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# Local Governments on the Frontline: The Integrated Role of Municipalities in Climate Adaptation and Disaster Risk Management

# Helyi önkormányzatok kiemelt és integrált szerepe az éghajlatváltozás okozta katasztrófakockázatok kezelésében

Mrekva László

Nemzeti Közszolgálati Egyetem, Víztudományi Kar, Víz-és Környezetbiztonsági Tanszék, Mesteroktató
LUDOVIKA University of Public Service, Faculty of Water Sciences, Department of Water and Environment Security, Master teacher
mrekva.laszlo@uni-nke.hu
ORCID: 0000-0001-8855-8743

## Abstract:

Local governments are increasingly positioned at the frontline of climate change action, where global challenges manifest in significant local consequences. Extreme weather events, including floods, heatwaves, storms, and wildfires, disrupt municipal services and create escalating demands for enhanced disaster management capabilities. This article examines the dual role of municipalities: maintaining the continuity of critical public functions while simultaneously safeguarding communities against climate-induced risks. This analysis investigates how municipalities integrate climate adaptation and disaster management into urban planning, infrastructure investment, and community engagement, utilising established international frameworks, such as the Sendai Framework for Disaster Risk Reduction and the EU Civil Protection Mechanism, along with a diverse array of case studies. Particular attention is given to local emergency planning, the protection of critical infrastructure, and the implementation of early warning systems. The findings suggest that, despite facing significant financial constraints and capacity limitations, municipalities can build resilience through the adoption of innovative technologies, the establishment of multi-level governance structures, and the promotion of participatory approaches. This paper contends that disaster management and climate adaptation should not be treated as parallel processes; rather, they should be understood as interdependent strategies within the municipal framework. Ultimately, the capacity of local governments to synthesise these dimensions will significantly influence both the sustainability of urban development and the security and well-being of citizens in an era characterised by escalating climate challenges.

Keywords: Local governments; climate change; disaster risk management; resilience; adaptation; urban governance; community preparedness; sustainable development

## Absztrakt:

A helyi önkormányzatok egyre inkább az éghajlatváltozás elleni küzdelem élvonalában állnak, ahol a globális kihívások jelentős helyi következményekkel járnak. Az extrém időjárási események – beleértve az árvizeket, hőhullámokat, viharokat és tűzvészeket – megzavarják a kommunális szolgáltatásokat, és növekvő igényt teremtenek a katasztrófaelhárítási képességek fejlesztésére. A cikk a települések kettős szerepét vizsgálja: a kritikus közszolgáltatások folytonosságának biztosítását és a közösségek védelmét az éghajlatváltozás okozta kockázatokkal szemben. Elemzi, miként integrálják az önkormányzatok az éghajlati alkalmazkodást és a katasztrófavédelmet a városi tervezésbe, az infrastrukturális beruházásokba és a közösségi szerepvállalásba, támaszkodva nemzetközi keretekre – például a Sendai Katasztrófakockázat-csökkentési Keretrendszerre és az EU polgári védelmi mechanizmusára –, valamint esettanulmányokra. Kiemelt figyelmet kap a helyi vészhelyzeti tervezés, a kritikus infrastruktúra védelme és a korai figyelmeztető rendszerek alkalmazása. Az eredmények szerint a pénzügyi korlátok és kapacitáshiány ellenére az önkormányzatok innovatív technológiákkal, többszintű kormányzással és részvételi megközelítésekkel erősíthetik ellenálló képességüket. A tanulmány amellett érvel, hogy a katasztrófavédelmet és az éghajlati alkalmazkodást nem párhuzamos, hanem egymástól függő önkormányzati stratégiákként kell kezelni. E dimenziók szintézisének képessége alapvetően befolyásolja a városfejlesztés fenntarthatóságát, valamint a polgárok biztonságát és jólétét az erősödő éghajlati kihívások korszakában.

Kulcsszavak: helyi önkormányzatok; éghajlatváltozás; katasztrófakockázat-kezelés; reziliencia; alkalmazkodás; városi kormányzás; közösségi felkészültség; fenntartható fejlődés

## 1. INTRODUCTION

The scientific community agrees that climate change poses severe challenges, including more intense weather events, hotter temperatures, flooding, and drought. The study by Kornhuber et al. shows that these symptoms have become more common and severe according to their research. The author who studied extreme weather patterns demonstrated how these events relate to global climate patterns and natural climate fluctuations, showing how local weather patterns connect to global climate events [1]. The Intergovernmental Panel on Climate Change (IPCC) has recorded these patterns, which show that climate conditions, including temperature, precipitation, and other weather factors, affect worldwide weather patterns. The research team has predicted that heavy rainfall events will occur more often, while dry periods will last longer, causing damage to water supply systems and agricultural production worldwide, according to previous evaluation reports [2]. The combination of rising temperatures and shifting rainfall patterns creates new risks that affect different areas through food shortages, health emergencies, and declines in species populations. Climate change effects become visible through the lens of locality because global climate change initiatives need to understand how different areas and their communities experience these changes. Climate impacts create unequal effects across regions, producing unique local problems that require tailored solutions for each area. The authors Reyes-García et al. emphasise that researchers need to study local climate change indicators because these indicators help them understand how climate systems manifest differently in various locations [3]. Research supports the need for localised understanding, as Indigenous Peoples and local communities have documented extensive climate change impacts on their social-ecological systems, underscoring the need for adaptation strategies that incorporate cultural context [4]. Implementing policy measures without adequate knowledge of local characteristics will not reduce climate-related risks and could make existing weaknesses worse. Local municipalities serve as the primary response units for addressing climate change challenges, given their unique geographic and socioeconomic conditions [5]. Municipal governments perform two essential functions: delivering vital public services and protecting their residents from the effects of climate change. Research shows that national policies fail to meet local needs because they do not account for the unique characteristics of each area [6].

The research by Schramm et al. Municipal governments demonstrate a better understanding of climate-related threats and their effects on public health, as this knowledge serves as a foundation for creating specific local health and environmental policies [7]. Local authorities need to develop climate adaptation plans that support national targets while addressing the current problems affecting their community members. The dual responsibility becomes challenging because different cities have varying capacities to address climate-related problems. The effectiveness of local climate response efforts depends on three main factors: local governance systems, resource distribution patterns, and community participation levels, according to Pereira et al. The research emphasises that municipal climate adaptation strategies must include local knowledge and community participation for success [8]. The research investigates how local governments handle climate-related challenges through the following essential questions. The research examines which climate-related problems affect local governments and assesses their impact on various population groups. What climate adaptation measures do local governments select for their service delivery and risk reduction efforts? Municipalities need local knowledge and community involvement to develop their adaptation strategies. The research investigates three main objectives: studying the effects of climate change on local government work and their adaptation strategies, and how community participation affects their adaptation initiatives. The research will use qualitative methods to study climate adaptation through case studies and interviews with municipal leaders and community focus groups, prioritising local knowledge for successful adaptation [9], [10]. The research uses this approach to connect global climate change discussions with local implementation efforts, thereby generating essential knowledge about municipal climate service delivery for their communities.

## 2. CLIMATE CHANGE AND DISASTER MANAGEMENT INTERLINKAGES

The occurrence of climatic extremes, including floods, flash floods, storms, wildfires, and heatwaves, has become more common due to climate change. The occurrence of these events has become more frequent and severe due to human-induced climate change, as multiple studies demonstrate that global warming is linked to rising numbers of severe climate-related disasters [11]. The IPCC predicts that climate change will continue to make disasters more severe and frequent, endangering human infrastructure and wild ecosystems [12]. The lack of reliable prediction for these extreme events creates multiple points of weakness which threaten to compromise disaster preparedness and response activities [13]. The worldwide distribution of extreme climate events shows different patterns because local environmental characteristics produce distinct effects which require different responses [14]. The most vulnerable communities across developing nations bear the brunt of disasters because they already face social and economic challenges and lack adequate infrastructure [15]. Research shows that areas that face ongoing droughts or unexpected flooding events experience higher levels of human suffering and economic destruction, leading to population displacement [13]. The current disaster management systems face growing challenges due to changing risks resulting from climate change. The current climate situation requires disaster management systems that operate reactively, as they fail to address the various risks [16]. The existing systems require immediate evaluation to enhance their climate resilience, according to multiple studies [17]. A disaster management system that works effectively needs to recognise how vulnerabilities change over time, while understanding the social environment that affects the situation. The current disaster management system faces challenges because sectors fail to work together effectively, creating obstacles to successful disaster response operations [18]. The current frameworks fail to recognise climate change adaptation as a vital element of disaster risk management systems, and this lack of recognition will have major consequences during emergencies [11]. The implementation of effective adaptation measures faces ongoing challenges due to differences in conceptual approaches between climate change adaptation and disaster risk reduction. The absence of a unified strategy leads organisations to overlook potential benefits from uniting their responses against increasing climate-related disasters [14].

The process of integrating climate risk into disaster management systems presents multiple obstacles that simultaneously create opportunities to develop better operational systems [19]. The rising complexity of climate change-related risks requires organisations to adopt crisis governance systems instead of their current risk management protocols. The current disaster management system focuses on response and recovery operations, but crisis governance promotes a comprehensive system that includes prevention and mitigation strategies [20]. The change is a vital requirement because standard systems treat disasters as separate events rather than recognising them as part of a complete crisis sequence, creating multiple system weaknesses that require comprehensive governance solutions [17]. The framework developed by Boin et al. The implementation of crisis management requires governments to work together at different levels of governance, including local, national, and international entities, to build adaptive capacity [21]. The current transboundary crises demonstrate that organisations need to develop collaborative systems that can handle complex risk developments rather than focusing on short-term requirements [19]. The new approach enables scientists to work with local communities and policymakers at various levels of government, thereby improving climate change response capabilities [18]. Multiple international frameworks exist to handle the changing relationship between climate change and disaster risk. The Sendai Framework for Disaster Risk Reduction, launched in 2015, requires substantial financial support for disaster risk management and climate change adaptation initiatives [11]. The framework shows how to reduce global disaster threats while understanding how they manifest in specific local areas. The EU Civil Protection Mechanism functions as an essential tool which enables European Union member states to work together during emergencies [22].

The organisation provides essential support to its member nations, enabling them to obtain the funding and specialised skills needed for effective disaster management. The system promotes teamwork to handle emergencies that affect multiple countries, as they require unified action to resolve them [23]. The Warsaw International Mechanism for Loss and Damage under the United Nations Framework Convention on Climate Change (UNFCCC) continues to develop as an essential framework that helps vulnerable areas manage the impacts of climate change. The system works to protect communities that experience climate-related destruction by promoting global unity and a unified climate change response [24]. Climate change, together with disaster management, has become a primary governance issue which experts now acknowledge. Managing future climate uncertainties requires global frameworks that work with local disaster management policies, linking climate adaptation to disaster risk reduction and social resilience objectives.

## 3. THE KEY ROLE OF MUNICIPALITIES IN CLIMATE RESPONSE

Municipalities need to create local adaptation and mitigation plans that address the specific climate-related issues affecting their communities. Research indicates that local governments lead climate change response efforts because they possess better knowledge of community needs and local susceptibility to climate change impacts (Budin-Ljøsne et al. [25]). Municipalities use adaptation strategies, including urban greening, flood risk management, and climate-resilient infrastructure development, to mitigate the effects of climate change [26]. Municipalities that adopt sustainable practices will achieve two goals: protecting their communities from climate change and making them more resistant to its impacts. Implementing climate adaptation strategies requires a comprehensive solution, which demands that municipal departments work together. Local governments should initiate programs focused on ecosystem-based adaptation to reduce climate risks through natural ecosystems while building stronger ties with their communities [27]. The effectiveness of local governance systems determines how well municipalities perform their climate change responsibilities, as these systems enable quick decision-making and help municipalities work with their local community members [28]. The success of local climate responses depends on sufficient funding for infrastructure. Municipal governments need to maintain and improve vital infrastructure, including drainage systems, because these systems help reduce flood risks resulting from climate change [29]. Studies show that green infrastructure systems, including permeable pavements, green roofs, and urban forests, help reduce urban heat island effects while managing stormwater in an environmentally friendly way [30].

Municipalities need to improve their transportation systems to support both low-emission and climate-resilient modes of transportation [31]. Public transit investments, together with biking infrastructure and pedestrian pathway development, help decrease greenhouse gas emissions while making communities more accessible to residents [32]. Municipal resources should align with strategic planning for sustainable development by creating comprehensive climate adaptation plans that integrate infrastructure funding with community needs [33]. Municipalities need effective land-use planning and regulatory systems to achieve their climate change mitigation goals. Local governments can create risk-sensitive land-use policies through proper zoning and complete planning procedures, which help them handle climate vulnerability. The process requires code revisions to establish new construction standards for buildings in flood-risk zones and disaster-exposed areas, based on research on municipal climate change responses [34][35]. Municipalities have a unique opportunity to integrate these elements into their existing planning systems. Spatial and land-use planning that adapts to climate risks enables communities to take action before future risks become more severe [36]. Risk-sensitive planning will protect community safety while enabling better land development and sustainable urban expansion in the fast-growing urban environment [37].

Municipal climate responses need citizen awareness programs and community engagement initiatives to function properly. The process of communicating climate risks and adaptation strategies leads to active community involvement in local governance and climate action [38][39]. Research indicates that municipalities that implement climate communication strategies that include citizen participation in adaptation planning will achieve better public support for sustainability initiatives [40]. Implementing educational programs that include workshops and events on climate change enables people to develop skills to support climate resilience initiatives [41]. The successful implementation of adaptation policies becomes more likely when community members work together, and their social connections grow stronger, thereby increasing their ability to resist climate-related challenges [42]. Municipalities that successfully engage their communities can access local knowledge and resources because research shows that community-based involvement leads to the development of effective climate adaptation strategies [43]. The process of community participation leads to climate action plans that align with local cultural needs and each community's operational requirements [44][45].

## 4. DISASTER MANAGEMENT DIMENSIONS

Municipalities play a vital role in emergency planning by creating evacuation plans, operating shelters, and protecting essential public facilities. Public safety during disasters depends on effective emergency plans, which require specific protocols to outline evacuation routes, shelter locations, and emergency response procedures [46]. Multiple successful municipal emergency plans exist worldwide because cities demonstrate their dedication to protecting citizens from disasters, which mainly affect flood-prone, wildfire-risk, and severe-weather zones [47]. Local governments need to lead the coordination effort between their organisations and national disaster management authorities. The partnership serves as a requirement to verify that local emergency plans follow national guidelines, resulting in unified emergency response operations [48].

Research indicates that national agencies which provide technical support to municipalities during crises help municipalities build their emergency response capabilities through proper funding and preparation [49]. Municipalities need to work with national disaster management authorities to achieve successful disaster management operations. Municipalities serve as the initial line of defence and require complete support and direction from national and state governments to execute their emergency response plans effectively [50]. Research shows that emergency response becomes more effective through intergovernmental partnerships, which enable better resource management, enhanced communication and improved emergency response coordination [49]. The Sendai Framework for Disaster Risk Reduction enables municipalities to develop disaster risk management strategies while providing a systematic method for integrating their local plans with national requirements [48]. National support systems that municipalities can access will strengthen their disaster response capabilities, thereby improving community resilience [51].

Local disaster management requires early warning systems and alert mechanisms to function as its essential foundation. The systems function as essential emergency communication tools that enable municipalities to send warning messages about approaching dangers, such as floods and severe storms [52]. Research shows that well-designed early warning systems help communities better prepare for emergencies, thereby reducing disaster-related threats [46].Local governments need to link their early warning systems with community outreach programs, which teach people about emergency response procedures. Municipalities that create emergency preparedness environments will develop more robust defence systems that protect people and buildings from disasters [53]. The system, which unites technological solutions with community-based participation, works to create an urban space which better resists climate-related threats [54].

Municipalities have established multiple disaster management best practices which demonstrate their essential contribution to strengthening community disaster resistance. Mobile flood barriers serve as an effective flood mitigation tool, enabling local authorities to establish protective barriers in areas that are at risk of upcoming flood events. Research findings from recent case studies show that these obstacles help protect cities from flooding events [55]. Municipalities now implement urban heat island mitigation programs to combat heat-related health problems, which climate change has worsened [56]. Methods for urban cooling include tree planting and green space development, as well as reflective roofing systems, which reduce city temperatures during hot summer days to improve public health outcomes [57]. Municipalities in areas with high wildfire risk need to implement active wildfire prevention strategies, including controlled burns and vegetation management practices. Research indicates that these methods effectively reduce the likelihood of destructive wildfires, safeguarding both natural ecosystems and human settlements [58]. The implementation of these best practices demonstrates how municipalities actively support disaster management to strengthen their communities against extreme climate events.

## 5. CHALLENGES AND LIMITATIONS

### Financial and Capacity Constraints

Municipalities face two major obstacles when they try to create climate response plans and disaster management systems: insufficient funding and resources. Local governments face financial constraints that prevent them from allocating sufficient funds to support essential infrastructure development, personnel training, and technological advancement programs. Municipalities face difficulties developing climate change adaptation strategies due to insufficient financial resources, thereby exposing their communities to extreme weather events and other climate-related risks. Research on healthcare systems in resource-constrained areas demonstrates that institutional capacity is a critical factor enabling successful service delivery. The developed effective strategies offer essential knowledge which helps municipalities solve their specific problems [59]. Municipalities cannot fulfil their climate resilience and disaster preparedness duties because they do not receive enough financial backing, and their internal development programs remain weak.

### Political Cycles and Short-Termism

The way governments operate, through political cycles and short-term thinking, creates additional barriers to local climate change management efforts. Elected officials tend to focus on short-term community needs, such as economic growth and public security, rather than implementing climate change adaptation plans, leading to unpredictable policy implementation [60].

The political environment creates challenges for municipalities in maintaining their climate adaptation plans, as it determines resource allocation and initiative selection, leading to short-term benefits rather than long-term outcomes. Research shows that local governments face multiple political priorities which reduce their ability to maintain steady climate action. The emphasis on immediate results prevents organisations from developing comprehensive emergency response systems that would help them prepare for upcoming climate-related disasters [61].

### Public Resistance and Social Vulnerability

Municipalities need to overcome public opposition to their climate action initiatives. The proposed measures face opposition from communities because they worry about higher costs, disruptions to daily life, and doubts about the fair distribution of the benefits and drawbacks of the climate initiative. The planning process needs community member participation through meaningful dialogue to achieve better stakeholder support and overcome current opposition.

Social vulnerability makes this situation worse because people who are marginalised cannot participate effectively in climate adaptation conversations. The existing gap between social groups could lead to climate-impact victims losing their right to participate in society, making it harder for people to adopt essential adaptation measures [62]. Municipalities need to create spaces which welcome all community members to participate in decision-making through an inclusive process.

Lack of Comprehensive Databases and Predictive Models

Municipalities face major challenges in their climate change response because they lack access to comprehensive databases and predictive models [63]. Local governments lack access to high-quality data needed to perform risk assessments and develop plans. Their responses to natural disasters become less effective because they rely on outdated or general information that does not account for specific climate changes in their area [64]. Municipalities face difficulties predicting climate pattern shifts because they lack sufficient predictive models, hindering their ability to prepare for upcoming disasters. The development of better disaster management systems requires advanced data analytics and modelling techniques to create more dependable and immediate response systems [65]. Municipalities should dedicate funds to complete data acquisition while working with research organisations to create better climate response plans through improved predictive methods.

## 5. FUTURE DIMENSIONS AND RECOMMENDATIONS

Municipalities need to develop integrated systems to protect their communities from climate change threats and to develop climate adaptation plans. The integration process enables researchers to develop comprehensive methods that address all aspects of urban risks [66]. Municipalities should integrate their disaster risk reduction work with climate adaptation initiatives to develop urban systems that are more resilient to extreme weather events and climate-related disasters. The method has proven effective across multiple research studies, which show that multiple strategic approaches create substantial enhancements in urban resistance. Municipalities need to create frameworks that enable different sectors and stakeholder groups to work together to achieve comprehensive and successful climate risk management. Climate action needs a governance system that connects local to international levels through national and regional frameworks. Municipalities need to establish direct communication channels across their governance levels to better coordinate with national climate policies and funding systems. The framework enables local governments to implement strategies that support national and regional targets while meeting the needs of their local communities [67]. The combination of local knowledge and priorities with national and international strategies will create more effective disaster management and climate adaptation policies, boosting resilience across all governance levels. Municipalities can obtain financial support, technical assistance, and innovative solutions for climate resilience through their partnerships with international and regional organisations. The future development of urban climate adaptation and disaster management requires innovative technologies as its foundation. Municipalities can establish real-time monitoring systems using IoT technology, enabling smart city development and enhancing their disaster preparedness and response capabilities [68]. Municipalities can use advanced data analytics and modelling tools to process extensive environmental data, enabling them to make emergency decisions quickly. Digital twins and smart analytics technologies enable city planners to create urban models that help them forecast climate change-related challenges [68][69]. Municipalities need to take an active role in implementing these technologies, as they will help make disaster management more proactive and strengthen urban resilience. The process of building community resistance against disasters needs to become the core focus for successful disaster response and climate change mitigation efforts. Municipalities should establish awareness programs that teach people about climate threats and involve them as active participants in local development planning [70].

The process of public participation enables community members to participate in decision-making, leading to better climate strategies that represent all segments of society. The community becomes more prepared for disasters through scheduled preparedness exercises, which help people learn emergency procedures and develop their abilities to handle crises [71]. Municipalities should make community engagement and disaster preparedness their top priorities, as this approach will help build a resilient society that enables people to address climate-related challenges together.

## 6. CONCLUSION

Local governments play a vital role in addressing the various problems climate change poses to their communities. The two main organizations that face the effects of climate change have established vital examples through their adaptation strategies, achieved results, and encountered challenges. Local adaptation initiatives need to work with community members to collect knowledge, as they must understand how different impacts affect their area. Municipal policies need this method to effectively combat both current and projected climate change risks. The complex relationship between climate change and disaster management requires new governance approaches to address these challenges. The growing threats posed by extreme climate events require researchers to study vulnerability factors while developing governance systems that unite global cooperation with community-based knowledge. Municipalities can build stronger climate resilience by integrating disaster management into their climate adaptation programs in today's unstable climate. Municipalities serve as essential agents of climate response at the local level by implementing adaptation and mitigation plans. The importance of investing in resilient infrastructure, creating strong regulatory frameworks, and conducting smart land-use planning, along with fostering active community participation, is vital. Local governments can better fight the effects of climate change and build stronger communities through their combined work in these areas. Municipalities play a crucial role in disaster management by developing emergency plans, collaborating with national agencies, and establishing early warning systems. Municipalities can enhance their ability to protect their communities from climate change-related threats by implementing best practices, such as mobile flood barriers, urban heat-island mitigation strategies, and wildfire prevention measures. Municipalities face multiple obstacles that prevent them from effectively responding to climate change, including limited funding and trained personnel, political instability, public opposition, and insufficient data. The solution to these problems requires multiple organisations to work together to establish new funding mechanisms and sustain political support over time, while creating spaces for public discussion and building comprehensive data systems that provide easy access to information. Municipalities can build their resistance to climate change threats by overcoming the obstacles that block their path to protection. Municipalities need to develop future strategies that integrate frameworks with multi-level governance systems, innovative technological solutions, and strong community participation to achieve effective climate response and disaster management. Local governments can create a sustainable and resilient urban environment by implementing these recommendations, thereby enhancing their ability to defend communities against worsening climate change threats.

## 7. REFERENCES


[1] K. Kornhuber, S. Osprey, D. Coumou, S. Petri, V. Petoukhov, S. Rahmstorfet al., "Extreme weather events in early summer 2018 connected by a recurrent hemispheric wave-7 pattern", Environmental Research Letters, vol. 14, no. 5, p. 054002, 2019. https://doi.org/10.1088/1748-9326/ab13bf (2025.12.15.)

[2] S. Raghavan, M. Vu, & S. Liong, "Regional climate simulations over vietnam using the WRF model", Theoretical and Applied Climatology, vol. 126, no. 1-2, p. 161-182, 2015. https://doi.org/10.1007/s00704-015-1557-0 (2025.12.15.)

[3] V. Reyes-García, Á. Fernández-Llamazares, M. Guèze, A. Garcés, M. Mallo, M. Vila-Gómezet al., "Local indicators of climate change: the potential contribution of local knowledge to climate research", Wiley Interdisciplinary Reviews Climate Change, vol. 7, no. 1, p. 109-124, 2015. https://doi.org/10.1002/wcc.374 (2025.12.15.)

[4] V. Reyes-García, D. García-del-Amo, S. Álvarez-Fernández, P. Benyei, L. Calvet-Mir, A. Junqueiraet al., "Indigenous peoples and local communities report ongoing and widespread climate change impacts on local social-ecological systems", Communications Earth & Environment, vol. 5, no. 1, 2024. https://doi.org/10.1038/s43247-023-01164-y (2025.12.15.)

[5] S. Woodhall, O. Landeg, & S. Kovats, "Public health and climate change: how are local authorities preparing for the health impacts of our changing climate?", Journal of Public Health, vol. 43, no. 2, p. 425-432, 2019. https://doi.org/10.1093/pubmed/fdz098 (2025.12.15.)

[6] A. Quandt and Y. Kimathi, "Perceptions of the effects of floods and droughts on livelihoods: lessons from arid Kenya", International Journal of Climate Change Strategies and Management, vol. 9, no. 03, p. 337-351, 2017. https://doi.org/10.1108/ijccsm-11-2014-0132 (2025.12.15.)

[7] P. Schramm, M. Ahmed, H. Siegel, J. Donatuto, L. Campbell, K. Raabet al., "Climate change and health: local solutions to local challenges", Current Environmental Health Reports, vol. 7, no. 4, p. 363-370, 2020. https://doi.org/10.1007/s40572-020-00294-1 (2025.12.15.)

[8] R. Pereira, L. Brazílio, M. Trejo-Rangel, M. Santos, L. Silva, L. Souzaet al., "Traditional and local communities as key actors to identify climate-related disaster impacts: a citizen science approach in Southeast Brazilian coastal areas", Frontiers in Climate, vol. 5, 2023. https://doi.org/10.3389/fclim.2023.1243008 (2025.12.15.)

[9] V. Reyes-García, D. García-del-Amo, P. Benyei, Á. Fernández-Llamazares, K. Gravani, A. Junqueiraet al., "A collaborative approach to bring insights from local observations of climate change impacts into global climate change research", Current Opinion in Environmental Sustainability, vol. 39, p. 1-8, 2019. https://doi.org/10.1016/j.cosust.2019.04.007 (2025.12.15.)

[10] V. Reyes-García, S. Alvarez-Fernández, P. Benyei, D. García-del-Amo, A. Junqueira, V. Labeyrieet al., "Local indicators of climate change impacts described by indigenous peoples and local communities: Study protocol", Plos One, vol. 18, no. 1, p. e0279847, 2023. https://doi.org/10.1371/journal.pone.0279847 (2025.12.15.)

[11] I. Kelman, "Climate change and the sendai framework for disaster risk reduction", International Journal of Disaster Risk Science, vol. 6, no. 2, p. 117-127, 2015. https://doi.org/10.1007/s13753-015-0046-5 (2025.12.15.)

[12] E. Kirchner and H. Dorussen, "New horizons in Eu–Japan security cooperation", Asia Europe Journal, vol. 19, no. 1, p. 27-41, 2020. https://doi.org/10.1007/s10308-020-00586-z (2025.12.15.)

[13] J. Frischen, I. Meza, D. Rupp, K. Wietler, & M. Hagenlocher, "Drought risk to agricultural systems in Zimbabwe: a spatial analysis of hazard, exposure, and vulnerability", Sustainability, vol. 12, no. 3, p. 752, 2020. https://doi.org/10.3390/su12030752 (2025.12.15.)

[14] E. Romieu, T. Welle, S. Schneiderbauer, M. Pelling, & C. Vinchon, "Vulnerability assessment within climate change and natural hazard contexts: revealing gaps and synergies through coastal applications", Sustainability Science, vol. 5, no. 2, p. 159-170, 2010. https://doi.org/10.1007/s11625-010-0112-2 (2025.12.15.)

[15] C. Parker, T. Persson, & S. Widmalm, "The effectiveness of national and EU-level civil protection systems: evidence from 17 member states", Journal of European Public Policy, vol. 26, no. 9, p. 1312-1334, 2018. https://doi.org/10.1080/13501763.2018.1523219 (2025.12.15.)

[16] A. Boin and P. Hart, "Organising for effective emergency management: lessons from research1", Australian Journal of Public Administration, vol. 69, no. 4, p. 357-371, 2010. https://doi.org/10.1111/j.1467-8500.2010.00694.x (2025.12.15.)

[17] C. Ansell, A. Boin, & A. Keller, "Managing transboundary crises: identifying the building blocks of an effective response system", Journal of Contingencies and Crisis Management, vol. 18, no. 4, p. 195-207, 2010. https://doi.org/10.1111/j.1468-5973.2010.00620.x (2025.12.15.)

[18] S. Kuipers, A. Boin, R. Bossong, & H. Hegemann, "Building joint crisis management capacity? comparing civil security systems in 22 European countries", Risk Hazards & Crisis in Public Policy, vol. 6, no. 1, p. 1-21, 2015. https://doi.org/10.1002/rhc3.12070 (2025.12.15.)

[19] K. Groven, C. Aall, M. Berg, A. Carlsson-Kanyama, & F. Coenen, "Integrating climate change adaptation into civil protection: comparative lessons from Norway, Sweden and the Netherlands", Local Environment, vol. 17, no. 6-7, p. 679-694, 2012. https://doi.org/10.1080/13549839.2012.665859 (2025.12.15.)

[20] T. Hengl, M. Walsh, J. Sanderman, I. Wheeler, S. Harrison, & I. Prentice, "Global mapping of potential natural vegetation: an assessment of machine learning algorithms for estimating land potential", Peerj, vol. 6, p. e5457, 2018. https://doi.org/10.7717/peerj.5457 (2025.12.15.)

[21] A. Boin, M. Rhinard, & M. Ekengren, "Managing transboundary crises: the emergence of European Union capacity", Journal of Contingencies and Crisis Management, vol. 22, no. 3, p. 131-142, 2014. https://doi.org/10.1111/1468-5973.12052 (2025.12.15.)

[22] C. Morsut, "The EU's community mechanism for civil protection: analysing its development", Journal of Contingencies and Crisis Management, vol. 22, no. 3, p. 143-149, 2014. https://doi.org/10.1111/1468-5973.12053 (2025.12.15.)

[23] C. Wendling, "Explaining the emergence of different European Union crisis and emergency management structures", Journal of Contingencies and Crisis Management, vol. 18, no. 2, p. 74-82, 2010. https://doi.org/10.1111/j.1468-5973.2010.00606.x (2025.12.15.)

[24] M. Adamczak-Retecka, "Warsaw international mechanism for loss and damage associated with climate change impacts.", Polish Law Review, vol. 2, no. 1, p. 127-0, 2016. https://doi.org/10.5604/24509841.1232094 (2025.12.15.)

[25] I. Budin-Ljøsne, Z. Nordeng, P. Schwarze, & S. Rao, "Linking climate change adaptation and public health: perspectives of Norwegian policymakers", Scandinavian Journal of Public Health, vol. 53, no. 2, p. 125-133, 2024. https://doi.org/10.1177/14034948241229486 (2025.12.15.)

[26] G. Giulio, R. Torres, M. Vasconcellos, D. Braga, R. Mancini, & M. Lemos, "Extreme events, climate change and adaptation in the state of São Paulo", Ambiente & Sociedade, vol. 22, 2019. https://doi.org/10.1590/1809-4422asoc0277r1vu19l4ao (2025.12.15.)

[27] C. Wamsler and S. Pauleit, "Making headway in climate policy mainstreaming and ecosystem-based adaptation: two pioneering countries, different pathways, one goal", Climatic Change, vol. 137, no. 1-2, p. 71-87, 2016. https://doi.org/10.1007/s10584-016-1660-y (2025.12.15.)

[28] N. Rogers, V. Adams, & J. Byrne, "Moving beyond the plan: exploring the opportunities to accelerate the implementation of municipal climate change adaptation policies and plans", Environmental Policy and Governance, vol. 35, no. 2, p. 276-291, 2024. https://doi.org/10.1002/eet.2142 (2025.12.15.)

[29] N. Nousiainen, V. Riekkinen, & T. Meriläinen, "Municipal climate communication as a tool in amplifying local climate action and developing a place brand", Environmental Research Communications, vol. 4, no. 12, p. 125003, 2022. https://doi.org/10.1088/2515-7620/aca1fe (2025.12.15.)

[30] E. Boyd, B. Nykvist, S. Borgström, & I. Stacewicz, "Anticipatory governance for social-ecological resilience", Ambio, vol. 44, no. S1, p. 149-161, 2015. https://doi.org/10.1007/s13280-014-0604-x (2025.12.15.)

[31] S. Allred, A. Chatrchyan, & G. Tsintsadze, "Local municipal capacity for climate change action in New York State: exploring the urban–rural divide", Review of Policy Research, vol. 39, no. 5, p. 570-601, 2022. https://doi.org/10.1111/ropr.12475 (2025.12.15.)

[32] E. Lioubimtseva, H. Zylman, K. Carron, K. Poynter, & B. Rashrash, "Equity and inclusion in climate action and adaptation plans of Michigan cities", 2024. https://doi.org/10.20944/preprints202407.1143.v1 (2025.12.15.)

[33] S. Ranabhat, R. Ghate, L. Bhatta, N. Agrawal, & S. Tankha, "Policy coherence and interplay between climate change adaptation policies and the forestry sector in Nepal", Environmental Management, vol. 61, no. 6, p. 968-980, 2018. https://doi.org/10.1007/s00267-018-1027-4 (2025.12.15.)

[34] C. Delgado, "Exploring agriculture, climate change, and food planning nexus", Cuadernos De Investigación Geográfica, vol. 50, no. 1, p. 109-121, 2023. https://doi.org/10.18172/cig.5679 (2025.12.15.)

[35] I. Campos, J. Guerra, J. Ferreira, L. Schmidt, F. Alves, A. Vizinhoet al., "Understanding climate change policy and action in Portuguese municipalities: a survey", Land Use Policy, vol. 62, p. 68-78, 2017. https://doi.org/10.1016/j.landusepol.2016.12.015 (2025.12.15.)

[36] M. Siña, R. Wood, E. Saldarriaga, J. Lawler, J. Zunt, P. Garcíaet al., "Understanding perceptions of climate change, priorities, and decision-making among municipalities in Lima, Peru to better inform adaptation and mitigation planning", Plos One, vol. 11, no. 1, p. e0147201, 2016. https://doi.org/10.1371/journal.pone.0147201 (2025.12.15.)

[37] T. Bausch and K. Koziol, "New policy approaches for increasing response to climate change in small rural municipalities", Sustainability, vol. 12, no. 5, p. 1894, 2020. https://doi.org/10.3390/su12051894 (2025.12.15.)

[38] T. Selseng, M. Klemetsen, & T. Rusdal, "Adaptation confusion? A longitudinal examination of the concept “climate change adaptation” in Norwegian municipal surveys.", Weather Climate and Society, 2021. https://doi.org/10.1175/wcas-d-21-0024.1 (2025.12.15.)

[39] H. Fünfgeld, "Facilitating local climate change adaptation through transnational municipal networks", Current Opinion in Environmental Sustainability, vol. 12, p. 67-73, 2015. https://doi.org/10.1016/j.cosust.2014.10.011 (2025.12.15.)

[40] T. Geleta, D. Dadi, W. Garedew, & A. Worku, "Feasibility of urban-based climate change adaptation strategies in urban centres of southwest Ethiopia: from a local climate action perspective", Atmosphere, vol. 15, no. 5, p. 595, 2024. https://doi.org/10.3390/atmos15050595 (2025.12.15.)

[41] P. Robinson and C. Gore, "Municipal climate reporting: gaps in monitoring and implications for governance and action", Environment and Planning C Government and Policy, vol. 33, no. 5, p. 1058-1075, 2015. https://doi.org/10.1177/0263774x15605940 (2025.12.15.)

[42] P. Ribeiro, J. Ferrão, & J. Seixas, "Mainstreaming climate adaptation in spatial planning. the case of Baixa Pombalina in Lisbon", Finisterra, vol. 53, no. 108, p. 15-38, 2018. https://doi.org/10.18055/finis13457 (2025.12.15.)

[43] D. Buschmann, K. Koziol, T. Bausch, & R. Steurer, "Adaptation to climate change in small German municipalities: sparse knowledge and weak adaptive capacities", Natural Resources Forum, vol. 46, no. 4, p. 377-392, 2022. https://doi.org/10.1111/1477-8947.12262 (2025.12.15.)

[44] E. Nabong, L. Whiteford, M. Arias, & J. Mihelcic, "Climate change adaptation priority strategies in the Philippines: differences between local government decision makers and marginalised coastal communities", Environmental Engineering Science, vol. 38, no. 5, p. 367-376, 2021. https://doi.org/10.1089/ees.2020.0285 (2025.12.15.)

[45] E. Brink and C. Wamsler, "Collaborative governance for climate change adaptation: mapping citizen–municipality interactions", Environmental Policy and Governance, vol. 28, no. 2, p. 82-97, 2017. https://doi.org/10.1002/eet.1795 (2025.12.15.)

[46] D. Henstra, "Evaluating local government emergency management programs: what framework should public managers adopt?", Public Administration Review, vol. 70, no. 2, p. 236-246, 2010. https://doi.org/10.1111/j.1540-6210.2010.02130.x (2025.12.15.)

[47] J. Wen, C. Wan, Q. Ye, J. Yan, & W. Li, "Disaster risk reduction, climate change adaptation and their linkages with sustainable development over the past 30 years: a review", International Journal of Disaster Risk Science, vol. 14, no. 1, p. 1-13, 2023. https://doi.org/10.1007/s13753-023-00472-3 (2025.12.15.)

[48] I. Kelman, "Climate change and the sendai framework for disaster risk reduction", International Journal of Disaster Risk Science, vol. 6, no. 2, p. 117-127, 2015. https://doi.org/10.1007/s13753-015-0046-5 (2025.12.15.)

[49] T. Measham, B. Preston, T. Smith, C. Brooke, R. Gorddard, G. Withycombeet al., "Adapting to climate change through local municipal planning: barriers and challenges", Mitigation and Adaptation Strategies for Global Change, vol. 16, no. 8, p. 889-909, 2011. https://doi.org/10.1007/s11027-011-9301-2 (2025.12.15.)

[50] C. Pandey, "Climate change, floods, and community resilience: a study of the kamala river basin, nepal", Journal of Flood Risk Management, vol. 18, no. 2, 2025. https://doi.org/10.1111/jfr3.70069 (2025.12.15.)

[51] K. Nguyen-Trung, "Examining disaster and climate change studies using the funnel of multiple capital deployment (FMAD) framework: A review of Vietnamese literature",, 2023. https://doi.org/10.31219/osf.io/fu487 (2025.12.15.)

[52] C. Ihinegbu, "Conceptualization and management of disasters and climate change events in Africa: A review", Sn Applied Sciences, vol. 3, no. 11, 2021. https://doi.org/10.1007/s42452-021-04829-5 (2025.12.15.)

[53] M. Siña, R. Wood, E. Saldarriaga, J. Lawler, J. Zunt, P. Garcíaet al., "Understanding perceptions of climate change, priorities, and decision-making among municipalities in lima, peru to better inform adaptation and mitigation planning", Plos One, vol. 11, no. 1, p. e0147201, 2016. https://doi.org/10.1371/journal.pone.0147201 (2025.12.15.)

[54] K. Mehiriz and P. Gosselin, "Municipalities' preparedness for weather hazards and response to weather warnings", Plos One, vol. 11, no. 9, p. e0163390, 2016. https://doi.org/10.1371/journal.pone.0163390 (2025.12.15.)

[55] C. Plein, "Resilience, adaptation, and inertia: lessons from disaster recovery in a time of climate change", Social Science Quarterly, vol. 100, no. 7, p. 2530-2541, 2019. https://doi.org/10.1111/ssqu.12658 (2025.12.15.)

[56] R. Olshansky and L. Johnson, "The evolution of the federal role in supporting community recovery after u.s. disasters", Journal of the American Planning Association, vol. 80, no. 4, p. 293-304, 2014. https://doi.org/10.1080/01944363.2014.967710 (2025.12.15.)

[57] C. Warren, "The facilities manager preparing for climate change related disaster", Facilities, vol. 28, no. 11/12, p. 502-513, 2010. https://doi.org/10.1108/02632771011066567 (2025.12.15.)

[58] I. Campos, J. Guerra, J. Ferreira, L. Schmidt, F. Alves, A. Vizinhoet al., "Understanding climate change policy and action in Portuguese municipalities: a survey", Land Use Policy, vol. 62, p. 68-78, 2017. https://doi.org/10.1016/j.landusepol.2016.12.015 (2025.12.15.)

[59] S. Matsuoka, N. Fujita, K. Koto-Shimada, & A. Zwi, "Regulation of nursing professionals in Cambodia: strategies to overcome underpinning challenges", International Nursing Review, vol. 68, no. 3, p. 399-411, 2021. https://doi.org/10.1111/inr.12658 (2025.12.15.)

[60] P. Caldwell, M. Zelinka, & S. Klein, "Evaluating emergent constraints on equilibrium climate sensitivity", Journal of Climate, vol. 31, no. 10, p. 3921-3942, 2018. https://doi.org/10.1175/jcli-d-17-0631.1 (2025.12.15.)

[61] J. Sun, L. Makosa, J. Yang, F. Yin, & L. Sitsha, "Does corporate tax planning mitigate financial constraints? Evidence from China", International Journal of Finance & Economics, vol. 28, no. 1, p. 510-527, 2021. https://doi.org/10.1002/ijfe.2433 (2025.12.15.)

[62] O. Maxwell, N. Chuku, A. Ananaba, R. Diallo, E. Sambo, O. Koladeet al., "Bed space, referral capacity and emergency response of the healthcare facilities in Lagos state: a key to improving healthcare", Moj Public Health, vol. 12, no. 1, p. 67-72, 2023. https://doi.org/10.15406/mojph.2023.12.00412 (2025.12.15.)

[63] Y. Zhang, M. Zhou, N. Kong, X. Li, & X. Zhou, "Evaluation of emergency response capacity of urban pluvial flooding public service based on scenario simulation", International Journal of Environmental Research and Public Health, vol. 19, no. 24, p. 16542, 2022. https://doi.org/10.3390/ijerph192416542 (2025.12.15.)

[64] Y. Chen, Q. He, & K. Paudel, "Quality competition and reputation of restaurants: the effects of capacity constraints", Economic Research-Ekonomska Istraživanja, vol. 31, no. 1, p. 102-118, 2018. https://doi.org/10.1080/1331677x.2017.1421996 (2025.12.15.)

[65] L. Yang, H. Zhang, Y. Zhan, K. Deng, & L. Dong, "Evacuation strategy considering path capacity and risk level for cruise ship", Journal of Marine Science and Engineering, vol. 10, no. 3, p. 398, 2022. https://doi.org/10.3390/jmse10030398 (2025.12.15.)

[66] C. Fernández and D. Peek, "Smart and sustainable? positioning adaptation to climate change in the European smart city", Smart Cities, vol. 3, no. 2, p. 511-526, 2020. https://doi.org/10.3390/smartcities3020027 (2025.12.15.)

[67] F. Shariatpour and M. Behzadfar, "A data-driven interactive system for smart urban planning and design", International Journal of Digital Innovation in the Built Environment, vol. 12, no. 1, p. 1-23, 2024. https://doi.org/10.4018/ijdibe.361591 (2025.12.15.)

[68] P. Boccardo, L. Riccia, & Y. Yadav, "Urban echoes: exploring the dynamic realities of cities through digital twins", Land, vol. 13, no. 5, p. 635, 2024. https://doi.org/10.3390/land13050635 (2025.12.15.)

[69] G. Vegah, U. Wajid, & B. Adebisi, "Smart-agent system for flexible, personalised transport service", The Journal of Engineering, vol. 2016, no. 12, p. 456-466, 2016. https://doi.org/10.1049/joe.2016.0284 (2025.12.15.)

[70] I. Pluchinotta, D. Esposito, & D. Camarda, "Fuzzy cognitive mapping to support multi-agent decisions in development of urban policymaking", Sustainable Cities and Society, vol. 46, p. 101402, 2019. https://doi.org/10.1016/j.scs.2018.12.030 (2025.12.15.)

[71] J. Colding, S. Barthel, & P. Sörqvist, "Wicked problems of smart cities", Smart Cities, vol. 2, no. 4, p. 512-521, 2019. https://doi.org/10.3390/smartcities2040031 (2025.12.15.)