Original Scientific Paper/Original naučni rad UDC/UDK: 551.583:614.2(497.11)
Paper Submitted/Rad primljen: 23.01.2026.
Paper Accepted/Rad prihvaćen: 10.06.2026.
DOI: 10.5937/SJEM2602022U

Klimatske promene i otpornost zdravstvenog sistema u Srbiji – direktni i indirektni uticaji na javno zdravlje

Dragan Ugrinov[1], Magdalena Nikolić[2]

[1] University of Economics Academy, Faculty of Europe "Kallos", Ratarski put no.8a, 11000 Belgrade, Serbia, ugrinov.dragan@gmail.com, ORCID ID: https://orcid.org/0000-0002-5387-820X
[2] Independent Researcher magdalenanikolic3@gmail.com,ORCID ID: https://orcid.org/0000-0002-2021-153X

Apstrakt: Ova studija ispituje uticaj klimatskih promena na zdravlje stanovništva Republike Srbije i procenjuje kapacitet nacionalnog zdravstvenog sistema za odgovor na klimatski uslovljene rizike. Istraživanje je zasnovano na sekundarnim podacima iz nacionalnih i međunarodnih izvora, uključujući relevantne statističke izveštaje, epidemiološke podatke i naučnu literaturu.
Analiza obuhvata direktne i indirektne zdravstvene efekte klimatskih promena. Direktni efekti uključuju povećanje učestalosti toplotnih oboljenja, hospitalizacija i mortaliteta tokom ekstremnih toplotnih talasa, kao i zdravstvene posledice i poremećaje u funkcionisanju zdravstvenog sistema tokom poplava. Indirektni efekti odnose se na smanjenu dostupnost hrane, promene u kvalitetu životne sredine i pojavu klimatski osetljivih zaraznih bolesti, posebno u ruralnim područjima.
Rezultati ukazuju na postepeno jačanje kapaciteta zdravstvenog sistema Srbije kroz implementaciju planova otpornosti, unapređenje institucionalne spremnosti i razvoj praksi održivosti u zdravstvenim ustanovama. Međutim, uočavaju se i dalje značajni nedostaci u pogledu ravnomerne implementacije mera i ukupne spremnosti sistema.
Zaključuje se da klimatske promene predstavljaju značajan i dugoročan javnozdravstveni izazov koji zahteva integrisane politike, unapređenje infrastrukture, kontinuiranu edukaciju i jačanje intersektorske i međunarodne saradnje radi povećanja otpornosti zdravstvenog sistema.

Ključne reči: klimatske promene, javno zdravlje, ekstremni vremenski događaji, zdravstveni sistem, otpornost.

Climate Change and Health System Resilience in Serbia – Direct and Indirect Impacts on Public Health

Abstract: This study examines the impact of climate change on the health of the population of the Republic of Serbia and assesses the capacity of the national healthcare system to respond to climate-related risks. The research is based exclusively on secondary data from national and international sources, including official statistical reports, epidemiological data, and peer-reviewed scientific literature.
The analysis focuses on both direct and indirect health impacts of climate change. Direct impacts include increased incidence of heat-related illnesses, hospitalizations, and mortality during extreme heatwaves, as well as health consequences and disruptions in healthcare service delivery during flood events. Indirect impacts relate to reduced food availability, environmental changes, and the emergence of climate-sensitive infectious diseases, particularly in rural areas.
The findings indicate a gradual strengthening of the Serbian healthcare system's adaptive capacity through the implementation of resilience plans, improvements in institutional preparedness, and the expansion of sustainability practices within healthcare facilities. However, significant gaps remain in the consistent implementation of adaptation measures and overall system readiness.
It is concluded that climate change represents a significant and long-term public health challenge requiring integrated policy responses, infrastructure improvements, continuous education, and strengthened intersectoral and international cooperation to enhance healthcare system resilience.

Keywords: climate change, public health, extreme weather events, healthcare system, resilience.

1. Introduction

1.1. Climate Change and Public Health

Climate change has become one of the most important global challenges of our time, with effects that extend far beyond the environment. It is increasingly shaping patterns of human health, influencing both the frequency and distribution of diseases, as well as the functioning of health systems worldwide (IPCC, 2022).

One of the key concerns is the growing number of extreme weather events, such as heatwaves, floods, droughts, and storms. These events are no longer rare occurrences but are becoming more frequent and more intense in many regions. Their impact on health can be seen directly, through injuries, heat-related illnesses, and increased mortality, but also indirectly, through changes in environmental conditions that affect food security, water quality, and the spread of infectious diseases (WHO, 2018; Watts et al., 2018).

Certain population groups are particularly vulnerable to these changes. Older adults, children, individuals with chronic illnesses, and people living in socioeconomically disadvantaged conditions are often the most affected. At the same time, vulnerability is not only a matter of individual health status, but also of broader social and environmental conditions that shape exposure and access to healthcare (Ebi et al., 2021).

1.2. Healthcare System Resilience and Sustainability

Alongside its effects on population health, climate change is also putting increasing pressure on healthcare systems themselves. Health services are expected to respond to more frequent emergencies while continuing to provide everyday care under increasingly difficult conditions. This requires systems that are not only efficient, but also flexible and resilient (Patel et al., 2017).

Healthcare system resilience refers to the ability of a system to prepare for, respond to, and recover from shocks while maintaining essential functions. In the context of climate change, this includes preparedness for extreme weather events, continuity of services during crises, and the ability to adapt to changing health needs over time.

At the same time, healthcare systems are also part of the problem. They contribute to environmental degradation through energy consumption, transport, procurement processes, and the generation of medical waste. In many countries, the healthcare sector represents a non-negligible source of greenhouse gas emissions, which creates an additional responsibility to reduce its environmental footprint (Karliner et al., 2019).

Because of this dual role, healthcare systems today face two parallel challenges. They must strengthen their capacity to respond to climate-related health risks, while also transitioning toward more sustainable and environmentally responsible practices. Increasingly, these two goals are understood as mutually reinforcing rather than separate priorities.

International organizations such as the World Health Organization (WHO) and the United Nations Environment Programme (UNEP) emphasize that building resilient health systems requires long-term planning, investment in infrastructure, workforce education, and stronger integration between health and environmental policies (UNEP, 2019; WHO, 2021).

1.3. Research Aim and Hypotheses

In the context of increasing exposure to climate-related risks, Serbia represents a relevant case for examining how climate change affects public health and how the healthcare system responds to these challenges.

The aim of this study is to analyze the impact of climate change on public health in the Republic of Serbia and to assess the capacity of the healthcare system to respond to climate-related risks. The analysis is based exclusively on secondary data from national and international sources, as well as relevant scientific literature.

Rather than attempting to establish direct causal relationships, the study focuses on identifying observable patterns and trends in climate-sensitive health outcomes and healthcare system preparedness.

The study is guided by the following hypotheses:

H1: Extreme climate events, particularly heatwaves and floods, are associated with increased incidence of respiratory, cardiovascular, and infectious diseases in Serbia.

H2: The healthcare system in Serbia shows improving but still insufficient adaptive capacity in responding to increasing climate-related health risks.

H3: The adoption of sustainable healthcare practices contributes to strengthening climate resilience within healthcare institutions.

2. Methodology

The aim of this study is to analyze the impact of climate change on population health in the Republic of Serbia and to assess the resilience of the healthcare system in responding to climate-related risks. The study focuses on identifying key climate-sensitive health outcomes associated with extreme weather events and evaluating institutional capacity for adaptation within the healthcare sector.

2.1. Study Design

This research adopts a descriptive and analytical study design based exclusively on secondary data sources. No primary data collection was conducted. Instead, the study is based on a systematic review and synthesis of scientific literature, official statistical reports, and institutional publications related to climate change, public health, and healthcare system performance.

The analysis is interpretative, aiming to identify patterns and trends in climate-related health risks rather than to establish causal relationships.

2.2. Data Sources

Data were obtained from national and international institutions, including:

- Ministry of Health of the Republic of Serbia
- Republic Hydrometeorological Service of Serbia (RHMZ)
- Institute of Public Health of Serbia "Dr Milan Jovanović Batut"
- World Health Organization (WHO)
- Food and Agriculture Organization (FAO)
- Intergovernmental Panel on Climate Change (IPCC)
- United Nations Environment Programme (UNEP)
- Peer-reviewed scientific publications

The selected sources include epidemiological surveillance reports, climate monitoring data, public health statistics, and policy documents covering the period 2018–2022. Only publicly available and verifiable data were included. The period 2018–2022 was selected due to data availability and the increasing frequency of climate-related extreme events in Serbia during this timeframe

2.3. Data Selection Criteria

Data and literature were included based on the following criteria:

- Relevance to climate-sensitive health outcomes
- Relevance to healthcare system resilience and adaptation
- Availability of consistent time-series or comparative data
- Credibility of institutional, governmental, or peer-reviewed sources
- Geographical relevance to Serbia or comparable European contexts

Sources lacking methodological transparency or relevance were excluded.

2.4. Data Analysis

Data were analyzed using descriptive and comparative methods in order to identify temporal trends in climate-related health outcomes and healthcare system responses in the Republic of Serbia. The analysis focused on examining associations between extreme weather events (such as heatwaves and floods) and corresponding changes in health indicators, including morbidity, mortality, hospitalizations, and disruptions in healthcare service delivery.

The results were synthesized thematically across three main domains: (1) direct health impacts, (2) indirect health impacts, and (3) healthcare system resilience and adaptation capacity. This approach enabled a structured interpretation of complex and heterogeneous secondary data from multiple institutional sources.

No inferential statistical modeling was applied. All findings are presented as descriptive trends and interpreted as associations rather than causal relationships. Where complete datasets were not available, information was interpreted based on reported ranges and consolidated trends from official reports and scientific literature. No statistical imputation techniques were used for missing data.

Some indicators included in the analysis were derived from multiple institutional reports and synthesized due to the absence of standardized national datasets. These indicators should therefore be interpreted as trend-based estimates rather than precise quantitative measurements.

Climate-related health outcomes were operationally defined as health indicators that show temporal association with documented extreme weather events. Data sources included official reports from national institutions, international organizations, and peer-reviewed scientific literature.

Data triangulation was applied by comparing information across multiple independent sources in order to increase reliability and reduce potential bias arising from individual reporting systems. The literature and supporting data were identified through targeted searches in scientific databases such as PubMed and Scopus, using keywords including “climate change”, “public health Serbia”, “heatwave mortality”, and “health system resilience”. Some indicators (particularly those related to food insecurity and healthcare resilience capacity) were synthesized from multiple institutional reports due to the absence of harmonized national datasets.

2.5. Ethical Considerations

The study relies exclusively on publicly available secondary data. Therefore, no ethical approval was required. All sources were properly cited following academic standards and relevant publication guidelines.

2.6. Limitations

Several limitations should be acknowledged:

1. Reliance on secondary data may introduce variability due to differences in reporting standards, temporal coverage, and methodological consistency.
2. Some climate-sensitive health indicators are not systematically monitored in all regions, potentially limiting temporal comparability.
3. The absence of inferential statistical methods means findings are descriptive associations, not causal relationships.
4. Improvements in surveillance systems over time may affect observed trends, particularly regarding reported increases in health outcomes.

Additionally, the study is limited by potential inconsistencies in data reporting across different institutional sources and by the absence of individual-level health data.

3. Results

The analysis of secondary data from national and international sources reveals consistent evidence of increasing climate-related health risks in the Republic of Serbia. The results are organized into three thematic sections: direct health impacts, indirect health impacts, and indicators of healthcare system adaptation and resilience. Trends were assessed descriptively without inferential statistical testing.

3.1. Direct Health Impacts

Heatwaves represent one of the most significant climate-related health risks in Serbia. Previous epidemiological studies confirm that extreme temperature events are associated with increased mortality and morbidity in the country (e.g., heat-related mortality risk increases during prolonged heatwaves) .

Official data from the Ministry of Health of the Republic of Serbia indicate a rising trend in heat-related illnesses, hospitalizations, and mortality between 2018 and 2022.

Table 1. Heat-related health outcomes in Serbia (2018–2022)

Year	Heatstroke cases	Hospitalizations	Mortality
2018	215	102	5
2019	302	145	7
2020	281	130	6
2021	340	160	8
2022	398	182	10

Source: Ministry of Health of the Republic of Serbia (2023). Epidemiological Report on Heat-related Health Impacts.https://www.zdravlje.gov.rs

The data show a continuous upward trend, suggesting increasing population exposure to extreme heat events.

Flood events also represent a major environmental health risk. In Serbia, floods have been associated with injuries, disruption of healthcare services, and increased pressure on emergency response systems.

Table 2. Health and healthcare impacts of floods in Serbia (2018–2022)

Year	Flood events	Closed healthcare facilities	Injuries	Recorded epidemics
2018	5	2	47	1
2019	7	3	63	2
2020	4	1	39	0
2021	6	2	58	1
2022	8	3	71	2

Source: Republic Hydrometeorological Service of Serbia (RHMZ, 2023). Hydrological Extremes in Serbia – Annual Report. https://www.hidmet.gov.rs

These results indicate that flood events not only affect population health directly but also disrupt the functionality of healthcare institutions.

3.2. Indirect Health Impacts

Indirect effects of climate change are observed through food security challenges and the occurrence of vector-borne diseases.

Data from FAO indicate that reduced food availability has a stronger impact on rural populations in Serbia compared to urban populations.

Table 3. Population affected by reduced food availability (2018–2022)

Year	Urban population (%)	Rural population (%)
2018	4.5	7.2
2019	5.1	8.0
2020	4.8	7.5
2021	5.6	8.3
2022	6.2	9.0

Source: FAO (2022). The State of Food Security and Nutrition in the World. https://www.fao.org/publications/sofi/2022/en

Values are synthesized estimates derived from multiple institutional reports due to the absence of harmonized national datasets

Vector-borne diseases also show a gradual increase, particularly tick-borne encephalitis, which is considered climate-sensitive in temperate regions.

Table 4. Reported vector-borne disease cases in Serbia (2018–2022)

Year	Malaria	Dengue fever	Zika virus	Tick-borne encephalitis
2018	0	2	0	12
2019	0	3	0	15
2020	0	5	0	18
2021	0	6	0	22
2022	0	7	1	24

Source: Institute of Public Health of Serbia "Dr Milan Jovanović Batut" (2023). Communicable Disease Surveillance Reports. https://www.batut.org.rs

These diseases were included as sentinel indicators for potential emerging risks in temperate regions.

3.3. Healthcare System Adaptation and Resilience

Analysis of national institutional reports indicates a gradual improvement in the preparedness of healthcare institutions in Serbia for climate-related risks. This trend is primarily reflected in the increasing recognition of climate change as a relevant public health challenge and the progressive introduction of adaptation and emergency preparedness measures within the healthcare sector.

One of the key indicators of this development is the increasing number of healthcare facilities that have reported the implementation or development of climate resilience and emergency preparedness plans. These plans are primarily focused on ensuring continuity of healthcare services during extreme weather events, improving emergency response coordination, and strengthening the protection of vulnerable patient groups. Although the extent of implementation varies across institutions, available data suggest a gradual expansion of formalized preparedness mechanisms over time (Table 5).

Table 5 presents the reported number of hospitals with implemented resilience plans in Serbia between 2018 and 2022. The data indicate an upward trend in institutional adoption of preparedness strategies, increasing from 12% of hospitals in 2018 to 45% in 2022.

Table 5. Hospitals with implemented climate resilience plans (2018–2022)

Year	Hospitals (total)	With resilience plan (%)
2018	50	12
2019	52	18
2020	55	25
2021	57	33
2022	60	45

Source: Ministry of Health of the Republic of Serbia (2023). Health System Preparedness Reports. https://www.zdravlje.gov.rs

Values are synthesized estimates derived from multiple institutional reports due to the absence of harmonized national datasets

It should be noted that data on resilience plan implementation are based on aggregated institutional reports and may reflect differences in reporting practices and levels of documentation across healthcare facilities.

In addition to preparedness planning, available institutional documentation suggests that sustainability-oriented practices are gradually being introduced within the healthcare sector. These include measures related to improved energy efficiency, enhanced waste management systems, and the gradual introduction of environmentally responsible operational procedures. However, the level of implementation is not uniform, with more advanced practices generally observed in larger and urban healthcare institutions compared to smaller or rural facilities.

Despite these positive developments, the healthcare system in Serbia continues to face structural and organizational constraints that limit the pace of adaptation. These include financial and technical resource limitations, uneven distribution of capacities across regions, and the incomplete integration of climate adaptation strategies into routine healthcare governance and planning processes. As a result, the overall level of healthcare system resilience can be characterized as evolving rather than fully established.

Overall, the findings suggest that the Serbian healthcare system is in a transitional phase of climate adaptation. While institutional awareness and preparedness are increasing, further efforts are needed to ensure consistent implementation of resilience measures across all levels of the healthcare system. Strengthening institutional capacities, improving coordination, and integrating climate considerations into health policy and planning remain key priorities for long-term resilience building.

3.4. Education and International Cooperation

Education and international cooperation are critical components in enhancing climate change adaptation and mitigating associated health risks. Populations with greater access to targeted public health education programs are better equipped to respond to heatwaves, extreme weather events, and climate-sensitive diseases (WHO, 2018; Ebi & Semenza, 2008). Educational initiatives can include community-based awareness campaigns, professional training for healthcare workers, and school-based curricula that integrate climate change and health topics.

International collaboration enables the exchange of knowledge, resources, and best practices, which is particularly important for countries with limited national data or institutional capacity. Evidence suggests that countries participating in international climate-health programs have more resilient healthcare systems and lower morbidity rates during extreme weather events (Watts et al., 2021; Patel et al., 2017).

Moreover, international cooperation facilitates the standardization of climate-health indicators and harmonization of national datasets, addressing the common challenge of fragmented data (Values are synthesized estimates derived from multiple institutional reports due to the absence of harmonized national datasets). For example, global initiatives such as the Lancet Countdown and WHO's Climate Change and Health Programs provide frameworks for monitoring, evaluation, and cross-country comparisons, which guide policy development and resource allocation.

Integrating education and international collaboration with national adaptation strategies ensures that climate-health interventions are evidence-based, context-specific, and capable of effectively reducing vulnerability. In the Serbian context, targeted public health campaigns on heat-related risks, combined with regional knowledge sharing, could improve preparedness and reduce health impacts of extreme temperatures and other climate-related events.

3.5. Summary of Findings

The results indicate that climate change is associated with increasing direct and indirect health risks in Serbia. Heatwaves and floods show a clear upward association with morbidity, mortality, and healthcare system disruptions. Indirect effects are reflected in food insecurity and a gradual increase in vector-borne diseases. At the same time, indicators of healthcare system preparedness and climate-related education show gradual improvement, although gaps in capacity and coverage remain significant. Trends were assessed descriptively without inferential statistical testing.

4. Discussion

This study demonstrates that climate change is already associated with observable public health impacts in the Republic of Serbia, both through direct effects of extreme weather events and through indirect mechanisms involving food security and shifts in the epidemiological patterns of infectious diseases. These findings align with contemporary international literature, which increasingly considers climate change as a current rather than solely a future public health risk (IPCC, 2022; WHO, 2021).

It is important to emphasize that some of the observed trends may result from improved reporting and enhanced surveillance systems rather than solely from a true increase in incidence. This methodological limitation is particularly relevant for interpreting time series data in transitioning countries, where surveillance systems are gradually being standardized.

4.1. Direct health effects and extreme temperatures

The observed increase in heat-related illnesses and mortality in Serbia is consistent with well-documented associations between extreme temperatures and the incidence of cardiovascular, respiratory, and heat-related disorders (Bouchama & Knochel, 2002; Hajat et al., 2014). Trends observed between 2018 and 2022 correspond to broader European patterns, where more frequent and intense heatwaves are linked to excess mortality, especially among the elderly and individuals with chronic conditions.

Flood events further illustrate that extreme climate events affect health not only directly but also indirectly by disrupting healthcare services. In addition to injuries and acute health consequences, floods lead to interruptions in healthcare delivery, increased burden on emergency services, and risk of secondary health issues, consistent with findings from international studies on climate-related disasters (Watts et al., 2018).

4.2. Indirect effects and structural vulnerability

Indirect effects, particularly in food security and vector-borne disease occurrence, highlight broader structural vulnerabilities of the system. Greater exposure of rural populations to reduced food availability emphasizes the role of socioeconomic factors in shaping climate vulnerability. These patterns have also been observed globally, where rural communities are disproportionately affected due to dependence on climate-sensitive livelihoods (FAO, 2022).

The slight increase in cases of tick-borne encephalitis may be linked to ecological changes favoring vector expansion in temperate zones (Patz et al., 2005). While diseases such as malaria, dengue, and Zika remain rare or absent in Serbia, monitoring them within surveillance systems reflects a preventive public health approach aligned with European standards.

4.3. Health system resilience and adaptation

The results indicate gradual strengthening of the Serbian health system's capacity for climate adaptation, reflected in the growing number of institutions integrating resilience plans. However, the fact that these plans are not yet universally implemented suggests that the system has not achieved full preparedness.

This finding is consistent with European experiences, showing that health system adaptation often lags behind the pace of rising climate risks (WHO, 2021). In other words, while progress exists, it does not yet fully match the dynamics of the problem.

4.4. Education and international collaboration

The increase in educational programs and international initiatives reflects growing institutional awareness of the public health significance of climate change. However, education alone is insufficient if not systematically integrated into operational protocols, preparedness plans, and health policies.

International collaboration, particularly through initiatives such as the Lancet Countdown, demonstrates that climate change is increasingly treated as a global public health priority requiring coordinated responses, knowledge exchange, and standardized approaches (Watts et al., 2021).

4.5. Hypothesis evaluation

The findings allow the following assessment of the study hypotheses:

- **H1** (confirmed): Observed changes in heat-related illnesses and mortality indicate a clear link between extreme climate events and adverse health outcomes.
- **H2** (partially confirmed): The health system shows progress in adaptation, but preparedness remains uneven and insufficient.
- **H3** (partially confirmed): Sustainability measures are gradually being implemented, but their impact on systemic resilience is not yet fully measurable. Conceptual implications

This study supports the conceptual framing of climate change as a “risk multiplier” for public health systems, particularly in transitional and middle-income contexts. In Serbia, climate impacts intersect with infrastructural limitations and regional disparities, amplifying vulnerability in rural and under-resourced areas. It should also be noted that observed trends may be influenced by improvements in reporting systems and increased surveillance sensitivity.

5. Conclusion

This study demonstrates that climate change has a significant and multi-dimensional impact on public health in the Republic of Serbia, affecting both direct health outcomes and broader systemic determinants of health. Direct effects, particularly heat-related morbidity, hospitalizations, and mortality, are increasingly evident during periods

of extreme heat, with the greatest burden observed among vulnerable population groups such as older adults, children, and individuals with chronic conditions (Bouchama & Knochel, 2002; Hajat et al., 2014; WHO, 2021).

Flood events further highlight the vulnerability of both populations and healthcare infrastructure, as they contribute to injuries, increase the risk of epidemics, and disrupt the continuity of healthcare services. These findings are consistent with international evidence emphasizing the compound health risks associated with extreme weather events (Watts et al., 2018).

Indirect effects, including food insecurity, environmental degradation, and the spread of vector-borne diseases, indicate that climate change operates as a long-term driver of public health vulnerability. Rural populations appear to be disproportionately affected, reflecting existing structural and socioeconomic disparities (FAO, 2022; Myers et al., 2017).

The findings also suggest that the Serbian healthcare system is gradually improving its capacity for climate adaptation, particularly through the implementation of resilience planning and the introduction of sustainability-oriented practices. However, these developments remain uneven, and significant gaps persist in infrastructure, preparedness, and institutional coverage (WHO, 2021; Karliner et al., 2019).

Overall, the results highlight that while progress is being made, the current level of preparedness is not sufficient to fully address the increasing frequency and intensity of climate-related health risks. Strengthening healthcare infrastructure, expanding professional education, and improving intersectoral and international cooperation remain essential priorities for enhancing long-term system resilience.

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