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Singidunum University International Scientific Conference
Međunarodna naučna konferencija Univerziteta Singidunum

INVITED PAPERS
Green economy
Original paper

SERBIA'S ADAPTATION TO CLIMATE CHANGE: A HYDROLOGICAL HAZARD PERSPECTIVE

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Abstract:

This paper examines Serbia's vulnerability to floods and droughts in the context of climate change, as well as its capacity to adapt to these hydrological hazards. Floods and droughts are among the most damaging climate-induced phenomena in Serbia, with severe consequences for agriculture, infrastructure, and society. The paper presents the results of a survey conducted among citizens and farmers (N = 204), which indicates high risk awareness but also dissatisfaction with institutional effectiveness. Through a review of the literature and a comparative analysis of regional experiences (e.g., Croatia, Hungary, etc.), key challenges are identified—ranging from insufficient investment and weak coordination to limited local resilience. The discussion highlights recommendations for strengthening adaptation, including the improvement of infrastructure and early warning systems, integrated risk management, public education, and the adoption of best practices from the region.

Keywords:

climate change, floods, droughts, adaptation, hydrological risks.

1. INTRODUCTION

Climate change has intensified extreme weather events worldwide, and Serbia is no exception. In recent decades, the country has been increasingly affected by destructive floods and persistent droughts that have severely impacted its economy, ecosystems, and public safety. The May 2014 floods, particularly in Obrenovac, caused extensive material damage, while the 2012 drought led to a sharp decline in agricultural yields and widespread water shortages. Floods primarily occur along the Danube, Sava, Tisa, and Morava river basins, while droughts are most common in Vojvodina and central Šumadija, where irregular rainfall and rising summer temperatures prevail. Both hazards have severe effects: floods damage infrastructure and degrade soil through erosion and pollution, while droughts deplete water resources, reduce productivity, and threaten biodiversity. Research shows a steady increase in drought frequency and episodes of heavy rainfall since the late twentieth century (Tošić & Unkašević, 2014; Gocić & Trajković, 2014), underscoring the need to strengthen resilience to hydrological hazards.

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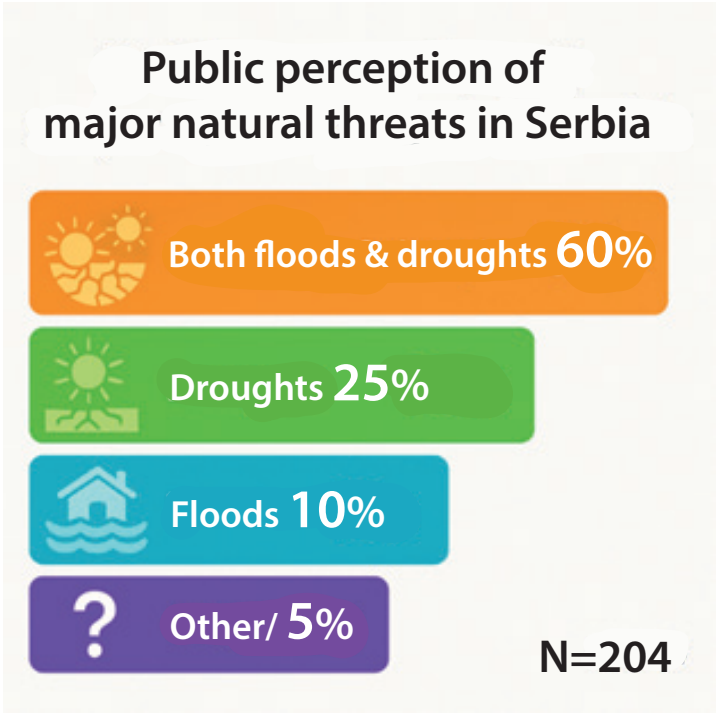
DOI: 10.15308/finiz-2025-10-16

Serbia has adopted several strategic and legal instruments—most notably the Water Management Strategy 2034 and the Law on Disaster Risk Reduction—but their implementation remains limited. Many local governments lack sufficient technical and financial capacity, and risk assessments are rarely integrated into spatial planning (Lukić *et al.*, 2018; Nikolić Popadić, 2021; Milutinović, 2023). Consequently, unregulated construction in floodplains persists, increasing exposure to hazards. Experiences from neighboring countries provide useful lessons: Hungary and Croatia have established integrated flood and drought protection systems—including levees, reservoirs, and evacuation mechanisms—that proved effective during the 2013–2014 extremes (Puđak, 2019). Conversely, much of the Western Balkans continues to struggle to translate lessons from past disasters into long-term adaptation policies (Puđak, 2019). Against this backdrop, the present study analyzes Serbia's current framework alongside regional practices to propose measures for strengthening resilience to floods and droughts under changing climate conditions. It combines climate and hydrological data, survey evidence, and regional policy comparison to identify priority measures for strengthening Serbia's adaptation to floods and droughts. Notably, respondents engaged in agriculture were even more likely to view both floods and droughts as equally serious threats (71.4% of farmers vs. 54.5% of non-farmers). Conversely, non-farmers more often identified floods as the greater danger (13.4% vs. 2.9% among farmers). A chi-square test indicates that this difference in threat perception is statistically significant, $\chi^2(2) = 7.51$, $p = 0.023$.

Figure 1. Public perception of major natural threats in Serbia in the coming years (floods vs. droughts). The majority of respondents (around 60%) consider both to be equally significant threats; about one quarter view droughts as the greater danger, while around 10% point to floods.



Source: Authors' survey (2025).

2. LITERATURE REVIEW

Floods and droughts are major hydrological hazards that, although less frequent, can cause severe social, economic, and environmental losses. Floods occur abruptly, while droughts develop gradually, requiring different risk management strategies. Climate change has intensified both phenomena: Serbia's temperate-continental climate is becoming increasingly unstable, with hotter, drier summers and heavier rainfall in spring and autumn. Studies confirm longer drought periods, more days of intense precipitation, and more frequent flash floods (Tošić & Unkašević, 2014; Gocić & Trajković, 2014; Plavšić *et al.*, 2014; Tošić *et al.*, 2025). In addition to climatic factors, human-induced changes—deforestation, land degradation, and rapid urbanization—reduce natural water retention and increase exposure to flooding. Poorly maintained irrigation and drainage systems, along with limited emergency preparedness further increase vulnerability: around half of Serbian municipalities still lack formal flood protection plans or trained personnel (Lukić *et al.*, 2018).

Regional experiences provide valuable guidance. With EU support, Croatia has developed detailed flood-risk maps and modernized key infrastructure, while Hungary has reinforced its levee system and introduced cross-border monitoring and early drought-warning models (Petrić & Jovanović, 2019). These measures have reduced agricultural losses through improved reservoir and irrigation management. Similarly, Bosnia and Croatia have enhanced public awareness and preparedness through local training and evacuation drills. Comparative evidence shows that countries with stronger institutions and sustained financing are more effective at mitigating hydrological disasters (Trgovčević *et al.,* 2020). According to the IPCC (2022) Sixth Assessment Report, Southeast Europe is projected to face more frequent extremes of both rainfall and drought, highlighting the need for integrated adaptation planning. In line with this, Serbia has adopted its Climate Change Adaptation Program 2023–2030 and Action Plan 2024–2026, prioritizing resilience in the water, agriculture, and infrastructure sectors. Analyses indicate that Serbia's mean temperature has increased by 1.8 °C since 1960, and that climate-related losses exceeded €6.8 billion between 2000 and 2020—over 70% due to droughts and heatwaves—underscoring the urgency of strengthening adaptation to hydrological hazards.

3. METHODOLOGY

To achieve the research objectives, a multidisciplinary approach was applied. First, meteorological and hydrological data from the Republic Hydrometeorological Service of Serbia (RHMZ) for the period 2000–2022 were analyzed to identify trends and extreme events. Based on these data and reports (e.g., RHMZ climate bulletins for 2000 and 2012, as well as government and international reports on the 2014 floods), a chronology of major floods and droughts from 2000 to 2024 was compiled (presented in Table 1), providing a contextual framework for the analysis of risks over time.

Table 1. Overview of Major Floods and Droughts in Serbia (2000–2024)

Year	Type of Hazard	Most Affected Areas	Consequences
2000	Drought	Vojvodina, Braničevo	Reduced crop yields; shortage of drinking water
2006	Flood	Eastern Serbia (Nišava, Juhor)	Damage to roads, houses, and infrastructure
2012	Drought	Central Serbia	Drastic drop in river levels; major crop losses
2014	Flood	Western Serbia (Obrenovac, Kolubara)	Catastrophic damage; >30 fatalities; mass evacuations
2022	Drought	Vojvodina, Šumadija	Agricultural losses; irrigation water restrictions
2023	Flood	Southern Serbia (Pčinja)	Local flash floods; damage in rural communities
2024	Drought	Braničevo District	Reduced yields; depletion of local water sources

Source: Republic Hydrometeorological Service of Serbia (reports for 2000, 2012, 2022); OSCE (2015); Plavšić *et al.* (2014).

A survey was conducted among Serbian citizens during June and July 2025 to assess experiences, perceptions, and preparedness related to floods and droughts. The online questionnaire, distributed via Google Forms, was completed voluntarily by 204 respondents, including both the general population and farmers. Approximately 34% of participants were engaged in agriculture (9% professionally, 25% occasionally), ensuring the representation of rural perspectives. Most respondents were aged 18–30 (about 65%) and had at least a secondary education. The survey contained 24 mainly closed-ended questions covering four thematic areas: (1) personal experience with floods and droughts; (2) risk perception in the local environment; (3) evaluation of institutional performance (early warning, investment, emergency response); and (4) individual preparedness (protective actions, emergency plans, and willingness to invest or relocate).

Data were analyzed using descriptive statistics and comparative tests between subgroups (farmers vs. non-farmers). Chi-square tests examined categorical associations, independent-samples t-tests compared mean Likert scores, and Spearman's rank correlation assessed the relationship between climate-change concern and willingness to invest. Statistical significance was set at $p < 0.05$. Although the purposive online sampling method led to a predominance of younger, internet-active participants and possible underrepresentation of older or rural populations, the findings still provide valuable insights into prevailing attitudes and behavioral trends concerning climate risks in Serbia. Future research should employ stratified random sampling to ensure greater representativeness across demographic segments and to enhance the comparability of results.

In addition, a qualitative comparative analysis examined institutional capacities and policy frameworks for managing floods and droughts in Serbia and neighboring countries (Croatia, Bosnia and Herzegovina, Bulgaria, and Hungary). Key indicators included investments in flood defenses (levees, reservoirs), adaptation plans, effectiveness of early-warning systems, and recent initiatives such as EU-funded projects and cross-border cooperation in shared river basins. Special attention was given to the catastrophic 2014 floods and the regional drought of 2017–2018 to extract lessons applicable to Serbia's adaptation and risk management strategies.

4. RESULTS AND DISCUSSION

4.1. HISTORICAL RISK TRENDS

The analysis shows that floods and droughts have become recurring phenomena in Serbia over the past two decades (see Table 1). Almost every year brings at least one significant event—a regional flood or a severe drought. After the extreme drought of 2000, several major floods followed in the mid-2000s, culminating in the catastrophic 2014 event, while dry years (2015, 2017, 2022) preceded another flood wave in 2023. Although no consistent upward trend is observed, climate variability is intensifying: extremely wet and dry years alternate more frequently, in line with climate projections (Ministry of Environmental Protection, 2017). The magnitude of these events has reached new records—2014 saw the highest Sava River level in a century, while 2022 ranked among the driest years on record, exposing weaknesses in flood defenses and water-supply infrastructure.

Spatial patterns of risk remain well defined: northern plains and major river valleys are most prone to flooding, while central, southern, and eastern Serbia are increasingly affected by droughts. Due to its flat terrain, Vojvodina experiences both phenomena—river floods (Tamiš 2005, Danube 2006) and recurrent droughts every few years. Western and southern mountain regions are prone to flash floods, whereas Šumadija and Pomoravlje alternate between prolonged dry and wet periods (Gocić & Trajković, 2014). Climate models predict further intensification of these contrasts: rising summer temperatures in the north will heighten drought risk, while increased precipitation in the west is expected to cause more frequent flood events (Ministry of Environmental Protection, 2017).

4.2. SURVEY RESULTS: EXPERIENCES AND RISK PERCEPTION

The survey provided valuable insights into citizens' experiences with floods and droughts, as well as their perception of related risks. About one-third of respondents had experienced flooding, while a similar share (37%) reported drought impacts; around 60% had not suffered direct damage. More than half (58%) stated that floods or droughts had occurred in their area at least three times in the past decade, indicating that these events are perceived as frequent and recurring.

The most commonly reported impacts included material losses, crop failures, and interruptions in water or electricity supply. Half of the farmers stated that drought had completely destroyed their crops at least once, while urban residents most often mentioned multi-day disruptions in utilities. These experiences are consistent with official data: during the 2022 drought, many municipalities imposed water restrictions, and the 2014 floods left tens of thousands without power and drinking water for days (Knez *et al*., 2022). Drought exposure differed sharply by occupation—72.9% of farmers reported direct drought impacts, compared with 18.7% of non-farmers—a highly significant difference ($\chi^2(1) = 55.49$, $p < 0.001$).

Risk awareness is very high. Nearly all respondents expect more frequent floods and droughts due to climate change—66% foresee a significant increase, 28% a moderate one, and almost none expect fewer events. The majority (≈60%) perceive both hazards as equally serious, 25% fear droughts more, and only 10% identify floods as the main threat. This indicates that recent recurrent droughts have had a stronger influence on public perception than rarer but severe floods. Overall, the public views both hazards as major risks, confirming the need for adaptation strategies that address them jointly.

Although the analysis relied primarily on descriptive statistics due to the exploratory design and limited sample size, basic inferential tests (e.g., chi-square, t-tests) were applied to compare key subgroups such as farmers versus non-farmers. Future research with larger, stratified samples could improve representativeness and enable more robust comparisons of risk perception and preparedness behaviors across demographic categories.

General concern about climate change is also high—around three-quarters of respondents are moderately or very worried. However, this awareness does not consistently translate into proactive individual behavior, as subsequent findings demonstrate.

4.3. ASSESSMENT OF INSTITUTIONAL RESPONSE AND PERSONAL PREPAREDNESS

Citizens largely expressed critical views on the performance of institutions responsible for flood and drought protection, including early warning, prevention, and emergency response.

The early-warning system received the lowest ratings, averaging 2.48 ± 1.07 on a 1–5 scale. More than half of respondents (51%) rated it as poor (1–2), 34% as average, and only 15% as good or excellent. Many noted that alarm systems in rural areas are missing or that warnings arrive late and lack precision, reflecting low public confidence. Strengthening early-warning capacity is also identified in the literature as a key priority for reducing disaster losses (IPCC, 2021).

Respondents widely believe that the state invests inadequately in prevention. Half reported insufficient funding, another 16% said none at all, 21% found investments partly adequate, and only 6% found them sufficient. The perception of chronic underfunding is reinforced by cases such as neglected levees during the 2014 floods and deteriorated water-supply systems exposed during droughts. Even officials have acknowledged long-term neglect of flood defenses (Nikolić Popadić, 2021), reinforcing the sense that authorities act reactively rather than preventively.

Public dissatisfaction extends to emergency response, rated 2.61 ± 1.05 on average. About 45% assessed service response as poor or very poor, 29% as average, and 18% as good or excellent. Commonly cited problems included slow evacuations, poor coordination, and shifting responsibilities among institutions. Although some praised firefighters, the army, and local authorities, the general perception is of delayed and fragmented action. Independent assessments confirm these weaknesses—the OSCE (2015) post-flood report highlighted unclear command chains and insufficient attention to vulnerable groups. Differences between subgroups were not significant (early warning: $t = 0.19$, $p = 0.848$; emergency response: $t = -1.33$, $p = 0.185$).

At the same time, public support for improvement is overwhelming. A total of 88% of respondents believe Serbia should invest more in protection (61% "much more"), while only 5% find current spending adequate. Such consensus indicates broad social backing for adaptation measures. Citizens particularly expect more investment in levees, reservoirs, and early-warning systems. Additionally, 79% view education on emergency preparedness as useful, showing willingness to strengthen personal capacity through training.

Despite this awareness, individual preparedness remains low. Only 9% have a personal plan for floods or droughts, 35% have none, and 30% only a partial plan; 26% have never considered it. More than half (51%) have taken no protective measures at home, and even among farmers, around 40% lack irrigation or wells, mostly for financial reasons. The mean willingness to invest in protection (3.00 ± 1.05) showed no significant difference between farmers and non-farmers ($t = 0.62$, $p = 0.535$). Notably, climate-change concern correlated positively with investment willingness (Spearman $r = 0.233$, $p < 0.001$), indicating that higher concern drives greater readiness to act. About 15% are highly proactive (rating 5), while roughly half show moderate willingness (score ≥ 3). The remainder rely primarily on state measures or lack financial capacity.

Migration as a risk-reduction option is rarely considered: only 7% have seriously contemplated relocation due to floods or droughts, while 76% never have. This demonstrates strong attachment to local communities and a preference for in-place adaptation rather than migration.

4.4. COMPARATIVE PERSPECTIVE AND KEY CHALLENGES

Comparison with neighboring countries highlights key factors of successful adaptation. The catastrophic floods of 2014 clearly illustrate these contrasts: while Bosnia and Herzegovina and Serbia suffered extensive damage, Hungary largely avoided serious consequences. Well-maintained levees along the Danube and an organized defense network enabled Hungary to contain the flood wave, whereas Bosnia experienced multiple levee breaches. Serbia fared somewhat better, yet failures of embankments on the Kolubara River led to the Obrenovac disaster. These outcomes confirm that robust infrastructure and institutional preparedness are decisive in limiting flood damage.

Croatia's co-financed program expanded levees and improved retention capacity along the Sava and Drava rivers, substantially reducing flood losses in high-risk areas. Meanwhile, Hungary operates an integrated drought-monitoring and early-warning system managed by the National Meteorological Service, providing real-time soil moisture and precipitation data to farmers and water authorities to support irrigation planning. Such examples show how sustained investment in infrastructure and data systems significantly strengthens adaptive capacity—an approach applicable to Serbia's hydro-climatic conditions (Beli *et al.*, 2025).

Similar lessons emerged from the 2017–2018 drought that severely affected regional agriculture. Hungary and Bulgaria both faced prolonged dry spells, but Hungary mitigated losses through modern irrigation and proactive water management based on seasonal forecasts. Bulgaria, in contrast, recorded yield losses exceeding 30% in cereal crops due to land degradation and limited irrigation capacity. Subsequently, Bulgaria and other countries invested in modernization and nature-based solutions—afforestation, shelterbelts, and wetland restoration—measures highly relevant for Serbia's adaptation agenda.

Financial capacity and administrative efficiency also play a decisive role. Croatia and Hungary strengthened defenses through EU-supported levee reconstruction, retention basins, and upgraded early-warning systems. Serbia likewise received post-2014 international assistance, yet limited institutional capacity and complex procedures slowed project implementation. Strengthening inter-agency coordination, streamlining administrative processes, and prioritizing investments in critical infrastructure—alongside public education, community engagement, and regional cooperation—remain essential for enhancing Serbia's adaptive capacity and long-term resilience to hydrological hazards.

5. CONCLUSION

Serbia faces a growing challenge from climate change, manifested through increasingly frequent floods and droughts. These hazards have already caused substantial losses, and without timely adaptation, their consequences will intensify. The study revealed high public awareness—most respondents expect more extremes and believe the state should invest more in protection—but also a pronounced gap between awareness and action. Citizens express dissatisfaction with institutional responses while taking few personal preparedness measures. The combination of rising threats and limited readiness heightens overall societal risk.

However, several clear priorities can strengthen Serbia's adaptive capacity:

- Infrastructure and technical systems: Reconstruct and reinforce levees and critical river regulation works, modernize irrigation and reservoirs to mitigate drought, and establish efficient early-warning systems with automatic monitoring and digital alerts—addressing the low mean public rating (2.48/5) and widespread dissatisfaction.
- Institutional coordination: Fully implement existing strategies, clearly define responsibilities among RHMZ, civil protection, and local authorities, and form joint emergency headquarters. Increase training and equipment for response teams, expedite access to international prevention funds, and integrate climate risk assessments into all sectoral policies.
- Local participation and education: Expand continuous education on floods and droughts (Crnčević & Orlović, 2018) and organize regular evacuation drills—supported by 79% of surveyed citizens—in the most exposed municipalities. Establish local volunteer risk teams as the first line of defense and improve transparency and communication to build public trust.
- Ecological measures: Integrate ecosystem-based solutions into adaptation plans—expand afforestation in erosion-prone areas, protect and restore wetlands, and apply soil conservation practices. Support farmers in adopting drought-resilient crops and drip irrigation systems (72.9% of farmers reported direct drought impacts). These actions simultaneously reduce hazard impacts and enhance biodiversity.
- Regional cooperation and knowledge exchange: Strengthen cross-border collaboration in water and disaster management, share hydrological data, and conduct joint flood drills. By adopting proven approaches such as Croatia's flood-risk mapping and Hungary's drought-forecasting models, Serbia can accelerate progress without duplicating efforts.

Implementing these measures will require political commitment, investment, and time, but the benefits are considerable. For the Western Balkans, early adaptation investments yield high net benefits—about four dollars returned per dollar spent—with early-warning systems among the most cost-effective (World Bank, 2024). Strengthening resilience will reduce future losses, stabilize agriculture and energy infrastructure, and help Serbia meet its climate commitments. Adaptation is a continuous process requiring learning and adjustment, but floods and droughts remain manageable risks if addressed comprehensively. Through combined engineering, social, and ecological solutions, Serbia can substantially increase its resilience to climate change and pursue sustainable development despite the growing hydrometeorological challenges.

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