatial units—municipalities. A total of 168 municipalities in the Republic of Serbia (see Fig. 1) were analysed, not including the population of Kosovo and Metohija, the territory under United Nations Security Council Resolution, No. 1244/99.

The municipality is the lowest territorial level for which the measures used in this study are available (Statistical Office of the Republic of Serbia, 2021). We focus on four variables of interest all calibrated for each municipality: the share of the population aged 65 and over, the share of deaths from respiratory diseases, the share of cancer deaths, and the share of deaths from diseases of the circulatory system. All data refer to 2020. The share of the municipalities' population that is older than 65 was chosen as many of the strictest restrictions under the state of emergency identified this group as being of high risk, and subsequently, most complications, hospitalizations, and deaths occurred among this group. Data on the number of infected are obtained from the Open Data Portal (Institute of Public Health of Serbia "Dr Milan Jovanović Batut", 2020a, 2020b).

Analytical strategy

The approach in this paper is to use hotspot analysis to identify statistically significant hotspots and coldspots of municipalities containing specific vulnerable groups. We use a Local Indicators of Spatial Association, known as the Getis-Ord Gi* statistics (Getis & Ord, 1992), implemented within

ArcGIS Pro 2.5 (Esri, 2020). The advantages of Gi* statistics over global indicators of spatial association (Moran I) are higher sensitivity, enabling users to explore the concentration pattern, and identifying and mapping hotspot and coldspot areas within a study area (Gu, Liu, & Shen, 2019). The formula for the Getis-Ord Gi* is:

$$G_i^* = \frac{\sum_{j=1}^{n} w_{i,j} x_j - \bar{X} \sum_{j=1}^{n} w_{i,j}}{S \sqrt{\frac{\left[n \sum_{j=1}^{n} w_{i,j}^2 - \left(\sum_{j=1}^{n} w_{i,j}\right)^2\right]}{n-1}}} \quad (1)$$

where: x_j is the value of the municipality j, $w_{i,j}$ is the assigned weight between municipalities i and j, and n is the total of municipalities (Getis & Ord, 1996).

The output of the hotspot analysis tool is *z*-score and *p*-value for each feature or municipality (Prasannakuma, Vijith, Charutha, & Geetha, 2011). The results of the analysis indicate the formation of statistically significant hotspots when the value of a municipality with a high *z*-score value is surrounded by other municipalities with a high *z*-score. The feature is marked as a coldspot when the value of the municipality is statistically significantly lower than the study area (low *p*-value and high *z*-score). We can use a confidence level of 90%, 95%, and 99% conditioned by *z*-score and *p*-value. Non-significant features (municipalities) do not belong to either a hotspot or coldspot and on the maps that follow are left blank.

Fig. 1: The municipalities in Serbia

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Results

By the end of 2021, 1,297,147 cases and 12,688 deaths had been recorded in Serbia. The number of new cases and deaths has varied over time (March, 2020–December, 2021); see Figure 2. The maximum number of new cases (203,380) occurred in October, 2021 and deaths (1,747) in November, 2021.

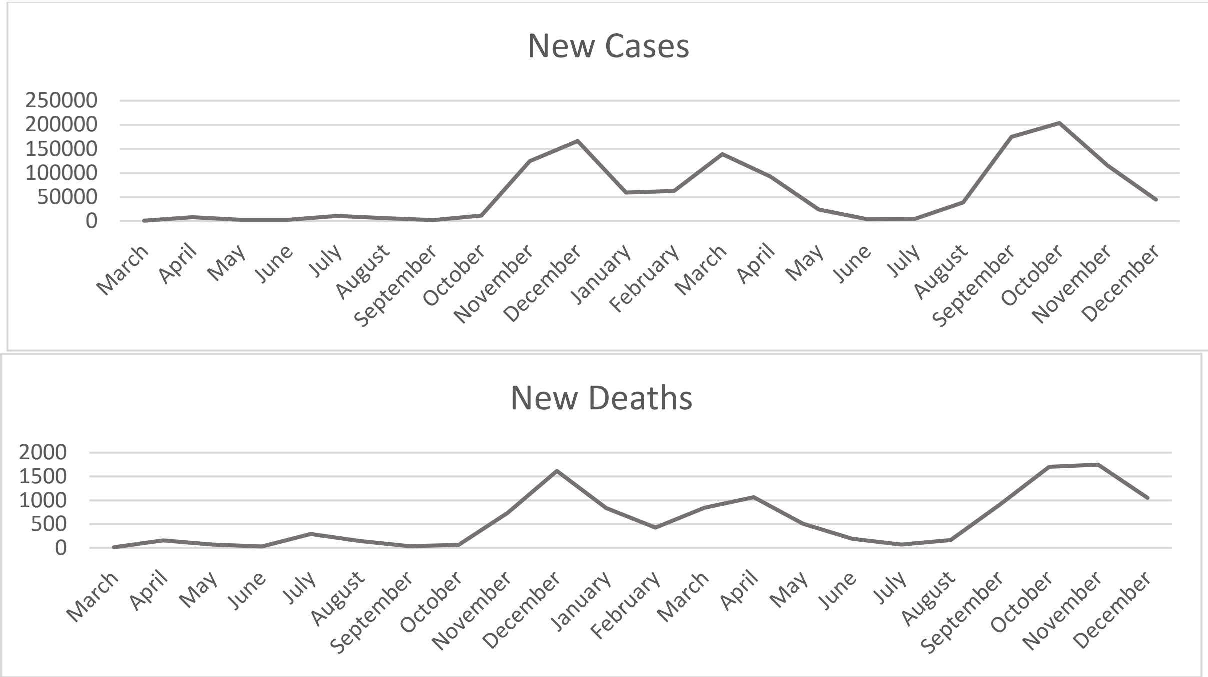


Fig. 2: New COVID-19 cases (top) and new COVID-19 deaths (bottom) by month, March 2020 through December 2021 in Serbia (World Health Organization, 2022)

The share of the population aged 65 and over in a municipality

Figure 3a shows the hotspot analysis of the share of the population aged 65 and over by municipality. The map indicates one strong cluster. A cluster of 38 municipalities is concentrated in the central, eastern, and southern parts of Serbia. In the municipalities in this region, the share of people over 65 is higher than the national average. The northern, southeastern, and southwestern cluster (a total of 41 municipalities), including the Belgrade region, is a coldspot. The maps reveal the stark regional differences in the percent of the population over 65 across the country.

The number of respiratory diseases deaths per 1,000 inhabitants of a municipality

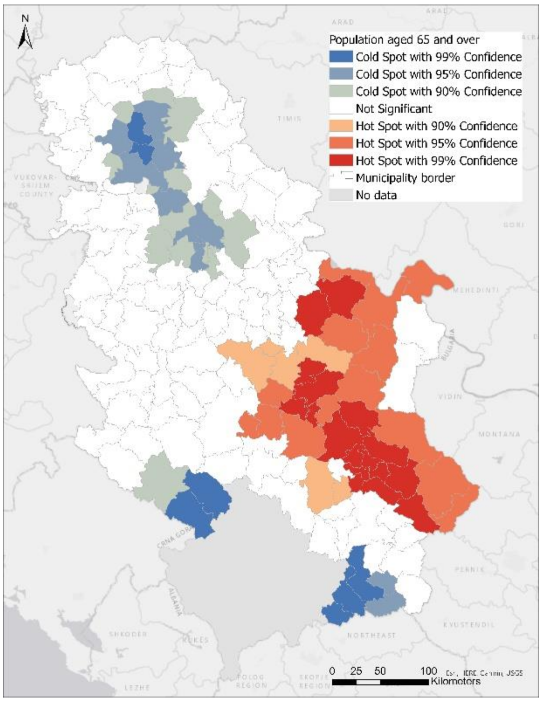
The results of the hotspot analysis for the number of deaths from respiratory diseases (Fig. 3b) indicates a different patterning to the distribution of the percent of the population over 65, with the hotspots found in the central and western parts of Serbia, and one isolated cluster of coldspots in the southeast. More specifically, hotspot analysis identifies a cluster of 19 municipalities with a higher number of deaths from respiratory diseases than average and 21 municipalities with a lower number of deaths from respiratory diseases than average.

The number of deaths from diseases of the circulatory system per 1,000 inhabitants of a municipality

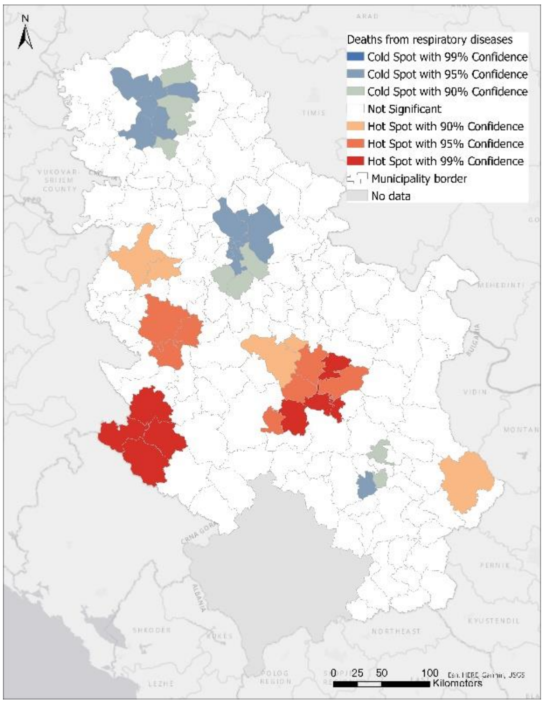
Figure 3c reveals the concentration of geographic hotspots and coldspots for the number of deaths due to diseases of the circulatory system. In total, 28municipalities for a coldspot in parts of northwestern and central Serbia, occupying a significant part of the Belgrade region. There is an isolated coldspot in the southwest (the municipalities of Tutin and Novi Pazar). The analysis also reveals one strong cluster of high values of deaths from diseases of the circulatory system in the east of the country. Also, two isolated clusters can be noticed (the municipality of Pirot in the southeast and Vrnjačka Banja)

The number of cancer deaths per 1,000 inhabitants of a municipality

The number of deaths from cancer diseases is highest and cluster in the northern and northwestern parts of Vojvodina(Fig. 3d). A few coldspot clusters are identified. The first is located in south Serbia, the second is in the southwestern part of the country. Two smaller clusters may be observed in western and eastern part of a country.



3a



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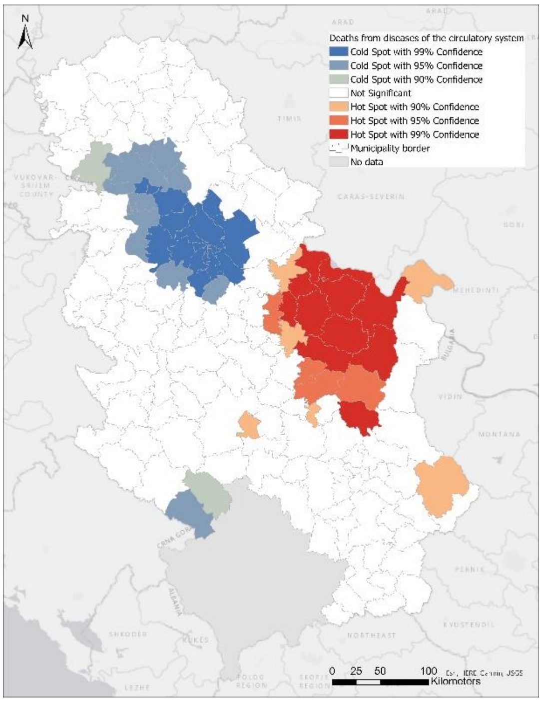
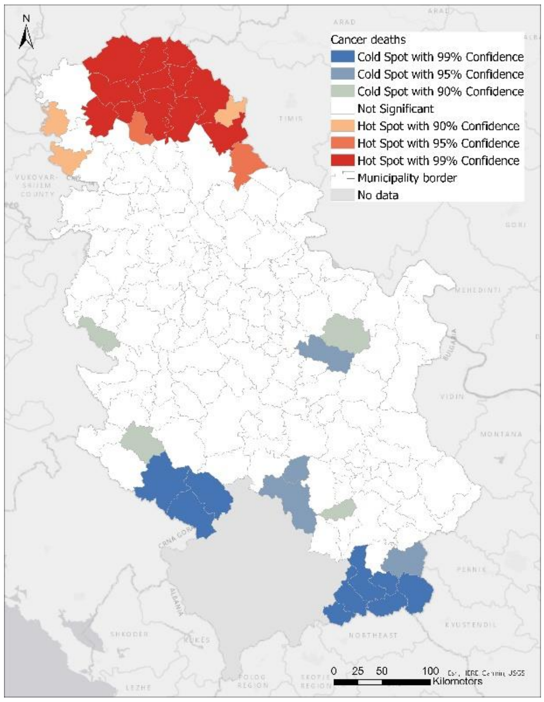


3c



3d

Fig. 3: The hotspot analysis of the studied indicators-the share of the population aged 65 and over in a municipality (3a), the number of deaths from respiratory diseases per 1,000 (3b), the number of deaths from diseases of the circulatory system per 1,000 (3c), and the number of cancer deaths (3d) per 1,000 inhabitants in Serbia, 2020

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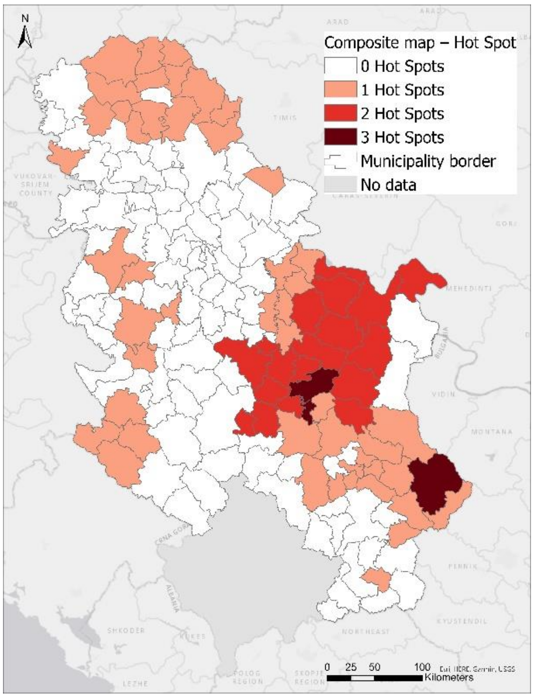
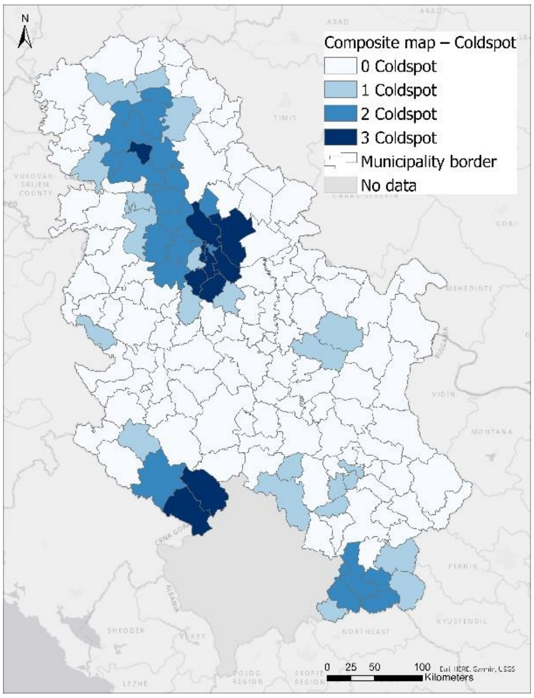
Composite maps of vulnerability to COVID-19

We can use the individual indicator coldspot and hotspot maps to examine the similarity in patterns across Serbia. That is, we can identify municipalities with the most (and least) vulnerable populations, those at risk of contracting or dying from COVID-19 (see Fig. 4). The composite map of vulnerability is derived from the count of hotspots and coldspots across the four indicators reported in each municipality.

Based on this approach, the most vulnerable parts of Serbia are municipalities in the central, eastern, and southeastern parts of the country: Ćićevac, Paraćin, and Pirot. For three of the four indicators, these areas were all health-related hotspots; the indicator that was not significant in these municipalities was cancer deaths per 1,000 inhabitants. This area belongs to the broader area of the region of Southern and Eastern Serbia (NUTS 2). According to Babović, Lović Obradović, and Prigunova (2016), this part of the country has a large elderly population and socioeconomically is one of the poorest regions of the country. Furthermore, unemployment is high, and the share of the population with high and the highest education is the lowest (Matović & Lović Obradović, 2021). Migrations were intensified after World War II, with the largest share of the population from working-age and fertile contingent and one that is characterized by decades of underdevelopment (Miletić, 2022) and known for recent high levels of depopulation (Milošević, Milivojević, & Ćalić, 2010, 2011; Panić, Drobnjaković, Stanojević, Kokotović Kanazir, & Doljak, 2022). The second cluster of municipalities can be seen in the north and northeast of Serbia, the area characterized by a depopulation process caused by long-term negative trends in natural and mechanical population movements (Lukić, 2022). A third hotspot cluster includes three smaller clusters in western Serbia. The current demographic, economic, and health status of areas identified as vulnerable to COVID-19 may deteriorate if targeted measures to protect the population from the current pandemic are not taken. Otherwise, these areas will become even more vulnerable in the future, which will further lead to their devastation.



A



B

Fig. 4: Municipalities by the total number of hotspots (a) and (b) coldspots

According to the total number of coldspots, one strong cluster is identified. Includes all municipalities of Belgrade region (most of them are marked as a coldspot according to three parameters). Indeed, the area between Belgrade and Novi Sad, to the north, is a regional coldspot. Belgrade and Novi Sad are the two largest centers of population concentration with a clear example of demographic implosions in certain micro-areas (Lović Obradović, 2019). This axis follows one part of the international Danube corridor. Belgrade and Novi Sad are connected by the international highway (E75), so the daily migrations of the population are pronounced. The concentration of the population (especially working-age and fertile contingent) is mostly a result of the continuous immigration process that began after the end of World War II. There is evidence of a second coldspot in southwestern Serbia, formed by four municipalities: Tutin, Novi Pazar (three indicators were identified as coldspots), Sjenica (two indicators), and Nova Varoš (one indicator). The main demographic characteristic of these municipalities is the higher share of the younger population, compared to the other parts of Serbia (Penjišević, 2012; Penjišević & Nikolić, 2011), which tend to experience milder COVID-19 symptoms and fewer deaths. The third and fourth clusters of coldspots are found in the southern part of Serbia.

Considering that the number of infected at the municipal level is available only for the early period from March 6 to June 9, 2020, the highest number of infected per 1,000 inhabitants of a municipality that are marked as a hotspot has Kragujevac (16.45) Aleksinac (11.79), and Jagodina (8.22) in Central Serbia, Pančevo (11.87) in the Vojvodina region, followed by municipalities of Vlasotince (11.07) and Leskovac (7.42) in southeastern Serbia. As for the distribution of the number of infected per 1,000 inhabitants in coldspot areas, the highest number is in Novi Sad (21.17) and Belgrade municipalities—Novi Beograd (15.6), Grocka (15.34), and Voždovac (14.35) (Institute of Public Health of Serbia "Dr Milan Jovanović Batut", 2020a, 2020b). It can be seen that municipalities that are vulnerable based on analysed health and demographic metrics had high values of the number of patients in relation to the number of inhabitants in the early phase of the COVID-19 pandemic. This means that at the beginning of the pandemic outbreak, it was necessary to adopt special protection measures and relocate human resources, i.e., health workers in these areas.

Municipalities with the highest degree of vulnerability to COVID-19 have from 14.4 to 32.5 doctors per 10,000 inhabitants in 2020 (Statistical Office of the Republic of Serbia, 2021). The smallest number of doctors per 10,000 inhabitants has Bač (7) and Vladimirci (9.9) in northern Serbia, followed by Rakovica in the region of Belgrade (9.4) and Krupanj in southwestern Serbia (9.4). However, the largest number is in the municipality of Savski venac (908.3) in the region of Belgrade, then in municipalities in southeastern central Serbia: Medijana (146.8), Ćuprija (79), and Kragujevac (48). These higher values are due to the specialized health care facilities found in these municipalities. Of the four mentioned, only the municipality of the Ćuprija is marked as vulnerable based on analysed parameters. A significantly higher number of doctors per thousand inhabitants of the municipality compared to other municipalities, gives this municipality leverage in the fight against COVID-19.

During the COVID-19 pandemic, patients with severe symptoms were transported from the municipalities to which they territorially belong to nearby regional health care centers that have better medical equipment and a larger number of health workers and specialists. The regional health care center for southern and eastern Serbia is district Niš, and for northern major nearby cities Sombor, Subotica, Kikinda, Zrenjanin, or Novi Sad. Patients from the western part of Serbia were transported to Kragujevac (central Serbia). Due to the lack of hospital capacity, two completely new hospitals, specialized only for COVID-19 patients, were built—one in Batajnica (Belgrade), which started operating in early December, 2020. The second COVID-19 hospital was built in Kruševac (southeastern Serbia) and received its first patients in the second half of December, 2020. This hospital is a gravitational center to the population from the southern, eastern, western, and central parts of the country. The construction of the third COVID-19 hospital in Novi Sad began in April, 2021. Thus, new specialized hospital capacities will be able to cope with a larger population of infected COVID-19.

Conclusion

From public health perspective, it is important to identify municipalities with high shares of the population that is likely vulnerable to COVID-19. Further, identifying spatial clusters of municipalities can serve as a basis for local, regional, and national strategies. The increased share of vulnerable groups within municipalities, or clusters of municipalities, also creates increased pressure on the health care systems.

After identifying clusters of vulnerable municipalities (based on the number of deaths from respiratory, circulatory, and cancer deaths and the share of the population aged 65 and over), the highest distribution of COVID-19 cases, and the lowest number of doctors per 10,000 inhabitants (as one segment of provision of health care infrastructure), two municipalities that need targeted population health care policy have been highlighted – Paraćin and Pančevo. Also, municipalities that are marked as a hotspot according to one or two parameters, require a special strategy to combat the spread of the pandemic.

This study contributes to the needs of the Crisis Response team and other decision-makers and seeks to improve preparedness to fight the pandemic in the most vulnerable areas. Determining the spatial clusters of the vulnerable population makes it possible to define measures in advance and thus protect the population that is more likely to become ill or die from COVID-19. Spatial analysis, more precisely Getis-Ord Gi* statistics, has proven to be a powerful tool in identifying spatial dependence among municipalities vulnerable to COVID-19. Namely, the Government of the Republic of Serbia, on the recommendations of the crisis headquarters, defined specific measures, but only after a period of a sharp increase in the number of the infected.

Limitations and further research

A methodological limitation of this study is the lack of data on the number of confirmed cases, hospitalizations, and deaths from COVID-19 at the municipal level. Aggregating data in the spatial extent and the shape of a municipality can hide local patterns of vulnerabilities at a lower territorial level, so the modifiable areal unit problem can be one more limitation (Openshaw, 1983). The latest available data are for June 9, 2020, and as a result, we can only access the state-level data, which are updated daily (containing the number of new cases daily, as well as the cumulative number of cases and deaths). An open data portal with relevant data on COVID-19 at the lower territorial levels updated daily would enable a more sophisticated approach to a vulnerability problem.

The method used in the paper can be applied at all administrative-territorial levels for which data are available, and future research will focus on the including of as many parameters that may indicate vulnerable groups as possible, so as gender differences and other socioeconomic dimensions of chosen indicators. The use of spatial analysis, in this case, hotspot analysis, has shown that geospatial information can help to fight COVID-19 to reduce the number of infections, hospitalizations, and death.

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Author contribution

Suzana Lović Obradović – Conceptualization, Formal Analysis, Writing - Original Draft

Stefana Matović – Data Curation, Review & Editing

Hamidreza Rabiei-Dastjerdi – Writing - Review & Editing

Stephen A. Matthews – Writing - Review & Editing, Supervision

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