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Citation for the original published paper (version of record):
Stenfors, E., Mickelsson, M., Landström, C. et al (2026). Evolving perceptions of drought risk and management: Insights from a repeated survey of Swedish municipalities. International Journal of Disaster Risk Reduction, 143.
http://dx.doi.org/10.1016/j.ijdrr.2026.106357

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International Journal of Disaster Risk Reduction 143 (2026) 106357

Contents lists available at ScienceDirect

International Journal of Disaster Risk Reduction

journal homepage: www.elsevier.com/locate/ijdrr

Evolving perceptions of drought risk and management: Insights from a repeated survey of Swedish municipalities

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ARTICLE INFO

Keywords:
Risk awareness
Repeated cross-sectional data
Hydrological extremes
Organizational response
Adaptation
Vulnerability

ABSTRACT

As societies face increasingly unpredictable climates, drought management plays an important role in resilience. Meanwhile, drought perceptions influence agenda-setting processes among local authorities. This repeated cross-sectional survey study in Sweden investigated municipalities' perceptions of the 2017, 2018 and 2022 droughts, future drought risk, and management practices. The share of municipalities reporting a drought plan increased from 14 % in 2018 to 24 % after 2022. Similarly, the share reporting no operational drought definition declined from 81 % to 51 % ($p < 0.05$). However, 58 % still reported no drought plan after 2022, and scientific drought typologies and terminology were rarely used. Across all drought years, municipalities rated management higher than preparedness, indicating stronger perceived capacity to respond to ongoing events than to prepare for future droughts. Municipalities perceived the 2022 drought as significantly less severe and less impactful than the 2018 drought ($p < 0.05$). Perceived drought severity in 2022 was not positively associated with SPI3 or SPI6 meteorological drought conditions across municipalities. Perceived future drought risk was significantly lower after 2022 than in 2018 ($p < 0.05$). More severe drought conditions in 2018 were associated with higher drought risk perceptions after 2022 among northern municipalities, but not across Sweden as a whole. The results show that formal drought preparedness remains limited and that municipal risk perceptions do not consistently reflect meteorological drought indicators. Strengthening proactive preparedness requires institutionalized drought plans, operational definitions, and monitoring approaches aligned with local perceptions and realities, including locally relevant impacts, exposure pathways, and municipal responsibilities.

1. Introduction

In a changing climate, societies are facing increasingly unpredictable extreme events [1]. Traditionally categorized as slow-onset

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https://doi.org/10.1016/j.ijdrr.2026.106357
Received 3 February 2026; Received in revised form 24 June 2026; Accepted 1 August 2026
Available online 1 August 2026

natural hazards [2,3], droughts often develop slowly over time with the potential of causing wide-ranging impacts affecting several parts of society [4]. Consequently, they are some of the costliest types of natural hazards, accounting for an estimated 13.3 billion dollars in economic losses and affecting 29.5 million people globally in 2024 alone [5]. Research suggests that drought intensity has already risen in response to climate change [2], and increases in drought frequency and severity have been globally observed [6] across all continents [7]. Extreme drought events, in which regional water deficits substantially diverge from normal conditions, have also risen in frequency, with regional hotspots in areas such as the United States, South America, Europe, Australia, Africa, and Russia [7]. The European continent has faced several large-scale drought events in recent years, such as the 2018 and 2022 droughts that affected large parts of the continent as well as Scandinavia [8,9]. The 2022 drought accounted for one of the worst drought events in the continent's history [9], resulting in over EUR 40 billion in economic impacts [10]. These recent European drought events also showed how cold high-latitude regions such as Sweden can be severely affected by droughts. In Sweden, the 2018 drought resulted in substantial impacts nationally, affecting sectors such as agriculture, forestry, and energy production [11], and causing damage to aquatic ecosystems [11,12]. These regions are expected to see increases in both temperature and precipitation in a changing climate [13], accompanied by shifts in hydrological regimes. Drought risk is governed not only by changes in drought frequency or intensity but also by complex interactions between drought events and the vulnerability of exposed systems. While drought events can emerge at regional or continental scales, their corresponding drought risks and societal impacts are shaped by the local contexts driving changes in exposure and vulnerability. Responsible for local planning, as well as providing reliable services such as drinking water supply and emergency services [14,15], municipalities, as local authorities, play a pivotal role in managing the risk of hydrological extremes [16] such as droughts.

In the disaster science community, disaster risk is regularly expressed as a product of a *hazard*, *exposure* to this hazard, and *vulnerability* to the hazard [17]. As a hazard, drought commonly arises from climatic variability and creates a regional water deficit compared to normal conditions [2,4,18]. While drought is frequently discussed alongside water scarcity, the two terms refer to distinct concepts. Drought is primarily a climate-driven phenomenon, sometimes intensified by anthropogenic processes [19], whereas water scarcity is a human-induced condition resulting from an imbalance between long-term water supply and demand. Clarifying this distinction is crucial as drought constitutes a natural hazard, while water scarcity reflects socio-economic and governance challenges, requiring different management strategies [20]. Drought is commonly classified according to the part of the hydrological system in which it manifests. Four main drought types are typically distinguished: meteorological drought (deficit in precipitation, occasionally combined with an increase in evapotranspiration), soil moisture drought (soil moisture deficit), hydrological (ground- or surface water deficits), and socioeconomic drought (drought effects on water as an economic good) [2,3]. These drought types affect different systems and exposure pathways [21]. For example, soil moisture drought can severely affect agriculture and forestry, whereas hydrological drought impacts water supply. Drought vulnerability, while proven hard to define universally, refers to the predisposition of an entity exposed to a drought to be negatively affected by the event [22,23]. It encompasses elements such as drought susceptibility and capacity to cope and adapt to drought events [24]. Coping capacity in this sense refers to the ability to employ short-term, reactive measures using existing resources and strategies to manage a drought event [24–26]. On the other hand, adaptive capacity involves long-term, strategic, and proactive transformation in anticipation of future drought events [24,25,27]. Measuring drought vulnerability is complex and dynamic, as it depends on multiple factors that can vary by drought type, exposed systems, scale, or time [28].

In socio-hydrological systems, vulnerability is affected by human-nature feedbacks that cause societies to respond to drought events at different hazard levels [4,29]. Such responses can influence both adaptive and coping capacities, altering societies' ability to adjust to future risks and strengthening (or weakening) societal resilience to droughts. Ultimately, human actions have the potential to either mitigate or exacerbate drought risk [16,30]. From the perspective of a local authority, drought responses can be reactive, focusing on temporary actions initiated after a drought event has started and aimed at relieving the effects of the ongoing event (e.g. emergency relief in the form of water trucks), without a focus on reducing long-term vulnerability [6]. Reactive crisis management has been criticized for, for example, causing inefficient solutions and not addressing underlying risk drivers or the potential impacts of future drought events [6]. In contrast to reactive crisis management, international disaster risk reduction frameworks, including the Sendai Framework for Disaster Risk Reduction, emphasize the need to anticipate, reduce, and manage risks before hazardous events occur [31]. Proactive drought risk management therefore aims to reduce drought vulnerability and strengthen preparedness and adaptive capacity through measures implemented before drought conditions develop. Such measures can include drought monitoring and forecasting, the development of new water sources or emergency supply systems, or administrative instruments like drought risk management plans and policies (hereafter: drought plans) [6,32,33]. These plans typically outline responsibilities, coordination mechanisms, mitigation and preparedness efforts, and procedures for activating measures during drought events, making them a critical component of proactive municipal drought management.

However, moving from reactive to proactive drought management can be challenging. Drawing on agenda-setting theory, the municipal policy agenda can be understood as the set of issues to which local political actors devote attention. Agenda setting is a competitive process in which issues gain or lose prominence depending on prevailing interests and attention [34]. How a problem or solution is perceived within these processes can therefore shape how drought management and policy solutions are designed and adopted [35–38]. The creeping, often slow-onset nature of droughts, together with their direct and indirect impacts, can reduce their perceived importance relative to more immediate issues and thereby reduce their salience on policy agendas [34,35]. Hence drought risk management practices and drought perceptions within local authorities play a critical role for societal drought resilience. Yet, there is still limited understanding of how municipal local authorities perceive drought risk and recent drought events [14,16,33,39]. While the relationship between risk perception and risk management has been widely explored in organizational contexts [40], few studies have investigated these dynamics within local authorities. Even fewer studies have explored how such dynamics in local authorities evolve over time [41]. This gap is significant, as drought awareness among authorities is a key factor affecting drought vulnerability [42]. Moreover, it has been suggested that risk perception can decay over time following extended periods with few extreme events [43] and that studying risk management over time contributes to a more nuanced and context-specific understanding of the concept [44].

In December 2018, Teutschbein et al. [33] conducted an online survey targeting municipal local authorities in Sweden to assess linkages between observed and perceived drought severity, impacts and management following the 2017 and 2018 droughts. Their findings revealed a mismatch between observed and perceived drought severity, where local authorities experiencing moderate to extreme drought conditions tended to underestimate the severity compared to observed data [33]. To investigate how such perceptions evolve over time, the survey was repeated in 2023, this time focusing on the 2022 drought. The same set of questions was again distributed to Swedish municipalities, allowing for a repeated cross-sectional comparison with the 2018 dataset. This repeated survey design provides a rare opportunity to explore the temporal dynamics of drought risk management and perception within local authorities. Contextual differences between the two drought events further enhance the value of this comparison. The 2018 drought event affected a majority of Sweden's landmass [33,45] and was record-breaking in terms of drought intensity across large parts of southern Sweden, representing the most severe spring and summer drought conditions since 1950 [45]. The drought event resulted in substantial impacts on several sectors [11,46,47], accompanied by extensive media coverage. In contrast, while the 2022 European drought did severely affect parts of Sweden, it had more limited spatial coverage [48], lower intensity, and received less public resonance regarding its effects on water availability [49].

Building on the study by Teutschbein et al. [33], this article aims to fill a gap in disaster science by examining how perceptions of drought risk and drought management within local authorities evolve over time, and how they relate to observed hazard severity. Although responses were provided by individual representatives, the survey was distributed through official municipal channels and framed to capture the organization's perspective rather than personal views. Using data from repeated surveys of Swedish municipalities that capture perceptions of both the 2018 and 2022 droughts, we investigate whether i) the implementation of drought plans, tools and terminology in Swedish municipalities has increased over time, ii) drought perceptions differ between the 2018 and 2022 events, iii) the perceived severity of the 2022 is correlated with observed drought conditions, iv) drought risk perception in local authorities changes over time, and v) whether it is influenced by previous drought experiences.

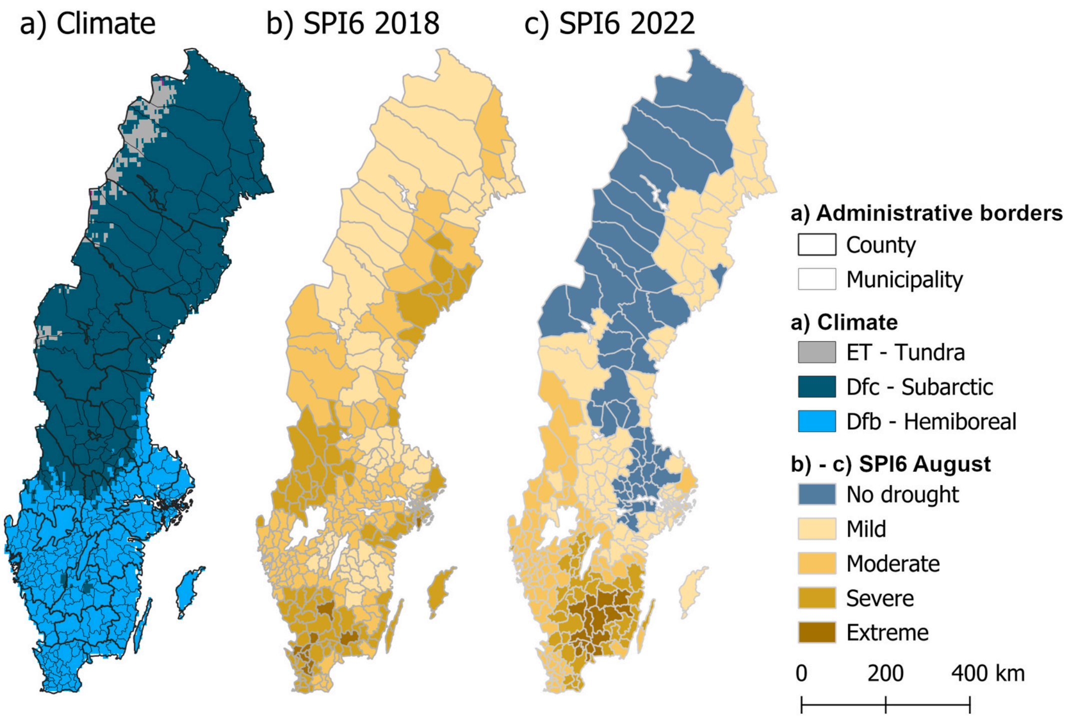

Fig. 1. Study area depicting (a) Köppen-Geiger climate zones [53] and administrative borders in Sweden, (b) drought conditions as of August 18th 2018 according to the Standardized Precipitation Index (SPI6) [33], (c) drought conditions as of August 1st 2022 according to SPI6 [54]. Climate zones comprise tundra climate (ET; warmest monthly mean temperature below 10 °C), subarctic climate (Dfc; cold, fully humid climate with cool summers), and hemiboreal climate (Dfb; cold, fully humid climate with warm summers).

2. Methods

2.1. Study area

The research was conducted in Sweden, northern Europe. Sweden has a population of 10.6 million [50], with most residents concentrated around the larger cities and along the coastline [51]. It covers approximately 408 000 square kilometers and is largely covered by forests. According to Beck et al. [52], Sweden mainly spans three climate zones ranging from tundra (ET) climate (<10 °C warmest month) in the Scandinavian Mountains in north-western Sweden, to subarctic boreal (Dfc) climate with cool summers in much of northern Sweden, to warm-summer hemiboreal (Dfb) climate in southern Sweden [52,53] (Fig. 1a).

Sweden is divided into 21 counties and 290 municipalities (Fig. 1a). Water management is primarily overseen by municipal self-governments, which are tasked with managing local water resources and ensuring the provision of water supply services. Swedish municipalities also have an important role in civil emergency preparedness (CEP). CEP in Sweden is governed by three basic principles: responsibility, proximity and similarity. The principle of responsibility implies that the actor in charge of operations during normal conditions should have the corresponding responsibility during societal disruptions. The principle of proximity implies that societal disruptions should be managed locally, by those directly affected and responsible. The principle of similarity means that operations should function as close to normal as possible during societal disruptions. Organizations should therefore not undergo more change than necessary in response to the disrupting event [15].

The role of Swedish municipalities in civil emergency preparedness is regulated by law in order to reduce vulnerability in municipal operations and ensure their ability to manage extreme events during peacetime [15]. The work can be categorized as responsibilities relating to analysis and planning, geographical area responsibility, training and exercises, and reporting. The analysis and planning stage stipulates that municipalities must analyze which extreme events (e.g., natural hazards, terrorism etc.) the municipality may face, how such events can affect municipal operations, and which risk-reducing measuresthat are applicable in the face of such risk [44]. The results should be assessed and summarized in a risk and vulnerability assessment (hereafter, RVA) [15]. The RVA plays a pivotal role in the Swedish emergency response and preparedness system. All Swedish municipalities, along with county administrative boards, regions and other monitoring agencies are required to prepare and report RVAs on a two- or four-year basis. Municipalities report their work with RVAs to the county administrative board, that compiles all municipal RVA reports and submits them to the Swedish Civil Contingencies Agency (in short: MSB) along with their own RVA report [55]. The RVA process has been described as strengthening risk awareness and risk competence within the organizations [44,55] and ensuring that work related to RVA is prioritized, providing a basis for further analysis and regular planning work [55]. At the same time, it has been argued that the results of the RVA process are not always sufficiently shared with the larger organization [44] and that the results are not always translated into risk-reducing measures [55,56].

Since January 2023, municipalities are also obligated by law to have an up-to-date water services plan, including a long-term plan for ensuring public water supply. to the plan must also include an assessment of relevant measures needed in order for public water and wastewater services to function during increased strain in connection with cloudbursts. The water services plan is evaluated every four years to ensure that it is up-to-date in relation to the municipalities' public water services [57].

While Sweden has traditionally been considered water-abundant, it has not been exempt from droughts. The country experienced several impacts during the 2018 drought, such as large drops in crop yields [58], low inflow to hydropower reservoirs [11], and large-scale forest fires [47]. Several municipalities introduced irrigation bans or advised their residents to use drinking water sparingly [59]. The 2018 drought affected all Swedish municipalities, resulting in widespread observed drought conditions (Fig. 1b). In contrast, the 2022 drought was spatially limited, affecting a subset of municipalities, while several municipalities did not experience drought conditions at all (Fig. 1c).

2.2. Data collection and categorization

An online survey was conducted using a web-based questionnaire on two occasions. The survey questions are provided in Supplementary Material, S1. The questionnaire was first sent out in December 2018 to the official email address of all 290 Swedish municipalities (118 responses, 41 % response rate). A follow-up survey was then conducted in June 2023 (55 responses, 19 % response rate) including the same questions as in the first survey round. The questionnaire included a combination of free-text, multiple-choice, ranking, binary, and respondent specific (e.g., municipality, job title) questions. Teutschbein et al. [33] provide a detailed description of the survey design used in December 2018. The second survey round was conducted within the scope of a larger European study [45] and also included additional questions that will not be addressed in this study.

Of the 118 municipalities that responded to the first survey and the 55 that responded to the second, 22 participated in both rounds of data collection. The municipalities answering both survey rounds were predominantly located in southern Sweden (73 %) and classified as rural (91 %).

To enable broader comparison across respondent groups, including all responses collected, the study was performed as a repeated cross-sectional study, in which respondents share key contextual characteristics (e.g., belonging to municipalities located in similar geographic or demographic characteristics). Municipalities were categorized geographically as either northern or southern, based on their location relative to the 60°N latitude. Furthermore, they were also classified demographically as either urban (population density > 300 per km^2) or rural (population density < 300 per km^2). Responses were then analyzed using descriptive statistics, studying the overall characteristics of management, perceptions of recent drought events, and perceptions of climate change and drought-related risk. Analyses were performed in Microsoft Excel and RStudio [60,61].

2.3. Data analysis

2.3.1. Changes in the use of drought plans, tools and terminology over time

Changes over time regarding aspects such as implementation of drought plans, operational drought definitions, and use of drought-related terminology were studied using responses obtained in the first and second survey rounds. Data were analyzed using descriptive statistics, including frequency distributions and percentages for categorical variables. Comparisons between the two survey rounds (2018 and 2023) were performed using chi-square tests for differences in proportions, with statistical significance set at $p < 0.05$. Open-ended responses that added further information regarding aspects such as lack of a drought plan or existing collaborations were coded into thematic categories and summarized as percentages of the total number of respondents providing additional information.

2.3.2. Perception of recent drought events

In order to study changes in the perception of recent drought events, the two survey rounds collected data regarding how respondents perceived recent drought events in their municipality with regard to severity, impact, municipal preparedness, and municipal drought management. The first survey round collected information regarding the 2017 and 2018 drought events, whereas the second survey round focused solely on the 2022 drought year. Respondents rated these parameters on a five-point ordinal scale (e.g. 1 (no impact) to 5 (large impact)) and the responses were analyzed using descriptive statistics including frequency distributions. Differences in perceptions between drought years and between regions (northern vs. southern Sweden) were analyzed using non-parametric tests: Pearson's chi-square tests of independence [62] for categorical comparisons, Kruskal–Wallis tests for group differences [63], and Wilcoxon rank sum tests for pairwise comparisons [64], applying corrections for multiple testing. The outcomes of the statistical analyses are available in Supplementary Table S2.

2.3.3. Perceived versus observed drought severity 2022

The results of the first survey conducted by Teutschbein et al. [33] indicated that there was limited correlation between perceived drought severity and observed drought severity for the 2017 and 2018 drought events, when analyzed from a hydrological perspective. Their results revealed that the only consistently significant correlations at the 5 % level were observed between perceived severity and SPI6 in 2018, whereas associations with SGI6 were limited and generally weak for both drought years. Such a disconnect can potentially hamper drought preparedness and effective drought management [33]. To follow up on this analysis, perceived severity of the 2022 summer drought was assessed through survey responses from the municipalities. Respondents were asked to rate water availability on a six-point scale: flood, normal conditions, mild drought, moderate drought, severe drought, or extreme drought. This approach captured both ends of the hydrological spectrum, from excess water to extreme drought conditions. If respondents were unsure, they could select the option "I don't know". These ratings were then compared with observed SPI3 [65] and SPI6 [54] data for the spring and summer of 2022. The datasets were obtained from the European Drought Observatory (EDO) with a spatial resolution of $0.25^{\circ} \times 0.25^{\circ}$. The SPI6 data were used to assess medium-term drought conditions from March to August in the surveyed municipalities, serving as an indicator of factors such as reduced streamflow and reservoir storage. SPI3 data (based on a three-month accumulation period between June and August) were used to evaluate short- to medium-term drought effects, such as reduced soil moisture and small-scale streamflow. The SPI drought indicator is among the most well-known and used drought indicators [66], and is promoted by the World Meteorological Organization for meteorological drought monitoring [67]. Specifically, SPI3 and SPI6 data for August 2022 were downloaded, and the mean and median SPI values were calculated for each municipality using zonal statistics based on spatial overlay with the respective SPI raster data. The mean and median SPI3 and SPI6 values for each municipality were used to represent the SPI-based drought intensity for each municipality in the subsequent analysis. All spatial processing was carried out in QGIS (version 3.40.6) using the Zonal Statistics tool. All SPI3 and SPI6 values were translated into measures of drought severity using a classification scheme ranging from normal conditions to mild, moderate, severe, and extreme drought conditions.

The computed drought severity for 2022 was compared to the perceived drought severity among the municipalities participating in the second survey round, using Spearman's rank correlation coefficient ρ_s [68].

2.3.4. Changes in perceptions of drought risk in future climates

The evolution of drought risk perception over time was studied by letting the respondents assess how the risk of drought will change in future climates in the two survey rounds. The respondents were asked to rate their assessment on a five-point rating scale (1 - strong decrease to 5 - strong increase). The data collected was analyzed using descriptive statistics including frequency distributions, and Wilcoxon rank-sum tests for comparison between the two survey rounds (2018 and 2023).

2.3.5. Influence of past drought experiences on risk perception

The SPI6 for August 2018 was used to analyze the potential effect of previous drought severity on drought risk perception. The SPI6 for 2018 was based on the computations by Teutschbein et al. [33] based on Sweden's national gridded 4×4 km precipitation dataset (PTHBV). The computed SPI6 values were used to analyze potential correlations with perceived drought risk under future climate scenarios, as reported by municipalities in the second survey round (2023), using Spearman's rank correlation. Similarly, perceived drought risk was compared to the computed mean and median (as detailed in the previous section) SPI3 and SPI6 values for the spring and summer seasons of 2022.

2.3.6. Non-response bias assessment

To assess potential non-response bias in the second survey round, response rates were examined in relation to municipalities' observed drought severity in 2018 and 2022, measured using SPI6. For each year, the response rate was calculated separately for each drought severity category. The response rate based on the 2022 drought was highest among municipalities with moderate drought at 25 %, followed by no drought conditions (19 %), while it was lower for severe and extreme drought conditions, at 12 % and 7 %. For 2018, the pattern was also nonmonotonic: municipalities experiencing moderate drought conditions had the highest response rate at 23 %, followed by severe at 18 %, mild at 13 %, and extreme at 9 %. This suggests that municipalities with more severe drought exposure were not systematically overrepresented among respondents. However, because the number of responding municipalities is relatively small, especially within the more severe categories, the results should be interpreted with caution.

3. Results

3.1. Respondent characteristics by survey round

The survey received 118 responses in 2018, and 55 responses in 2023 (Table 1). Most respondents were managers (66 % in 2018, 44 % in 2023), most of whom worked with water and/or wastewater. The rest of the respondents primarily worked as engineers (18 %, 22 %), strategists (7 %, 15 %), coordinators (4 %, 9 %), or a mix of other municipal roles such as ecologists, inspectors, or investigators (5 %, 11 %). Most municipalities answering the survey were categorized as rural (89 %, 93 %), with a majority of the municipalities responding being located in the south of Sweden in both survey rounds.

3.2. Cross-sectional findings from survey rounds 1 and 2

3.2.1. Status, barriers, and practices in local drought risk management

The share of municipalities having a drought plan increased between the two years (14 % in 2018, 24 % in 2023). However, a majority of the municipalities still lack a drought plan (72 %, 58 %) or have not sufficiently informed their employees about its existence. For example, 14 % of respondents in 2018 and 18 % of respondents in 2023 answered that they "did not know" if the municipality has a drought plan. The municipalities reported insufficient resources (49 % of municipalities without a drought plan), time constraints (33 %), and lack of knowledge (10 %) as reasons for not having a drought plan in place. More than half of the municipalities in both survey rounds indicated other reasons for the lack of a drought plan. Not all municipalities specified what constitutes *"Other"* reasons *(All municipalities offered specification in 2018, 48 % in 2023)*. However, among the "*Other"* reasons specified by the respondents in 2018 and 2023, some municipalities described that they saw "*no need*" for a drought plan (30 % of provided specifications in 2018, 17 % in 2023), that they had "*little to no issues with drought" (24 %, 8 %)*, or that they perceived their municipality to have "*a reliable water resource, or backup reserves" (19 %, 17 %)*. Most respondents in both survey years (81 %, 51 %) answered that the municipality does not have operational drought definitions, and more than 15 % answered that they "did not know" in both survey rounds. However, the proportion of municipalities reporting an operational drought definition increased, with a significant difference ($p < 0.05$) in response frequencies between the two survey rounds. Meanwhile, there was a strong, statistically significant association between having a drought plan and having operational definitions ($\chi^2 = 19.25$, $p < 0.001$), where municipalities reporting having a drought plan were more likely to also report having an operational definition.

Among the respondents, broad terms relating to water availability such as "*water scarcity"* and "*drought*" were more frequently used than more detailed descriptions of drought types (Fig. 2). For example, "*socioeconomic drought*", which relates to when drought affects water as an economic good in the socioeconomic system, was reportedly never used by a vast majority of respondents in both survey years. The collaborations reported by the municipalities were similar between the two survey rounds, following an overall similar pattern across the survey years. When working with droughts, a majority of respondents collaborate with other departments within their municipality (65 %, 67 %), and other authorities (64 %, 56 %). Some municipalities reported collaborating with independent experts (14 %, 15 %), NGOs (11 %, 18 %), or landowner associations (14 %, 11 %). Several municipalities (8 % in 2018, 7 % 2023) also reported working with other municipalities, when specifying "*other"* collaborations than the pre-existing alternatives to the question.

3.2.2. Perceptions of recent drought events

The 2018 drought event stood out across the survey rounds in terms of perceived severity (Fig. 3a). A majority of respondents in the first survey round reported experiencing at least mild drought conditions during that year. In comparison, the 2022 drought was perceived as less severe, where the difference in perceived severity between the 2018 and 2022 droughts was significant ($p < 0.05$). Similarly, there was a significant difference in perceived impact of the three drought events ($p < 0.05$). Here, the 2018 drought year especially stood out when studying the drought events' perceived effects on the municipalities (Fig. 3b). While perceived impacts significantly differed for northern and southern Sweden for the 2017 and 2018 drought years, no significant difference in perceived

Table 1
Distribution of responses (%) based on region (north/south) and population density (rural/urban) and the total number of responses per year.

	North	South	Rural	Urban	No. municipalities
Sweden	26	74	92	8	290
Survey responses:					
First Survey Round	22	78	89	11	118
Second Survey Round	24	76	93	7	55

	2018 Never	2018 very rarely	2018 rarely	2018 often	2018 very often	2023 Never	2023 very rarely	2023 rarely	2023 often	2023 very often
Water scarcity	1%	18%	33%	36%	12%	4%	11%	38%	42%	5%
Drought	6%	21%	34%	34%	5%	13%	17%	42%	23%	6%
Hydrological dought	48%	20%	25%	6%	2%	47%	27%	20%	5%	0%
Meteorological Drought	51%	26%	15%	5%	3%	53%	26%	13%	8%	0%
Socioeconomic drought	74%	19%	6%	1%	0%	75%	13%	11%	0%	0%
Soil moisture drought	41%	33%	20%	6%	0%	49%	25%	19%	8%	0%

Fig. 2. Heatmap showing the distribution of response frequencies regarding how often respondents reported using specific drought terms in their day-to-day work. Frequency categories range from "Never" to "Very Often." Darker shades indicate higher response counts within each category.

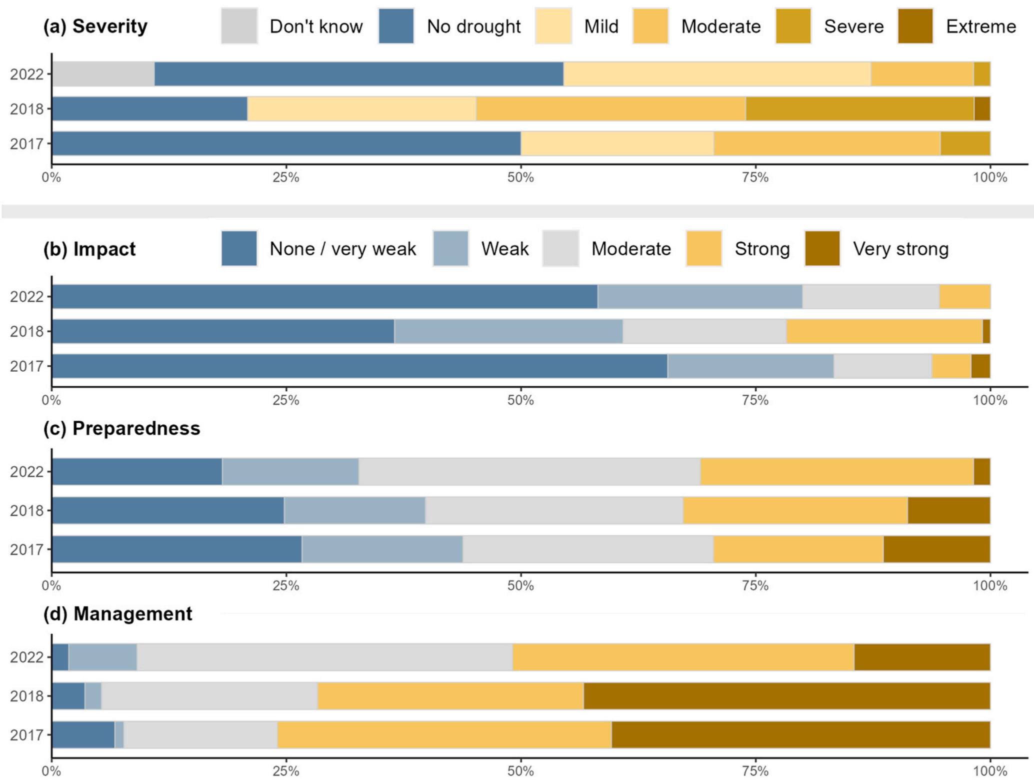

Fig. 3. Perceived (a) severity, (b) impact, (c) preparedness, and (d) management regarding the three drought events (2017,2018, and 2022).

impacts depending on geographical location was seen for the drought in 2022. Interestingly, the municipalities, across all three drought events, rated their preparedness (Fig. 3c) for the respective drought events lower than their management (Fig. 3d), potentially indicating a greater perceived reactive operational capacity compared to proactive planning. Simultaneously, perceived municipal preparedness appeared to increase over time, especially in southern Sweden, though the change is not statistically significant.

Overall, perceptions of municipal drought management were positive across all drought events. Northern municipalities showed slight tendencies for more negative perceptions of municipal drought management compared to southern municipalities. The results also showed an increase in ratings corresponding to moderate management in the second survey round compared to the first. Some of the most frequent measures reportedly taken by the municipalities in relation to drought across all three drought years related to *regular measurements and monitoring of the situation, information campaigns,* and *contact with relevant authorities* (Fig. 4). In the second

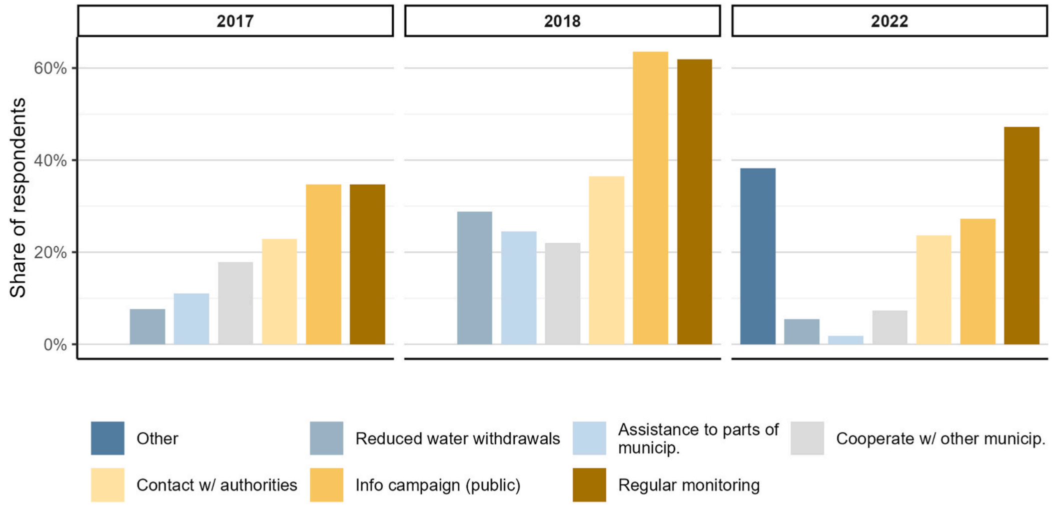

Fig. 4. Share of municipalities reporting each drought-response measure, by drought year.

survey round, a large share of municipalities provided additional information as "*Other*" measures. Within this category, a majority stated that they did not need to take any measures in 2022 (76 % of responses provided under the alternative "*other*", representing 29 % of all municipalities responding in 2023), where some municipalities described not experiencing drought conditions at all.

3.2.3. *Differences in perceived vs observed severity*

According to the computed SPI6, the 2022 drought year resulted in drought conditions ranging from mild to extreme (Fig. 5a). Particularly severe drought conditions were experienced in the southern and southeastern municipalities of Sweden. In contrast, the northwestern municipalities did not experience drought conditions according to the drought indicator. Similar drought patterns appeared when studying shorter term drought conditions using SPI3 (Fig. 5b). For example, South-east Sweden experienced severe to extreme droughts during the summer months, whereas north-western Sweden was mostly unaffected. However, the observed drought conditions were not reflected in the responses provided by the municipalities. Several municipalities, in both northern and southern Sweden, reported not experiencing drought conditions (Fig. 5c). Among respondents who reported drought conditions, most classified

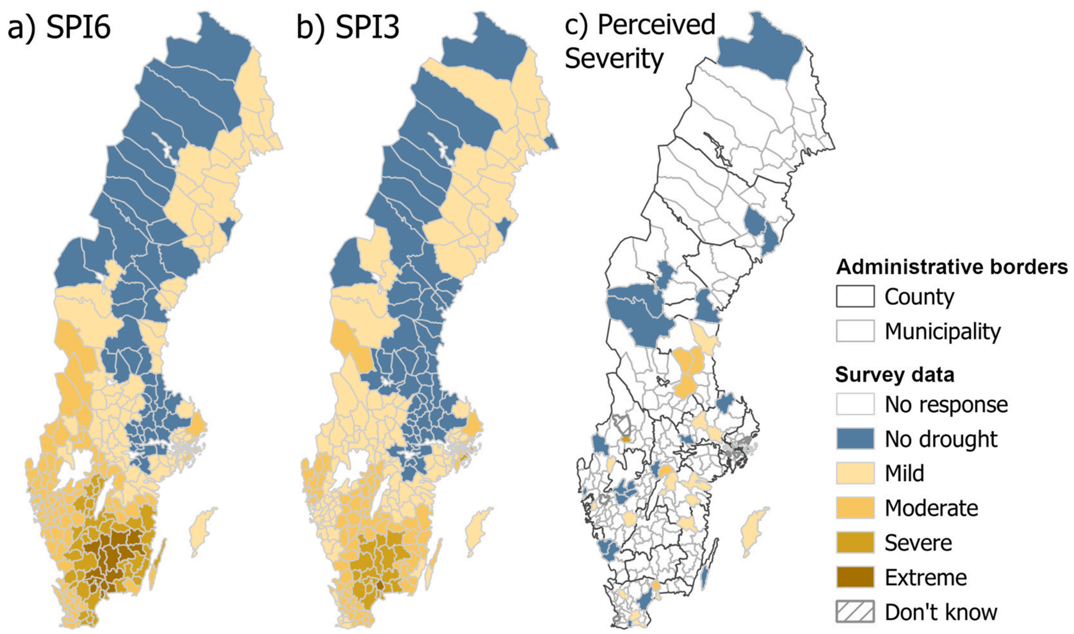

Fig. 5. Computed and perceived drought conditions during 2022 for each municipality, where (a) is median SPI6 for August 2022, (b) median SPI3 calculated for September 1st 2022 and (c) is the perceived drought severity reported by the municipalities. Map lines delineate study areas and do not necessarily depict accepted national boundaries.

the severity as mild or moderate, with only a few municipalities reporting severe drought conditions. No significant correlation between perceived drought severity and observed drought conditions (according to SPI6 or SPI3) was observed for the municipalities. Interestingly, the perceived drought severity among northern municipalities was inversely related to SPI3 (Spearman's $\rho = -0.61$, $p < 0.05$), indicating that short-term meteorological anomalies and perceived severity do not align systematically in this region. Furthermore, no significant differences in perceived severity were found based on the respondent's job titles.

3.2.4. Changes in perceptions of drought risk in future climates

There was a significant difference in the drought risk perception between the two survey years (Wilcoxon rank-sum test, $p < 0.05$). Respondents in 2018 tended to report higher future drought risk ratings than those in 2023 (rank-biserial correlation rrb = 0.25). Comparison of frequency distributions in drought risk ratings between the two survey rounds revealed this change in risk perception. In 2018, a strong majority perceived that drought risk would increase in future climates. Meanwhile, in 2023 an increase in the number of municipalities perceiving that drought risk would not change or would decrease in future climates could be observed (Fig. 6). Notably, drought risk perception differed significantly depending on whether the municipality reported having a drought plan ($p < 0.05$). Municipalities with a drought plan consistently reported that drought risk will increase, whereas those without a plan reported more heterogeneous risk perception.

3.2.5. Influence of past drought events on drought risk perception in 2023

No association between drought risk perception in 2023 and observed drought conditions in 2022 was seen (Table 2). However, SPI6 conditions in August 2018 showed a weak, non-significant association with perceived drought risk in 2023 across all municipalities ($\rho = 0.25$, $p = 0.067$). This suggests a possible tendency for municipalities that experienced drier conditions in 2018 to report higher drought risk perception in 2023. This pattern was particularly evident in northern municipalities, where the association between 2018 SPI6-severity and perceived drought risk in 2023 was moderate and statistically significant ($\rho = 0.64$, $p < 0.05$).

4. Discussion

Using a repeated nationwide survey on municipal drought management and risk perception, this study provided a unique opportunity to explore the progression of drought perceptions and management practices over time. By analyzing correlations between observed and perceived drought conditions, the influence of semantics and stakeholder perspectives, and the temporal decay of risk perception , the study highlights how cognitive processes and experiential cues shape drought appraisal. The study further situates these dynamics within a decentralized governance context, where cultural narratives, institutional capacity, and limited mandates can influence whether heightened awareness translates into sustained preparedness.

4.1. Mismatch between observed and perceived drought severity

Consistent with Teutschbein et al. [33] as well as Blauhut et al. [39], our results indicate a misalignment between observed and perceived drought severity among Swedish municipalities. While a statistically significant association was detected between SPI3 and perceived severity in northern municipalities, it was negative, indicating that municipalities tend to underestimate drought conditions. Several factors may explain this. For example, Teutschbein et al. [33] found a significant correlation between observed SPI6 values and perceived severity for the 2018 drought, but not for the 2017 drought. This difference may reflect a decline in hazard appraisal over time, as the longer interval between the 2017 event and the survey could have reduced respondents' recall of the event [69,70]. The second survey round was conducted approximately one year after the 2022 drought year; hence, a potentially fading collective memory of the event may play a role in the misalignment [69]. Other cognitive biases may also play a role, such as availability heuristic [71] and affect heuristics [72] that can cause respondents to favor more rapid, observable hazards or drought events that cause strong emotional responses (such as the more severe drought conditions in 2018). In this context, the 2018 drought event may also form a reference point against which the severity of subsequent drought events is evaluated.

The perceived drought severity may also involve aspects related to experienced impacts rather than actual severity. This connects to the disaster-risk framework, which frames drought risk as a combination of hazard, exposure, and vulnerability [17]. While drought

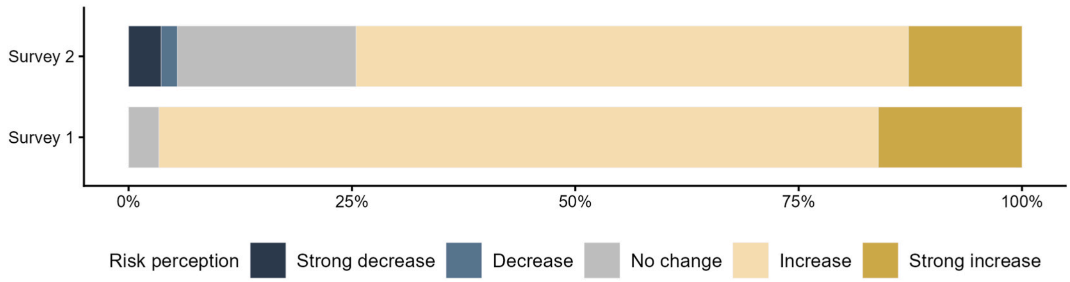

Fig. 6. Perceived assessment of whether drought in the future will decrease, not change, or increase as reported by the municipalities in the first (2018) and second (2023) survey round.

Table 2
Spearman correlations between perceived drought risk in 2023 and meteorological drought indicators (median SPI3 and SPI6 for August 2022, and SPI6 for August 2018), disaggregated by municipality groups (All, North, South, Rural, Urban). Statistically significant correlations ($p < 0.05$) are marked with an asterisk.

Variable 1	Variable 2	Municipalities	Correlation (Spearman's rho)	p-value
Perceived drought risk in 2023	SPI3 August 2022	All	−0.14	0.296
		North	−0.03	0.921
		South	−0.17	0.287
		Rural	−0.17	0.239
		Urban	-	-
	SPI6 August 2022	All	−0.17	0.221
		North	−0.14	0.646
		South	−0.19	0.230
		Rural	−0.16	0.259
		Urban	-	-
	SPI6 August 2018	All	0.25	0.067
		North	**0.64***	**0.019***
		South	0.19	0.22
		Rural	0.22	0.11
		Urban	-	-

indicators measure hazard parameters, municipal perceptions may also reflect perceived impacts, as municipalities respond to drought consequences rather than statistical anomalies. The overall risk of experiencing negative effects of a drought event stems not only from the hazard severity itself, but from aspects such as the exposure and vulnerability to the hazards. As such, lower perceived drought severity compared to observed drought severity could potentially also be an indication of generally low municipal vulnerability to hydrologically moderate or severe drought events.

Semantics may also contribute because different stakeholders can attach different meanings to a word [73]. For example, the survey required municipalities to rate the perceived *water availability* during the summer of 2022, with response alternatives ranging from "more than normal (flood)" to "substantially below normal conditions (extreme drought)". Consequently, some respondents may, for example, associate the term *"water availability"* primarily with drinking water supply, overlooking other critical water needs such as environmental flows. This is not uncommon, as studies have shown that the needs of the environment often receive less priority than human needs [19,74]. This links back to the use of drought terminology and distinguishing drought types; what a "drought is" is perceptually complex. For example, similar to Kohl and Knox [37], McEwen et al. [75] showed that different drought types can be perceived and experienced differently by different stakeholders within the same catchment. They stress the importance of locally tailored risk communication and science-narrative "threshold thinking" in areas where public narratives revolve around catchment wetness rather than dryness. Hence, while SPI6 captures medium-term drought conditions affecting surface water storage, it may not reflect local or personal drought thresholds used for hazard appraisal by the respondents. However, Blauhut et al. [39] showed that Swedish and Finnish water managers and water agencies tended to underestimate drought severity in comparison to a range of drought indicators with different temporal resolutions. Furthermore, Kohl and Knox [37] found that the societal context of a respondent influences their sensemaking in response to drought. For example, governmental officials were shown to see drought as primarily caused by climatic conditions, whereas stakeholders employed in the green industry attributed droughts to a combination of climatological and societal interactions [37]. In other words, the understanding of water availability and drought will be influenced by the perspective and knowledge context of the respondent.

4.2. The role of semantics, terminology, and drought typologies

This highlights the important role of drought definitions. The repeated survey structure revealed an increase in municipalities with operational drought definitions. However, the frequencies of municipalities reporting having an operational drought definition are still low, and municipalities showed little tendency to use common scientific terminology regarding different drought types. Instead, the concepts of "water scarcity" and "drought" are more widely used compared to more detailed drought classifications. While the results do not indicate how respondents distinguish between "drought" and "water scarcity," it is important to underline that they refer to two distinct phenomena and should not be used interchangeably. The former refers to exceptional anomalies in water availability as a result of climatic variability, whereas the latter revolves around water deficits resulting from unsustainable human pressures on water resources [20]. Although both concepts can result in socio-hydrological impacts related to water availability, they require different management approaches for effective risk reduction. Conflating the two terms obscures the source of risk and may result in drought being misdiagnosed as purely a management problem [20]. This misinterpretation can lead to maladaptation, for example, through over-investing in infrastructure while ignoring risk management strategies like early warning systems or measures that reduce vulnerability, including reduced water demand or strengthened societal capacity.

Additionally, the results provide important insights into a potential mismatch between scientific drought discourse and practical drought management. Scholars often differentiate droughts depending on where in the hydrological system they occur [2,76], with various drought indicators being more or less suited to capturing the occurrence and impacts of these distinct drought types [77]. The different drought types are also associated with different exposure pathways and vulnerability profiles, which require different management approaches [32,78]. Hence, the limited conceptual precision among local authorities may hinder tailored monitoring approaches, responses and effective risk communication within and across authorities. This makes targeted action more difficult and risks overlooking potential drought risk management approaches appropriate for the local water dependencies [79].

4.3. Dynamics of drought risk perception

Following the high level of risk perception among respondents in the first survey round, our study found indications that drought risk perception seems to decay over time. Similar results for risk perception have been found for other hazards. For example, Mondino et al. [80] saw that flood risk awareness in Italy decreased over time in the absence of new flooding events, and Trumbo et al. [81] observed a considerable decline in hurricane risk perception following periods of low hurricane activity after the last major event. The high level of risk perception seen in 2018 is in line with previous research showing heightened risk perception among individuals directly after experiencing a severe event [80,81]. Yet, while several municipalities in our study perceived at least mild drought conditions again in 2022, the high level of risk perception seems to decline. Several mechanisms may be involved in this dynamic, such as the cultural narratives prevalent in regions traditionally seen as water-abundant [82,83] and other forms of cognitive bias [72,82,84,85]. Sweden has traditionally been perceived, both nationally and internationally, as water-abundant. This perception can influence interpretations of drought risk, where cultural narratives suppress the perceived plausibility of drought [79,82]. For example, Ahopelto et al. [83] described the challenge of promoting drought and water-stress-related measures in Finland, a country with strong narratives relating to water richness. Likewise, Weitkamp et al. [82] highlighted the cultural narrative of wetness as a particular challenge affecting drought risk perception and communication, leading to lower drought risk perceptions and even positive associations with dry weather.

While the record-breaking 2018 drought event [45] resulted in heightened risk perception, the milder perceived severity and limited impacts of the 2022 drought do not seem to reinforce this heightened awareness. Similar results have been seen in the Netherlands, where farmers experiencing less severe and infrequent droughts had lower risk perception than those experiencing severe and frequent events [86]. This could be due to factors such as confirmation bias [85,87], where respondents interpret new information in ways that confirm their existing beliefs. Although the 2018 drought temporarily increased drought risk perception, later and less severe drought events may have made municipalities view 2018 as an unusual exception rather than as evidence of a growing long-term risk. The less clear impacts of the 2022 drought may also have reinforced existing beliefs that drought is not a major concern in Sweden. It may also relate to optimism bias [84], where the milder impacts experienced in 2022 reinforce municipal confidence in their own management and resilience [88], rather than trigger concern for future risks. At the same time, the association between severe drought conditions in 2018 and elevated drought risk perception in 2023 indicates that the more severe 2018 drought year seems to play a role in risk perception years later, even if the overall perception decays over time. This association is consistent with availability- [71] and affect-based heuristics [72], whereby extreme, disruptive events produce more durable cognitive and institutional imprints. The fact that this association was significant in northern municipalities may also be a result of the event's perceived abnormality [89], where more severe conditions challenged perceived municipal resilience or prior cultural beliefs.

The results provide empirical insights into the dynamics of drought risk perception that could influence drought risk management and adaptation. For example, Zhang and Maroulis [43] found that slowing the decay in risk perception has the potential to sustain organizational attention to climate risks over time, thereby increasing the likelihood of adaptive action even in the absence of recent extreme events. The authors suggest measures such as scenario planning, story-based communications, and organizational sensemaking as countermeasures for risk perception decay. Furthermore, some studies have shown a link between occupational roles and disaster risk perception [90], where, for example, managers seem to experience higher disaster risk perceptions compared to lower level roles. Although no significant relationship was found between respondents' occupational roles and their perceptions of recent drought events in this study, potential differences based on occupational role could warrant further investigation.

4.4. From perception to governance: cultural and institutional consequences

While Sweden is generally experiencing a wetting trend [91,92], the country has experienced several drought events during the last 60 years, with especially severe and widespread droughts hitting the country in 1976, 1996 [91,92] and 2018 [45]. In essence, droughts are extreme events that can happen in any climate. As such, no region is exempt from droughts. Meanwhile, a number of municipalities in both survey rounds described not seeing a need for a drought plan (30 % of respondents in the first survey round, 17 % of those providing additional information in second survey round), perceiving the municipality to have little to no issues with drought or to have reliable water resources. These sentiments link back to the complex dynamics of risk perception and the potential role of both limited conceptual clarity and cognitive bias. For example, our results show that the perceived municipal management of all three events was higher than the perceived preparedness. This illustrates a perception of strong municipal operational capacity, where positive self-evaluation may foster complacency and reinforce reactive responses [88]. The notion that municipalities rated the management of the 2018 drought highly, even in the absence of a drought management plan, may also hinder proactive management, as perceived success can reinforce confidence in existing practices and reduce incentives for anticipatory adaptation [88]. Meanwhile, the lower perceived municipal preparedness indicates a weaker structural resilience among the municipalities, where reactive management may be favored over proactive risk planning. This issue also links back to how drought as a societal challenge is understood by decision makers. Whether drought is considered as a short-term, rare issue or as part of a long-term challenge will influence municipal responses [36,88].

While the share of respondents reporting having a drought plan in place in 2023 is still low, the results show that an increasing number of municipalities have implemented drought plans and operational definitions over time. This could potentially indicate how focusing events like the 2018 drought can create policy windows and move drought risk management approaches up in prioritization in the agenda setting process, thereby driving policy changes [35]. Nevertheless, many municipalities still lack a drought management plan or operational drought definitions, which highlights the challenge of sustaining policy attention beyond severe drought events. Here, the observed association between municipal drought plans and operational drought definitions suggests that these management tools tend to co-occur. Our findings also suggest a close relationship between municipal drought planning and risk perception, as all municipalities reporting having a drought plan also perceived drought risk as increasing. Although no assumptions about directionality can be made, this pattern indicates a strong association between perceived risk and drought planning, where high risk perception may lead to implementation of drought plans, or conversely, that having a drought plan may help sustain risk perception. At the same time, as risk perception seems to diminish over time, the problem framing of drought as a societal challenge may in effect change as time passes after severe events. Such perceptual changes and problem framings may in turn influence droughts' prioritization in the agenda setting process [93] and favor other competing risks that dominate the policy agenda. Here, the creeping nature of drought can affect its perceived salience, where impacts may be diffuse and often delayed. This, in combination with a cultural narrative mainly focused on risks relating to excess water (e.g. floods, cloudbursts) may also reduce legitimacy for investments in drought management and preparedness [94]. Such narratives may persist unless challenged by mandates or other guidelines. At present, EU policy frameworks provide more developed and binding instruments for flood risk governance than for drought risk management [45,95], thereby potentially reinforcing existing governance biases toward wet extremes.

Implementing drought plans and proactive management has been argued to be an important tool in drought risk reduction [39,96–98], with the potential to increase flexibility [99] and improve water security [83]. According to Wilhite et al. [100], some of the key elements to drought risk management include conducting impact and vulnerability assessments and setting up mitigation and response strategies. Such work is already required by municipalities to be done every four years in Sweden, according to the requirement of the production and submission of municipal RVA reports [15]. Hence, the Swedish municipal system for risk and vulnerability analysis (RVA) provides a valuable foundation for developing drought plans, making the exceptionally low number of such plans reported in our study particularly counterintuitive. Sweden's approach to civil emergency preparedness is characterized by a strong reliance on decentralized governance, where municipal actors play a pivotal role. Meanwhile, the lack of clear mandates for hazard selection in hazard-oriented RVAs increases the risk that hazard inclusion is guided by perceived relevance rather than by systematic assessment of present and future risks [94]. This in turn can produce uneven municipal preparedness among Swedish municipalities, lead to insufficient prioritization regarding budgeting and planning efforts, and create structural blind spots in municipal risk assessments and management approaches [93]. The issue of uneven preparedness is further complicated by the uneven municipal capacities relating to financial constraints, time, and personnel. Here, clear mandates, harmonized guidance, and support could play an important role in leveling preparedness across municipalities by ensuring that drought risk is consistently considered regardless of capacity constraints [93,101] or fluctuating risk perceptions.

4.5. Study limitations

Although this study provides valuable insights into the evolving perceptions of drought risk and management, it also has several limitations. Firstly, the first survey round received considerably more responses compared to the second survey round. Although respondents in both survey rounds exhibited comparable structural characteristics to the national municipal population with respect to geographic distribution and rural-urban composition, the uneven sample sizes may introduce bias and affect the overall generalizability of comparisons between the two years. Municipalities with ongoing engagement in drought-related issues, prior impacts, or continued concern may, for example, have been more likely to respond in 2023 than municipalities that perceived drought risk as low, or irrelevant. Meanwhile, the assessment of potential non-response bias for the second survey round showed that response rates did not increase consistently with observed drought severity in either 2018 or 2022. The decline in response rate could also be an effect of factors such as survey fatigue, competing administrative demands, or limited resource capacity. The decline could also indicate an overall decline in municipal drought risk perception, as supported by our findings. In this sense, reduced survey participation may reflect broader municipal dynamics in which drought issues lose priority in the absence of severe or disruptive drought events. Simultaneously, differences in municipal capacity (e.g. financial resources, time, personnel, competing demands) may further influence the participation rate. Such institutional capacity constraints were highlighted in our results. In light of these considerations, the study was intentionally designed as a repeated cross-sectional analysis, focusing on system-level tendencies rather than municipality-level trajectories. Accordingly, the findings are best interpreted as offering insight into evolving patterns of drought perception and management practices across two survey rounds, rather than as precise estimates of their prevalence across all Swedish municipalities. Furthermore, the study is based on the perceptions of municipalities as offered by a single municipal representative. As a result, internal variation across departments or professional roles may not be fully captured. Accordingly, the findings reflect informed institutional viewpoints rather than capturing the full range of perspectives or internal consensus within municipalities.

Observed drought conditions were captured using SPI over two accumulation periods, reflecting short- to medium-term and medium-to long-term drought conditions for the spring and summer of 2022. As the SPI is promoted internationally as a baseline indicator for meteorological drought monitoring, analyzing its alignment with local perceptions offers important insights into how drought monitoring tools reflect locally perceived realities. Concurrently, several other indicators exist that can offer more precise assessments of drought-type-specific conditions, and their potential impact on different parts of the hydrological or socio-hydrological system. Thus, broadening the analysis to include other drought indicators could offer further insights into how drought indicators are aligned with local perceptions. Meanwhile, in line with our results, previous research studying perceived and observed drought indicators has shown that drought indicators such as the SGI (anomalies of groundwater storage) [33] can also fail to adequately capture the perceived drought severity.

5. Conclusion

As local authorities face increasingly unpredictable climate extremes, knowledge of how droughts are perceived and managed over time in regions traditionally considered water-abundant provides a deeper understanding of potential societal vulnerabilities and possible directions for future drought risk management. This study examined how perceptions of drought and drought management within local authorities evolve over time and how they relate to observed drought severity, employing a repeated cross-sectional survey following the 2017/2018 and 2022 drought years. Similar to previous studies, we found that perceived drought severity differed from observed drought conditions in 2022. Our study indicates that risk perception among local authorities tends to lessen over time. Meanwhile, our results suggest that more severe drought events are associated with sustained higher risk perceptions years after these events in some geographical settings.

Together, these findings point to three practical directions for strengthening municipal drought preparedness. First, because risk perception can influence the prioritization of drought risk management on municipal agendas, preparedness should not depend solely on heightened awareness following severe drought events. Instead, municipalities need governance mechanisms that sustain attention to drought risk even when recent events are less severe or less salient. This could support a shift from reactive crisis management toward more proactive and long-term drought risk management. Second, from a policy perspective, periods of heightened drought awareness may create windows of opportunity for embedding drought risk management more firmly into local governance. This could involve systematically incorporating drought considerations into municipal RVAs and related planning instruments, supported by national mandates, guidelines, and resources. Such efforts could reduce municipal reliance on fluctuating risk perceptions and help reduce uneven levels of drought preparedness across municipalities. Third, future drought risk management should place greater emphasis on clearly defining and communicating what constitutes drought under local conditions. Rather than relying solely on standardized meteorological indicators, drought monitoring should also account for locally relevant exposure pathways, water dependencies, operational thresholds, and municipal responsibilities. Aligning drought indicators with local impact pathways could improve policy relevance, strengthen risk communication, and support coordination between scientific experts, practitioners, and decision-makers. In this way, municipal drought risk management can better integrate the core components of drought risk: hazard, exposure, and vulnerability.

Strengthening such institutionalized approaches helps ensure that drought risk management does not depend on episodic events alone or institutional capacity, but remains a sustained component of local risk management in an increasingly uncertain future.

Declaration of generative AI and AI-assisted technologies in the manuscript preparation process

During the preparation of this work, the author(s) used Microsoft 365 Copilot in order to improve writing style and to check for grammar and spelling on an earlier version of the paper. After using this tool/service, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the published article.

Funding

This work was supported by the Svenska Forskningsrådet Formas (grant nos. 2023-00515_Formas and 2015-01123_Formas) and the Royal Swedish Academy of Sciences (grant no. LN2016-0101).

CRediT authorship contribution statement

Elin Stenfors: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Visualization, Writing – original draft, Writing – review & editing. **Martin Mickelsson:** Conceptualization, Writing – review & editing. **Catharina Landström:** Conceptualization, Writing – review & editing. **Claudia Teutschbein:** Conceptualization, Funding acquisition, Methodology, Project administration, Supervision, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ijdrr.2026.106357.

Data availability

Data will be made available on request.

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