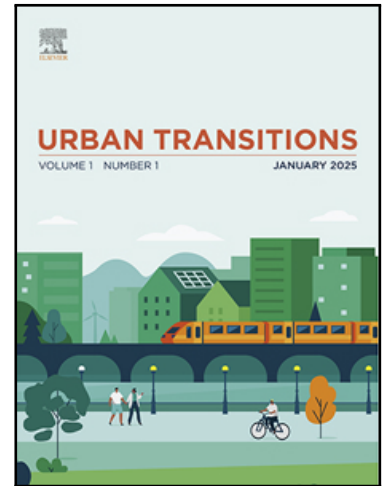


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Enhancing Municipal Climate Adaptation: Evaluating Communication Strategies in Lithuanian Cities

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Ethics approval and consent to participate

The survey data used in this study were collected by Baltijos tyrimai, an independent public research organization. According to the information provided by the company, data collection followed established ethical guidelines and participants gave informed consent.

This study was approved by Ethical monitoring board at Citizen Science Hub at VILNIUS TECH, reference number No. CSH-2023-02. All participants provided informed consent prior to taking part in the research.

Consent for publication

All participants provided consent for anonymized data to be used in publications.

Competing interests

The authors declare that they have no competing interests.

Author contributions

Monika Mačiulienė led the research project, overseeing the study design, analysis, and manuscript preparation. She was primarily responsible for drafting and writing the report, ensuring that the research objectives were clearly articulated and met. Aelita Skaržauskienė, Kristina Kovaitė, and Paulius Šūmakaris provided essential support by managing the survey implementation and coordinating the data collection process, particularly for the communication aspects. Their contributions were invaluable in gathering and processing the primary data that underpinned the study's findings.

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Availability of data and materials

The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

Abstract

Municipalities are increasingly recognized as key actors in addressing climate change adaptation. However, a significant challenge remains in translating legislative authority into effective, action-oriented implementation. This study evaluates municipal climate adaptation communication and its public perception in Lithuania. A mixed-methods approach was employed, combining data from a representative survey of Lithuanian residents ($n=1013$) and a content analysis of climate-related communications from all 60 municipalities in Lithuania, gathered from their official websites and Facebook accounts throughout 2024. The survey results revealed significant differences in how citizens perceive and access municipal climate information across key demographic groups. Notably, lower education levels are associated with higher municipal information scores (ANOVA: $F = 3.92$, $p < 0.001$), potentially indicating more effective outreach to this group but also raising questions about information interpretation. Significant variations were also found in municipal information scores across occupational categories (ANOVA: $F = 3.63$, $p < 0.001$), highlighting the need for tailored communication strategies that consider the diverse needs and constraints of different professions. The content analysis of municipal communications revealed that adaptation-specific messaging is often limited, comprising only 24.7% of climate-related messages. Interestingly, rural municipalities demonstrated higher climate communication intensity (1.83 messages per 10,000 inhabitants) compared to major urban centres (0.58 messages per 10,000 inhabitants), suggesting a greater emphasis on public outreach in less densely populated areas, though urban centres focused more on adaptation messaging. These findings emphasize that simply raising awareness is insufficient. To truly close the gap between authority and capacity, municipalities need to adopt nuanced, targeted communication strategies that not only inform but also empower citizens with actionable adaptation guidance. Enhanced citizen engagement through strategic communication is, therefore, essential for transforming legislative intentions into meaningful and effective climate adaptation actions.

Keywords: climate adaptation; municipal communication; climate communication; citizen engagement.

1. Introduction

Anthropogenic climate change is one of the most pressing challenges of our time, and its impacts are increasingly felt at the local level (Vandecasteele et al. 2024; Marbaix et al. 2025). Cities and municipalities, as first responders to these impacts, are central in both mitigating climate change and adapting to its consequences (Lin et al. 2021, Birchall and Bonnet 2021). The European Union (EU) and other international bodies have emphasized the centrality of cities in climate action through various initiatives (e.g., Green City Accord, EU Missions to address climate change in cities and regions, Global initiative for information integrity on climate change). However, despite increasing recognition of the importance of local adaptation, implementation often lags behind policy, and municipalities face numerous challenges in planning and executing effective adaptation strategies (Aboagye and Sharifi 2024). Despite widespread acknowledgment of their significance, municipalities continue to face substantial difficulties translating climate adaptation policies into effective action (Hurlimann et al. 2021).

Research on urban climate governance shows that the adaptation-action gap is not only a problem of information or communication but is also shaped by the material and institutional conditions under which municipalities operate. Local governments often work with limited financial, human and technical resources, must balance adaptation against other pressing policy priorities (e.g., social welfare or economic development), and have only partial authority to act across sectors and scales (Measham et al 2011; Biesbroek et al 2013; Rogers et al 2023). Low

public and political awareness of climate risks, uncertainty about future impacts and the long-time horizons over which adaptation benefits become visible can further weaken incentives to invest in proactive measures, especially in small and medium sized municipalities with already stretched capacities (Olazabal et al 2021; Olazabal et al 2022). These non-communication factors shape whether climate adaptation reaches local agendas, how it is framed in municipal plans and strategies, and to what extent communicative efforts are translated into sustained action rather than remaining symbolic or project-based commitments (Biesbroek et al 2014; Barnett et al 2015).

The literature increasingly points to enhanced communication and citizen engagement as important venue to close this implementation gap (Khatibi et al. 2021). Effective climate adaptation requires not only local government action but also active citizen participation, which can only be achieved through strategic communication between municipalities and their constituents (Chitsa et al. 2022). Successful cases from various regions (e.g., Rudge 2021) demonstrate that when municipalities effectively engage citizens through strategic communication, climate adaptation efforts gain momentum and produce tangible results. Yet, citizen-municipality interactions regarding climate adaptation have received insufficient academic attention, particularly concerning the tailoring of messages to specific local contexts and diverse audiences.

Against this backdrop, this research examines municipal climate related communication in Lithuania to explore how local authorities present climate risks and adaptation in public facing channels, and how such communication reflects or potentially challenges the structural constraints that shape local adaptation practice. It also aims to evaluate the effectiveness of municipal communication by analysing citizens' perceptions of local government support and conducting a content analysis of municipal communication strategies. The research addresses the following questions:

RQ1: How do Lithuanian citizens perceive the adequacy and effectiveness of municipal support for climate adaptation?

RQ2: What types of climate-related information are Lithuanian municipalities sharing through their official websites and Facebook accounts?

RQ3: How can the municipalities adapt their communication strategies to better address citizen needs and expectations regarding climate adaptation?

To answer these questions, the study employs a mixed-methods approach, combining quantitative survey data from a representative sample (n=1013) of Lithuanian residents with content analysis of municipal climate communication across all 60 municipalities in Lithuania. Lithuania is particularly well-suited for this research due to its rapidly changing climate conditions and pronounced regional vulnerabilities. Recent data from the Lithuanian Hydrometeorological Service (2024) underscores significant warming, with the national average annual temperature reaching 9.5°C in 2024, 2.1°C above the historical average (1961-1990). Concurrently, hydrological extremes, including record-high water levels in the Nemunas River, highlight increasing climate volatility. Economic impacts further illustrate the country's vulnerability, with extreme weather events in 2022 alone causing approximately 243 million euros in damages (European Environment Agency 2022). Additionally, recent municipal vulnerability assessments reveal regional variations, reinforcing the need for tailored local adaptation measures and making Lithuania a uniquely valuable case study for examining municipal adaptation communication.

The manuscript is structured as follows. First, the literature review contextualizes the gap between legislative authority and implementation, emphasizing the critical role of municipal communication and citizen engagement. Next, the methodology section details the mixed-methods approach used in this study, explaining the survey design and content analysis of municipal communications. The subsequent results section presents findings from both the quantitative and qualitative components, highlighting demographic variations in perceptions and the disparities in messaging across different municipalities. Finally, the discussion synthesizes these findings to propose strategic recommendations for enhancing communication efforts.

2. Background

2.1. Implementation gap in climate adaptation governance at the local level

Local governments play a crucial role in climate adaptation, serving as frontline responders to climate impacts while navigating complex implementation challenges. Rogers et al. (2023) through systemic analysis of relevant literature identified two interconnected factors that affect the mainstreaming of municipal adaptation: the authority to adapt and the capacity to adapt. More specifically, authority to adapt refers to the authorizing environment from national or sub-national government, or from local government leaders, for adaptation action by a municipal administration. Capacity to adapt refers to access to resources, professional networks, and supportive organizational systems and culture, that enable local government adaptation (Rogers et al. 2023).

In the EU context, the authority dimension is largely addressed through well-established policy frameworks at both EU and national levels. More specifically, in 2013, the European Commission (EC) adopted the first EU Strategy on Adaptation to Climate Change (EC 2013), establishing a framework to enhance preparedness and capacity to respond to climate change impacts at local, regional, national, and EU levels. In 2018, the EC conducted an evaluation of the 2013 strategy, concluding that while progress had been made, Europe remained vulnerable to climate impacts both within and beyond its borders (EC 2018). In 2021, the EC adopted a new EU Strategy on Adaptation to Climate Change (EC 2021), which significantly strengthened the previous approach by focusing on smarter, more systemic, and faster adaptation, as well as stepping up international action placing greater emphasis on nature-based solutions and local adaptation actions. In this legislative framework, cities possess the formal mandate to implement adaptation measures, with directives and regulations explicitly requiring local governments to develop and execute climate adaptation strategies.

Lithuania's evolving climate adaptation strategy is a clear reflection of this EU guidance. The country initiated its efforts with the 2012 National Climate Change Management Strategy and complementary inter-institutional plans, which initially prioritized mitigation. In alignment with evolving EU directives, Lithuania subsequently advanced its policy framework through the National Climate Change Management Agenda (Government of the Republic of Lithuania 2021) and the National Adaptation Plan for 2024-2030 (Government of the Republic of Lithuania 2022). The latter document stresses regional collaboration and mandates local authorities to proactively lead adaptation efforts. By calling for municipalities to prepare adaptation strategies ahead of escalating risks, Lithuania demonstrates a commitment to building resilience, reducing the damage from extreme weather events, and safeguarding public health, emergency management, and ecosystem protection. This approach not only echoes the transformative mandates from the EC but also reflects a long-term commitment to building climate resilience across society and the economy.

Despite holding the requisite authority, many cities struggle with substantial capacity challenges. Research indicates that the capacity to adapt is heavily dependent on access to financial resources, technical expertise, robust organizational structures, and professional networks. For instance, Reckien et al. (2023) and Weitzel et al. (2023) document how limited budgets and insufficient skill sets hinder the effective translation of policy into practice. Furthermore, at the local level, climate adaptation legislation must compete with other non-mandatory issues, influencing implementation priorities and resource allocation (Lee et al. 2023; Rahman et al. 2023; Measham et al. 2019). As a result, this disconnect between formal authorization and operational capability leads to uneven progress in adaptation efforts, particularly in smaller municipalities or regions with fewer resources (Reckien et al. 2018; Lee et al. 2022).

The implementation gap is further highlighted by the European Court of Auditors (2023). Their special report on "EU Climate Action and Adaptation at Local Level" revealed that a significant proportion of municipalities are unaware of core adaptation strategies at the EU, national, and regional levels. Specifically, nearly 70% of municipalities surveyed were unaware of the EU Climate Change Adaptation Strategy, while 60% and 54% remained unaware of national and regional plans, respectively. Alarming, only 16% of the municipalities had developed a local adaptation plan, underscoring the challenges posed by limited capacity despite clear policy mandates. This authority-capacity dynamic underscores the need for innovative approaches that can bridge the implementation gap.

2.2. Transformative potential of communication and engagement of citizens

As discussed in the previous section, governing transformational change in climate adaptation is inherently challenging and necessitates innovative planning, collaboration, and technical innovation (Glaas et al. 2022; Wolfram et al. 2019; Hjerpe et al. 2017). Municipalities increasingly acknowledge the transformative potential inherent in effective communication and authentic citizen engagement (Hölscher et al. 2019). Anchoring adaptation strategies through citizen co-production not only enhances local commitment and empowerment but also integrates community-specific challenges, ideas, and motivations, thereby creating sustained adaptive capacity (Agger 2021; Hügel and Davies 2020; Castán Broto et al. 2019; Mees et al. 2019).

While citizens hold legal responsibilities for protecting their property from climate-related events (Brink and Wamsler 2018; Wamsler 2016), their behaviors significantly influence public adaptation efforts (Bick 2024), particularly regarding personal and public safety during extreme events (Ouyang et al. 2023; Wolff 2021; Wamsler and Brink 2014). Meaningful citizen involvement in municipal adaptation planning enhances relevance, fairness, and acceptance of adaptive measures (Zhu et al. 2022; Lidskog et al. 2022; Cattino and Reckien 2021; Mees et al. 2019). Despite municipalities' proximity to residents and their influence over local adaptation capacities, ranging from emergency management to spatial planning (Zapata Arango et al. 2024; Horlings et al. 2021; Howarth et al. 2021), interaction dynamics between citizens and municipalities remain underexplored, particularly in Western societies (Böhme et al. 2022; Kiss et al. 2022). Many municipal planners continue to overlook the value and impact of actively collaborating with citizens (Glaas et al. 2022; Brink and Wamsler 2018), and even local governments open to citizen collaboration often hesitate to devolve responsibilities fully (Uittenbroek et al. 2022).

Effective communication strategies are fundamental for mobilizing transformative potential in local adaptation. Municipalities that frame climate adaptation messages around tangible, local impacts, and achievable community-focused solutions typically experience higher citizen engagement and adaptive behavioral change (Glaas et al. 2022; Moser 2016; Corner and Clarke

2017). Highlighting co-benefits, such as improved health or financial savings rather than solely environmental justifications, further encourages citizen uptake of adaptive actions (Skarzauskiene et al. 2024; Howell and Allen 2019). Two-way communication mechanisms also significantly enhance local responsiveness and resilience (Aragon et al. 2019; Burch et al. 2018). However, municipal communication must also navigate substantial barriers, including the technical complexity of climate science, specialized jargon, and cognitive overload from the volume of information (Maibach et al. 2023; Andrews et al. 2022; Harold et al. 2020). Narrative-driven, locally relevant communication frameworks and layered information design facilitate deeper public engagement, accommodating varying expertise and interest levels (Degeling and Koolen 2022; Bloomfield and Manktelow 2021; De Meyer et al. 2021; Jones and Peterson 2017; Wibeck et al. 2018). Further, effective local climate communication requires understanding community perceptions and pre-existing knowledge, enabling tailored messages that align with cultural values and identities (Wamsler and Bristow 2022; Schweizer et al. 2013; Nerlich et al. 2010; Gislason et al. 2021; Clayton and Manning 2018).

Cognitive and psychological factors significantly influence citizens' adaptive behaviors. Self-efficacy (i.e., individuals' beliefs in their capacity to meaningfully contribute) critically affects their responsiveness to adaptation messages (Van Valkengoed et al. 2024). Additionally, emotional responses to climate change, such as fear or psychological distancing, alongside conflicts between climate realities and deeply held cultural or identity-based beliefs, create psychological barriers that impede adaptive action (Hochachka 2024; Clayton 2020; Arikan and Günay 2020; Kahan 2015; Spence et al. 2012). Social barriers stemming from community norms and limited exposure to diverse perspectives further compound these challenges (Wamsler and Bristow 2022; Boulianne et al. 2020; Geiger and Swim 2016; Norgaard 2011). Political ideologies, corporate interests, and politicization of climate information additionally shape the efficacy of local climate communication (Berkebile-Weinberg et al. 2024; Moore et al. 2024; Christy et al. 2024; Brulle 2014; Biesbroek et al. 2013; McCright and Dunlap 2011).

Despite long-standing municipal involvement in climate adaptation, there seem to be few studies looking specifically at how cities communicate their climate actions (Boussalis et al. 2018), but it has been identified as a challenge (Nousiainen et al. 2022). The following section addresses this gap through an analysis of municipal climate adaptation communication and public perceptions in Lithuania, offering insights into current challenges and opportunities.

3. Methodology

In order to understand the status quo of municipal communication on climate adaptation with citizens in Lithuania and identify the gaps between policy and implementation, this study adopts a mixed-methods approach. By triangulating data from two primary sources, the research examines how municipalities engage with the public. On one hand, a representative survey of the Lithuanian population provides quantitative insights into citizens' perceptions and their access to municipal climate information. On the other hand, a structured content analysis of climate adaptation communications across all 60 Lithuanian municipalities offers qualitative evidence on the nature and scope of messaging strategies. This integrated approach is particularly valuable in the field of climate communication research, as it captures the complex interplay of social and institutional factors driving public engagement (Maibach et al. 2023; Creswell and Plano 2018).

3.1. Representative survey of Lithuanian population

3.1.1. Study design

The survey questionnaire was originally developed by Brink and Wamsler (2019) to capture a range of factors related to climate-related hazard experiences, worldviews, climate change

concerns and adaptation actions, drawing on theories of climate change adaptation, risk and environmental behaviour. With explicit permission from the original authors, we adapted and translated the instrument for use in the Lithuanian context. The instrument underwent translation and back-translation procedures to ensure conceptual equivalence with the original questionnaire while adapting to the Lithuanian linguistic and cultural context. While the complete questionnaire contained multiple sections, for this study, we focused exclusively on the dimensions related to municipal climate information, climate risk perceptions, adaptation behaviours, and relevant socio-demographic characteristics. Full questionnaire is provided in the supplementary materials.

The *municipal climate information dimension* assessed respondents' interaction with climate-related communications from local governments. Respondents evaluated statements regarding the accessibility and comprehensibility of municipal climate adaptation information using 5-point Likert scales ranging from "Strongly Disagree" to "Strongly Agree." These measures collectively provided insights into both the reach and perceived effectiveness of municipal climate communications.

Climate risk perceptions were measured through a series of statements assessing general awareness of climate change and localized vulnerability perceptions. Respondents indicated their level of agreement with assertions regarding the reality, severity, and anthropogenic nature of climate change. Additionally, they evaluated the likelihood and severity of specific climate impacts on their local communities, including flooding, heat waves, storms, and droughts. The instrument distinguished between cognitive and affective components of risk perception, capturing both intellectual understanding and emotional responses to climate threats. These items employed consistent 5-point scales to facilitate comparative analysis.

The *adaptation behaviors dimension* documented both implemented and intended climate adaptation actions. Respondents reported on specific measures they had already undertaken, such as home insulation improvements, water conservation practices, and emergency preparedness steps. For actions not yet implemented, respondents indicated their likelihood of adoption within specified timeframes and identified barriers to implementation, including financial constraints, information deficits, and efficacy concerns. This approach allowed for a nuanced understanding of both current adaptation practices and factors influencing future behavioral intentions.

Socio-demographic characteristics were captured through standard demographic questions positioned at the conclusion of the questionnaire. Variables included age categories, gender, education level, occupation, residential context (urban/rural), length of residence, home ownership status, household composition, and income brackets based on Lithuanian economic parameters. These demographic measures enabled analysis of how climate perceptions and adaptation behaviors vary across different population segments and served as control variables in multivariate analyses

3.1.2. Sample and data collection

To ensure broad national representation, the survey targeted Lithuanian residents aged 18 and over, using a multistage, stratified random sampling method. Stratification was based on geography (urban/rural), age, gender, education, and occupation to match national population patterns. In total, 1,013 individuals were surveyed between October 23 and November 7 2023, across 109 locations in 31 cities and 43 villages. The fieldwork was carried out by Baltijos tyrimai, a public opinion research company operating in Lithuania and the UK.

A nationally representative sample was obtained through stratified random sampling. The sample was stratified by geography (urban and rural areas), age, education, occupation, and

gender to ensure proportional representation. The sample was gender-balanced (54% women, 46% men) and skewed slightly toward older age groups, with 51% aged 50 or older. The vast majority of respondents identified as Lithuanian (91%), with small percentages of Polish (4%), Russian (3%), and other nationalities (2%). Household income varied: 28% earned up to €1,000 per month 26% between €1,001-€1,800, and 24% over €1,800, while 22% chose not to disclose their income. Educational backgrounds were diverse, with most participants having vocational (27%), technical (18%), or secondary education (20%); only 18% held university degrees. Geographically, 43% lived in suburban areas of Lithuania's five largest cities 25% in other cities, and 32% in villages. Participants were drawn from all ten counties, with the largest share from Vilnius (30%) and Kaunas (20%).

All interviews were conducted face-to-face, following standardized procedures. Participants were selected in line with ESOMAR guidelines, which align with EU standards for public opinion research. Participation was voluntary, and all respondents received a clear explanation of the study, including their rights and the option to withdraw at any time without consequences. Consent was obtained through a two-step process to ensure participants fully understood their involvement. No financial incentives were provided. To protect privacy, all responses were anonymized immediately, and data were stored securely. The full dataset and questionnaire are available on Zenodo¹.

3.1.3. Data analysis

The data analysis was conducted using Python 3.x and its advanced statistical and visualization libraries. Descriptive statistics were applied to demographic variables, including age, gender, education and income, to assess the representativeness of the sample. Access to municipal information and their correlations with adaptation actions were examined using *scipy.stats*. Python's data science ecosystem, including *pandas* and *numpy*, ensured an efficient analysis. We also employed an Analysis of Variance (ANOVA) test to evaluate the differences in the number of adaptation actions across different demographic groups. This statistical method allowed us to determine whether the mean number of actions varied significantly among groups with differing levels of access to municipal information.

3.2. Structured content analysis of municipal climate-related communication

3.2.1. Study design and channel selection

This study used a structured content analysis to document how Lithuanian municipalities communicate about climate change and climate adaptation in channels they directly manage. We focused on official municipal websites and official municipal Facebook pages because these outlets are publicly accessible, broadly used across municipalities and provide the most comparable and consistently archived record of municipal announcements and citizen-facing updates across all 60 cases within a fixed calendar year. The unit of analysis was a single communication item. On municipal websites, this referred to a news item or a page describing a specific activity, project, plan or announcement. On Facebook, this referred to an individual post with its accompanying text. Items were included if they were published on an official municipal channel and contained at least one reference to climate change, climate impacts or climate-related environmental themes.

3.2.2. Data collection

¹ <https://zenodo.org/records/17994953>

Data collection covered January to December 2024 and included all 60 Lithuanian municipalities. For each municipality, the research team identified the official municipal website and the corresponding official Facebook page. Relevant items were retrieved using a keyword-based search strategy designed to capture broad climate content (i.e., klimatas, klimato prisitaikymas, prisitaikymo strategijos, atsparumas klimato poveikiui, potvynių valdymas, sausrų mažinimas and žalioji infrastruktūra). Website items were located using internal site search functions when available, complemented by Google site-restricted searches. Facebook items were located through manual review of the feed. Each item that met the inclusion criteria was logged in a structured coding sheet with the municipality name, platform, URL, publication date and a brief description of the content. Using this procedure, the final dataset comprised 320 climate-related communication items published in 2024. The full dataset is available on Zenodo².

3.2.3. Coding procedure and analytic variables

Coding was conducted by two researchers working in tandem using a shared coding template and an agreed codebook. The first coding step classified each item as adaptation-related or not. Adaptation was defined as communication about actions intended to reduce vulnerability or strengthen resilience to current or expected climate impacts at local or regional level. Mitigation was treated separately as communication focused on reducing greenhouse gas emissions or enhancing carbon sinks. After the adaptation classification, each item was coded for the main stakeholder group addressed or implied in the message (i.e., general residents, businesses, schools, farmers community organizations). Items were then coded for their primary communicative function, distinguishing between informational reporting on plans, projects strategies or events, promotional invitations to campaigns or activities, instructional guidance that provides concrete behavioral advice, consultative messages that request public input and emergency or alert messages related to specific hazards. Full coding instructions, keyword lists and examples of adaptation and non-adaptation messages are included in the supplementary materials.

To compare municipalities of different sizes, message counts were converted into rates per 10,000 inhabitants. Municipalities were grouped by population size for comparative analysis: rural municipalities below 30,000 residents (n=35), regional centers with 30,000 to 100,000 residents (n=19) and major urban centers above 100,000 residents (n=6). Population figures used for classification and rate calculation were taken from the Official Statistics Portal of Lithuania dataset “Resident population, area and population density by county and municipality at the beginning of the year.” The total population covered in the analysis was 2,885,891 residents.

Finally, given the moderate volume of climate-related items, the two researchers maintained consistency through joint calibration at the start of coding, ongoing discussion of borderline cases and agreed updates to the codebook when recurrent ambiguities appeared, particularly when distinguishing adaptation from mitigation and when assigning functions and frames. Items that raised uncertainty were reviewed together and resolved through consensus, creating a documented decision trail within the coding sheet and supporting notes.

4. Results

4.1. Survey results

² <https://zenodo.org/records/17994899>

4.1.1. Citizen perceptions of municipal climate information access by demographic variables

The survey analysis revealed significant differences in how Lithuanian citizens perceive municipal climate information access, particularly concerning education, occupation, and town size, while age showed no significant impact. Notably, lower education levels are associated with higher municipal information scores (ANOVA: $F = 3.9246$, $p < 0.001$; Table 1), suggesting that individuals with lower formal education perceive (or possibly benefit from) more targeted municipal efforts, or it could reflect different expectations. The results also yielded significant differences in municipal information scores across occupational categories (ANOVA: $F = 3.63$, $p < 0.001$; Table 2). This may indicate potential disparities in information access across different job sectors. Moreover, municipal information varies significantly by town size (ANOVA: $F = 4.92$; $p < 0.001$; Table 3), although there is no clear trend between urban and rural settings, as both correlate with small and large degrees of municipality information access. This suggests that municipal information access is not uniform across urban versus rural settings. Age groups, however, showed no statistically significant differences in municipal information access (ANOVA: $F = 1.15$; $p = 0.333$; Table 4).

Table 1. Municipal information by education level

<i>Education level</i>	Mean	Count	Standard dev.
<i>Unknown/other</i>	1.404	47	0.496
<i>Master's/Doctoral degree</i>	1.460	126	0.500
<i>Bachelor's degree</i>	1.547	214	0.499
<i>Non-university higher education (college)</i>	1.566	182	0.497
<i>Higher technical education</i>	1.619	113	0.488
<i>Vocational school</i>	1.648	261	0.479
<i>Secondary school</i>	1.714	63	0.455
<i>Incomplete secondary education</i>	1.857	7	0.378

Table 2. Municipal information by occupation

<i>Occupation</i>	Mean	Count	Standard dev.
<i>Civil servants</i>	1.231	26	0.430
<i>Students</i>	1.375	16	0.500
<i>Skilled workers</i>	1.506	233	0.501
<i>Farmers</i>	1.607	84	0.491
<i>Other</i>	1.619	21	0.498
<i>Private sector employees</i>	1.619	281	0.486
<i>Retired</i>	1.629	284	0.486
<i>Entrepreneurs</i>	1.750	8	0.463
<i>Unemployed</i>	1.818	11	0.405

Table 3. Municipal information by size of town

<i>Size of town</i>	Mean	Count	Standard dev.
<i>30,001-50,000 residents</i>	1.154	13	0.376
<i>300,001-500,000 residents</i>	1.400	50	0.495
<i>100,001-200,000 residents</i>	1.452	31	0.506
<i>2,001-10,000 residents</i>	1.573	103	0.497
<i>500,001+ residents</i>	1.596	188	0.492
<i>up to 2,000 residents</i>	1.621	320	0.486
<i>10,001-30,000 residents</i>	1.629	132	0.485
<i>200,001-300,000 residents</i>	1.857	35	0.355
<i>50,001-100,000 residents</i>	1.875	16	0.342

Table 4. Municipal information by age

Age group	Mean	Count	Standard dev.
30-40	1.500	134	0.502
40-50	1.571	168	0.496
50-60	1.582	184	0.495
<30	1.598	184	0.492
>60	1.603	343	0.490

4.1.2. Climate perception variables analysis

The survey data indicates that respondents hold moderate levels of climate change perception, with mean values ranging from approximately 2.7 to 3.1 on a 5-point scale. Notably, climate perception varies significantly across education levels i.e., respondents with lower levels of educational attainment exhibit the highest degrees of climate risk perception. This trend mirrors the pattern observed in the relationship between municipal information and education. When analysed by age groups, average climate perception scores show only slight variations, suggesting minor age-specific differences.

Table 5. Correlation between climate perception and municipal information, adaptation actions

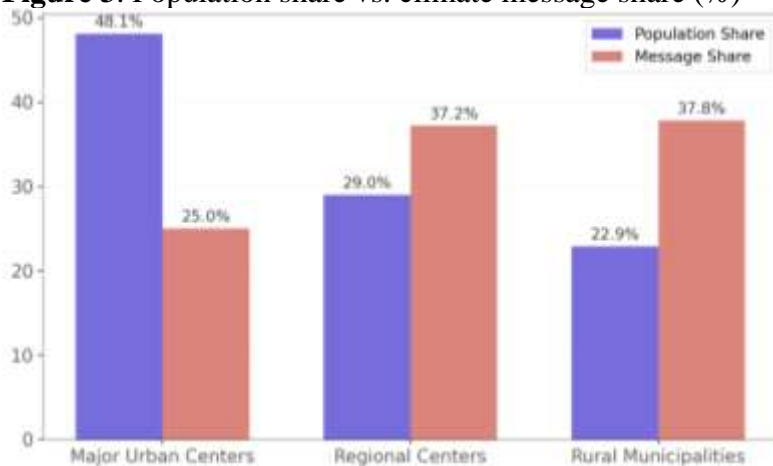
	Cognitive climate perception	Affective climate perception	Municipality information access	Municipality communication
Cognitive climate perception	-	-	-	-
Affective climate perception	0.35 (***)	-	-	-
Municipality information access	0.12 (***)	0.09 (**)	-	-
Municipality communication	0.08 (**)	0.04 (ns)	0.25 (***)	-
Total adaptation actions	-0.12 (***)	-0.02 (ns)	-0.13 (***)	-0.02 (ns)

* Significance: * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$; ns: not significant

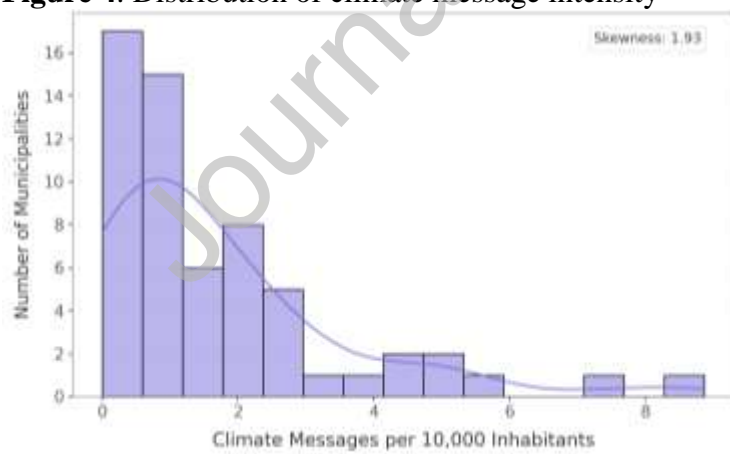
More specifically, weak yet statistically significant positive correlations were found between climate perceptions and municipal information access ($r = 0.12$ for cognitive and $r = 0.09$ for affective perception, with $p < 0.01$ or better), pointing to a limited influence of access to municipal information on climate perceptions. Meanwhile, the correlation between climate perceptions and municipal communication was even lower ($r = 0.08$ for cognitive, $p < 0.05$; and $r = 0.04$, not significant, for affective), reinforcing that the current communication strategies may not sufficiently shape climate awareness. More critically, a weak negative correlation was observed between cognitive climate perception and adaptation actions ($r = -0.12$, $p < 0.001$), while the affective dimension showed a negligible association ($r = -0.02$, not significant). Furthermore, municipality information access also exhibited a significant negative correlation with total adaptation actions ($r = -0.13$, $p < 0.001$), whereas the correlation between municipality communication and adaptation actions was weak and non-significant ($r = -0.02$, ns).

4.2. Content analysis results

The content analysis of municipal climate-related communications reveals variations in communication strategies across municipality types. The dataset comprises 320 climate-related messages across all 60 Lithuanian municipalities, with 24.7% focused explicitly on adaptation. Municipalities communicate about climate issues at a rate of 1.11 messages per 10,000 inhabitants, with 0.27 adaptation-specific messages per 10,000 inhabitants.

Figure 3. Population share vs. climate message share (%)

Communication strategies vary by municipality size in several ways. Rural municipalities report a much higher message intensity (1.83 messages per 10,000 inhabitants) compared to major urban centres (0.58 per 10,000 inhabitants), indicating that, per capita, rural areas are more active in communicating about climate issues. However, a considerably higher proportion of messages in major urban centres (43.8%) are dedicated to adaptation compared to regional centres (15.1%) and rural municipalities (21.5%). Despite representing nearly half of the total population, major urban centres contribute only 25% of the overall climate communications, while rural municipalities (22.9% of the total population) account for 37.8% of all messages. The top city in terms of adaptation messaging is Tauragė. This finding fits the broader context and commitments of the municipality since Tauragė is one out of two municipalities (the other one is Vilnius) which are selected to participate in the EU Mission for 100 climate-neutral and smart cities by 2030, also known as the Cities Mission.

Figure 4. Distribution of climate message intensity

Function coding indicates that municipal climate communication was predominantly informational, with 77.0% of items reporting on completed or ongoing actions such as projects, strategies or events rather than inviting engagement or offering practical guidance. This pattern held for both adaptation-specific and other climate-related messages, but adaptation posts were more likely to appear as emergency or alert communication (13.4% vs 3.2%) and were the only ones coded as consultative (4.9%), typically linked to public presentations or consultations on adaptation-relevant plans. Non-adaptation messages, in contrast, were much more often

promotional or event-oriented (19.0% vs 3.7%), while instructional messages that provide concrete behavioral advice were rare in both groups and accounted for about one percent of all communications. Stakeholder coding (non-exclusive) shows that messages were most commonly directed at the general public (about 87% of all items) with non-adaptation communication more frequently tagged as relevant to educators and young people (50% and 42% of non-adaptation items, respectively), whereas business audiences appeared in about two fifths of all messages and were tagged more often in adaptation-related items (49% vs 37%), suggesting that adaptation outreach is broader and less frequently routed through school-based or youth-oriented messaging.

5. Discussion and implications

This study combined a nationally representative survey with a systematic analysis of climate-related messages published by Lithuanian municipalities on official websites and Facebook pages. The two components are complementary rather than tightly matched in time: the survey captures citizen perceptions and self-reported behaviours in late 2023, while the communication dataset describes what municipalities published during 2024. Read together, they still provide a coherent picture of local adaptation communication as it is experienced by residents and as it is produced by municipalities, while keeping in mind that direct one-to-one alignment between individual perceptions and the 2024 message environment cannot be assumed. Overall, the findings point to a mismatch between the current structure of municipal climate communication and what would be needed to support household-level adaptation. Citizens report uneven access to municipal information across social groups, and the survey shows that higher perceived access is not associated with more reported adaptation action. At the same time, municipal messages are dominated by reporting on institutional activity, with relatively little instructional guidance and little framing that positions residents as active partners in adaptation.

5.1. Social patterning in perceived municipal information

Perceived access to municipal climate information varies by education, occupation and settlement size, while age differences are small. These results match earlier findings that adaptation is experienced unevenly across social groups and places (Hjerpe et al 2017; Vandecasteele et al 2024).

The education gradient in this sample is notable because respondents with lower formal education report higher municipal information scores than those with higher education. This runs against a simple expectation that more educated groups will always feel better informed, and it suggests that “information access” in the survey captures both exposure and evaluation. The data do not identify a single mechanism behind this pattern, but two interpretations fit the evidence and prior work on information inequality. One possibility is that groups apply different standards when judging whether municipal information is “enough.” General visibility of climate topics, hazard warnings or project announcements may be evaluated as adequate by some groups, while other groups expect more specificity, clearer links to locally relevant risks and practical guidance and therefore rate the same information as insufficient. These variations echo work on adaptation that stresses the importance of sectoral and territorial context for how climate risks and responses are perceived (Gislason et al 2021; Olazabal et al 2022). A second possibility is that municipalities reach certain groups more consistently through routine local institutions and channels, including settings linked to work, services or community life, while other groups rely more on non-municipal sources. These explanations are not mutually exclusive, and the key point for interpretation is that reach and usefulness should be treated as separate communication outcomes.

Furthermore, differences by occupation and settlement size reinforce that municipal information is embedded in everyday routines and local contexts. The limited age gradient is also informative, but it should not be read as evidence that digital divides do not matter. It may simply mean that people form judgements based on general visibility of municipal messaging, not on active searching or detailed comprehension. Without direct measures of channel use and exposure, the survey can identify patterned perceptions but cannot explain through which routes people are reached or which formats they find most usable.

5.2. Climate perception, municipal information and adaptation behaviour

A second key finding is the weak and partly negative association between climate perception, perceived municipal information access and self-reported adaptation actions. Climate perceptions are moderate and slightly higher among respondents with lower education, yet neither cognitive nor affective perception is strongly linked to the number of adaptation actions. Municipal information access is weakly related to perceptions and does not show a positive association with action. This pattern aligns with international evidence on the awareness-action gap: awareness and concern do not reliably translate into behaviour change when efficacy beliefs are low, when responsibility is attributed primarily to institutions, or when material constraints shape what households can do (De Meyer et al 2021; Maibach et al 2023; Hochachka 2024). In Lithuania, earlier work has noted low self-efficacy and a tendency to assign responsibility for climate response to higher governance levels, which may limit the behavioural impact of additional information (Balžekienė et al 2020; Telešienė et al 2021). In such a context, information about risks can raise salience without increasing a sense of feasible action, especially for adaptation measures that involve costs, permissions, housing conditions or reliance on municipal infrastructure (Van Valkengoed et al 2024; Wamsler and Bristow 2022). The negative correlations should not be treated as evidence that municipal communication discourages adaptation. The survey is cross-sectional, and it is plausible that those who are more aware of risks also recognise barriers more clearly, or that those who take actions rely on other information sources, which would weaken any association with municipal information. The more defensible interpretation is that perceived access to municipal information, as currently experienced, is not sufficient to support adaptation behaviour at scale.

5.3. Municipal climate communication and adaptation capacity

The content analysis indicates that municipal climate communication is uneven and that only about one quarter of identified climate-related items focus explicitly on adaptation. Results indicate that per-capita communication rates are higher in rural municipalities, while major urban centres post fewer climate-related messages per resident but devote a larger share of their messaging to adaptation. These differences should be interpreted cautiously. Per-capita rates are sensitive to denominator size, meaning a small number of posts can shift rates strongly in smaller municipalities. In addition, the analysis captures two official channels. Larger cities may communicate through additional channels not included here (e.g., newsletters, local media partnerships or other social platforms), which could lead to an underestimate of their overall activity. Communication patterns may also be shaped by year-specific events and project cycles. For these reasons, rural-urban differences in message intensity should not be read as a direct ranking of commitment or organisational capacity. With those caveats in mind, the composition of messages is consistent and informative across municipality types. Most communication is informational reporting about projects, strategies or events, while instructional messages that provide concrete behavioural guidance are rare. Adaptation messages stand out mainly because they appear more often as alerts and because a small share takes the form of consultative notices linked to planning processes. This suggests that adaptation communication becomes visible primarily when hazards are immediate or when

municipalities are required to publicise formal procedures, rather than as sustained, guidance-oriented engagement with residents.

These patterns are consistent with earlier work that documents the difficulties many European municipalities face when moving from formal mandates and plans toward sustained adaptation practice (Reckien et al 2018; European Court of Auditors 2023; Reckien et al 2023). They cannot be taken as direct evidence of limited capacity, since this study did not measure resources or staff numbers, but the low intensity and one way character of communication sit comfortably with the broader picture of cities working under tight budgets, small communication teams and competing priorities (Lee et al 2022; Rogers et al 2023).

5.4. Aligning citizen perceptions and municipal communication

Because the survey and the message dataset come from adjacent time periods, they cannot be combined to make strong claims about causality or direct exposure. Still, they converge on the same practical issue. Many residents report some degree of municipal information access, yet adaptation actions are limited and not positively associated with that information. At the same time, municipalities mainly communicate by reporting institutional activity and by using frames that highlight risk and technical planning rather than explaining household-level options and support. A plausible explanation is that current municipal communication makes climate risks visible and signals that municipalities are active, but it does not reliably help residents translate concern into feasible steps. Reporting on projects and plans can strengthen accountability and legitimacy, but it can also leave residents uncertain about what to do, how to prioritize actions, what support exists and how household responsibilities connect to municipal measures. Under that interpretation, the weak association between perceived information access and reported action is not surprising. It also points to why social differences appear in perceived access: groups may judge visibility and adequacy differently even when the underlying content remains largely non-instructional.

The stakeholder patterns are consistent with this diagnosis. Messages are largely directed at the general public, with limited segmentation. Where differences appear, non-adaptation messages more often connect to schools and youth audiences, while adaptation messages more often reference business audiences. This suggests that adaptation content is not consistently anchored in settings that support everyday learning and household decision making, and it is not systematically tailored to groups likely to face different risks and constraints. The Lithuanian case thus aligns with wider arguments that communication needs to be more action oriented, locally grounded and attentive to structural barriers if it is to contribute meaningfully to closing the adaptation-action gap (Moser 2016; De Meyer et al 2021; Degeling and Koolen 2022).

5.5. Practical implications

The findings suggest that improving municipal communication is not mainly a question of producing more posts. It is a question of making communication more action-supporting and better connected to feasible pathways under real constraints. Given that many messages already report on projects and plans, a practical improvement is to pair reporting with short, locally specific guidance that clarifies what residents can do, what the municipality provides and how residents can access support. Without tangible support or clear procedures behind the message, communication is unlikely to shift behavior, so content changes should be tied to actual services, programs or planning processes. The prominence of alerts in adaptation messaging offers a concrete opportunity. Alerts capture attention, and they can be followed by brief, practical guidance tied to local conditions and municipal services. Similarly, consultations can be communicated as more than procedural requirements. Plain-language summaries of what is being decided, what trade-offs are involved and how resident input will be used can make

participation more meaningful. This would also address the current gap between consultative functions and the lack of participation framing by making shared agency explicit rather than implicit. Audience differentiation is another implication. Differences in perceived municipal information access by education, occupation and settlement size indicate that a single “general public” approach will miss important audiences. Municipalities can test formats that accommodate different routines and constraints, including layered communication where short posts link to stable web pages with local checklists, maps, contact points and eligibility information for support. Such adjustments will not remove structural barriers (i.e., resource constraints on the municipality side), but they can reduce uncertainty, increase perceived feasibility and clarify responsibility boundaries, which are preconditions for action in settings where resources are limited.

5.6. Limitations and future research

Several limitations shape interpretation of the results. The survey captures perceptions and self-reported behaviours at one point in time, so associations are correlational and may be affected by recall and social desirability. The content analysis covers one calendar year and two official channels, which likely undercounts communication through local media, printed newsletters, other platforms and face-to-face engagement. In addition, survey fieldwork took place in late 2023 while the communication dataset covers 2024, which limits temporal alignment between individual perceptions and the coded message environment. The analysis therefore supports triangulation and diagnosis, but not strong causal claims. Additionally, coding was conducted using a shared template and consensus-based resolution of ambiguous cases, which supports internal consistency and produces a documented decision trail, but independent double-coding designed for formal reliability statistics was not part of the workflow. Finally, per-capita indicators also require caution because distributions are skewed and denominators differ substantially across municipality types. Future research could address these limits by tracking municipal communication across multiple years and expanding channel coverage, by linking communication patterns to municipality characteristics such as staffing and budget proxies, and by using designs that better support causal inference. This could include panel surveys, message experiments that test specific guidance formats, and follow-up measurement of efficacy beliefs and uptake of feasible adaptation actions.

6. Conclusions

The findings of this study offer valuable guidance for municipalities seeking to enhance their climate communication and promote adaptive behaviours. It is essential to acknowledge that there is no single perfect communication strategy; instead, a nuanced and adaptive approach is required, with continuous monitoring and improvement of communication efforts. Crucially, it must be recognized that communication is only one component of a broader strategy for achieving sustainable change. As highlighted by Nerlich et al. (2010), effective behaviour change necessitates the integration of communication with practical interventions, such as supportive policies and concrete climate action, all of which require substantial resources. Municipalities must therefore prioritize a holistic approach that combines effective communication with tangible actions to build climate-resilient communities.

Ethics approval and consent to participate

The survey data used in this study were collected by Baltijos tyrimai, an independent public research organization. According to the information provided by the company, data collection followed established ethical guidelines and participants gave informed consent.

This study was approved by Ethical monitoring board at Citizen Science Hub at VILNIUS TECH, reference number No. CSH-2023-02. All participants provided informed consent prior to taking part in the research.

Consent for publication

All participants provided consent for anonymized data to be used in publications.

Competing interests

The authors declare that they have no competing interests.

Author contributions

Monika Mačiulienė led the research project, overseeing the study design, analysis, and manuscript preparation. She was primarily responsible for drafting and writing the report, ensuring that the research objectives were clearly articulated and met. Aelita Skarzauskiene, Kristina Kovaitė, and Paulius Šūmakaris provided essential support by managing the survey implementation and coordinating the data collection process, particularly for the communication aspects. Their contributions were invaluable in gathering and processing the primary data that underpinned the study's findings.

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Availability of data and materials

The datasets generated and/or analyzed during the current study are available on Zenodo.

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Declaration of interests

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