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# The role of drought preparedness in building and mobilizing adaptive capacity in states and their community water systems

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**Abstract** The likely intensification of extreme droughts from climate change in many regions across the United States has increased interest amongst researchers and water managers to understand not only the magnitude of drought impacts and their consequences on water resources, but also what they can do to prevent, respond to, and adapt to these impacts. Building and mobilizing 'adaptive capacity' can help in this pursuit. Researchers anticipate that drought preparedness measures will increase adaptive capacity, but there has been minimal testing of this and other assumptions about the governance and institutional determinants of adaptive capacity. This paper draws from recent extreme droughts in Arizona and Georgia to empirically assess adaptive capacity across spatial and temporal scales. It combines quantitative and qualitative methodologies to identify a handful of heuristics for increasing adaptive capacity of water management to extreme droughts and climate change, and also highlights potential tradeoffs in building and mobilizing adaptive capacity across space and time.

**Abbreviations**

| | |
|---|---|
| AM | Adaptive management |
| ASDPP | Arizona State Drought Preparedness Plan |
| CLIMAS | Climate Assessment for the Southwest |
| CWS | Community water system |
| DRC | Drought Response Committee |
| EHC | Event history calendar |
| EPD | Environmental Protection Division |
| GDMP | Georgia Drought Management Plan |
| ICG | Interagency Coordinating Group |
| IR | Integrated resources planning |
| IWRM | Integrated water resources management |

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|---|---|
| LDIG | Local Drought Impact Group |
| LHC | Life history calendar |
| MNGWPD | Metropolitan North Georgia Water Planning District |
| MTC | Monitoring Technical Committee |
| NGO | Non-governmental organization |
| RISA | Regional Integrated Sciences and Assessments |
| SECC | Southeast Climate Consortium |
| SPI | Standardized Precipitation Index |
| SRP | Salt River Project |
| U.S. | United States |

## 1 Introduction

Rapid population growth is increasing demand for high quality water resources, and pressures on water supply and quality from current climate variability are likely to become even more pronounced with climate change in the United States (U.S.) (Dai 2010). In the face of these pressures, there is growing interest amongst state and local water managers to understand not only the magnitude of drought impacts and their consequences, but also what they can do to prevent, respond to, and adapt to these impacts (U.S. Climate Change Science Program 2008), a concept known as adaptive capacity. To aid decision makers in this pursuit, it is critical for researchers to understand what builds adaptive capacity within a system.

This paper explores the adaptive capacity of states and local community water systems (CWSs) in relation to extreme drought events. It investigates two contrasting cases, Arizona and Georgia, which have experienced intense, multi-year droughts over the past decade. The paper aims to help fill a void in evidence-based work on adaptive capacity (Engle 2011), particularly with respect to the management, governance, and institutional factors affecting adaptive capacity. The major contribution of this research is that it uses quantitative and qualitative methods to empirically assess the influence of drought preparedness on adaptive capacity across spatial and temporal scales.

From a practical perspective, the research identifies a handful of heuristics for increasing adaptive capacity of water management to extreme droughts in Arizona and Georgia. More broadly and theoretically, it shows potential tradeoffs in building and mobilizing adaptive capacity across space and time. Without careful consideration and coordination between state and local CWS scales, attempts to improve adaptive capacity may conflict with one another. Similarly, at the local CWS level, the data suggest a tension in adaptive capacity to persist and adaptive capacity to transform in the face of climate change.

## 2 Background

### 2.1 Arizona and Georgia droughts and climate change

Recent droughts in the Southwest (including Arizona) and the Southeast (including Georgia) provide comparable cases during which extreme conditions affected a large portion of the region for consecutive years. In the Southwest, the several multi-year droughts of interest in this study, most notably from 2001–2005, are generally attributed to La Niña and cooler sea surface temperatures in the Pacific Ocean (Seager et al. 2007). There is evidence that future extreme multi-year droughts in the Southwest associated with La Ninã events will be exacerbated by changing base conditions under climate change (Seager et al. 2007). Research also indicates the extreme aridity associated with the 2001–2005 drought is indicative of what the ‘new climatology’ of the Southwest might resemble with climate change (Woodhouse et al. 2010).

In the Southeast, multi-year droughts like those of interest in this study (i.e., 2006–2008) are weakly attributable to La Niña and cooler sea surface temperatures in the Pacific Ocean in winter months, and more strongly associated with random atmospheric variability in summer months (Seager et al. 2009). Climate change models for the Southeast project increases in precipitation and evaporation, leaving some uncertainty about the precise impacts of climate change on future droughts in the region (Seager et al. 2009). However, dendrochronology data show that meteorological characteristics of the 2006–2008 drought were not unique in comparison to earlier droughts in previous decades and centuries (e.g., the 1998–2002 drought was as severe). This implies that multi-decadal droughts are not only possible, but are recurrent in this region (Seager et al. 2009). The acute impacts of this ‘normal extreme’ drought on socio-economic systems in the region suggest that with or without climate change, severe droughts are bound to affect the Southeast in the future.[1]

Regardless of a direct link between any given drought and climate change, droughts and the manner in which they are governed provide proxies for climate change. As with the phenomenon of drought, climate change operates on long time scales and it is difficult to identify and define its development and associated impacts. These similarities with drought allow for positive and normative insights into how society might manage climate change.

### 2.2 Understanding adaptive capacity

There have been mounting calls in recent years for a greater emphasis on the under-researched area of adaptation (Pielke et al. 2007). Adaptation studies are not only on the rise, but new and ambitious agendas for future adaptation research have been outlined and are underway (Arnell 2010). One pivotal concept for aiding adaptation is adaptive capacity, formally defined as the ability of a system to prepare for stresses and changes in advance or adjust and respond to the effects caused by the stresses (Smit et al. 2001).

One important set of factors assumed to significantly influence adaptive capacity is governance, institutions, and management, for they either facilitate or inhibit adaptive capacity building (Brooks et al. 2005; Engle and Lemos 2010). As noted, most of the work in this area has yet to move from a normative approach to understanding of adaptive capacity to studies that test and unpack the theorized determinants of adaptive capacity (Engle 2011). Perhaps nowhere else is this gap more evident than in the realm of water planning and management.

### 2.3 The role of drought preparedness

States and local governments are generally in charge of drought planning and management, through a combination of water supply and demand measures. Each state addresses droughts somewhat differently, but states have traditionally prioritized responding to rather than preparing for droughts. This reactive approach has purportedly led to greater vulnerability

[1] Since conducting this research, the Southwest and Southeast have both experienced additional extreme droughts, such as the widespread drought of 2012.

due to reduced self-reliance and a lack of coordination across institutions and sectors (Hayes et al. 2004).

‘Good management’ practices for preparatory drought planning and management center on ‘drought preparedness’, which is defined by three basic categories; monitoring and early warning/prediction, risk/impact assessment, and mitigation and response (Wilhite et al. 2005). States have recently begun to improve drought preparedness (Hayes et al. 2004; Wilhite et al. 2005), as evidenced by a greater number of state drought plans and the proliferation of tools to aid these state-level drought planning initiatives (Wilhite 2009). While researchers expect drought preparedness to positively influence adaptive capacity, there has yet to be significant testing of the influence of drought preparedness on adaptive capacity; specifically, which aspects of drought preparedness states should emphasize to increase adaptive capacity.

Drought preparedness is also an important paradigm for local water management. CWSs, the local public and private drinking water providers, are an integral component of the water sector for maintaining livelihoods and protecting the vitality of ecosystems goods and services.

Drought preparedness manifests at the local CWS level in various forms. The relatively recent water management models of integrated water resources management (IWRM), adaptive management (AM), and integrated resources planning (IRP) capture various principles related to drought preparedness at the local CWS level. Generally speaking, these models collectively emphasize flexibility, participation and deliberation amongst stakeholders, integration within and between various levels of institutional and actor/organizational networks, demand management (in equal or greater consideration as supply management), and experimentation and learning (Beecher 1995; Blomquist et al. 2005; McLain and Lee 1996; Medema et al. 2008; Olsson et al. 2004). Compared to the state-level, there is a more focused literature suggesting these IWRM-, AM-, and IRP-related drought preparedness approaches should positively shape water systems’ adaptive capacities to climate and other stresses (Cromwell et al. 2007; Pahl-Wostl et al. 2007). However, similar to the state level, it is unclear which particular approaches CWSs actually draw upon in preparation for and response to extreme droughts. A better understanding of when and why CWSs are implementing drought preparedness measures should help streamline knowledge of how local water systems build and mobilize adaptive capacity.

## 3 Research design and methods

This paper seeks to improve adaptive capacity research in three ways: (1) contribute evidence-based research that empirically evaluates recent adaptive actions as surrogates for adaptive capacity; (2) investigate adaptive capacity across scales (spatial and temporal); and (3) utilize qualitative and quantitative methods to more thoroughly and systematically assess adaptive capacity.

First, adaptive capacity is cumbersome to evaluate because of its latent nature. One promising development in this realm is empirical investigations of past/recent stress events as analogues for adaptive capacity (Adger et al. 2007). This approach helps identify those structures, relationships, processes, and other variables that either facilitated or hindered such adaptations (i.e., adaptive capacity). Thus, the recent droughts in Arizona and Georgia provide an excellent opportunity to empirically assess the influence of drought preparedness on adaptive capacity.

Second, previous assessments tend to focus on a single spatial and temporal scale (Eriksen and Kelly 2007). The research presented here looks explicitly across scales, with the intention of evaluating how adaptive capacity interacts between spatial scales and how it develops over time. Also, related to the need for empirical assessments, there is some evidence that the management, governance, and institutional determinants of adaptive capacity may conflict with one another (Engle and Lemos 2010). That is, a system might not be able to universally implement all presumed factors that build adaptive capacity in tandem. The multiple scale focus of this research allows for exploring these types of tensions in adaptive capacity (e.g., those associated with building adaptive capacity across scales).

Third, data collection and analysis methods used in previous assessments of adaptive capacity vary greatly, and include case studies, survey techniques, modeling, mapping, and ethnography. While some studies are highly quantitative, using aggregated indices to assess adaptive capacity based on a set of deterministic assumptions (Brooks et al. 2005), others are richly qualitative and descriptive, capturing the context-specificity of adaptive capacity within a particular case (Nelson et al. 2007). Few efforts, however, employ both quantitative and qualitative methods, which relinquishes an opportunity to pull from the benefits of each to more comprehensively understand adaptive capacity. This study utilizes both.

## 3.1 State level drought preparedness and adaptive capacity

The study analyzed archival data and in-depth semi-structured interviews to assess the influence of drought preparedness on adaptive capacity at the state level. Archival data included each state's formal drought and water plans, statutes, and legislation,[2] which were analyzed along the three drought preparedness categories (monitoring and early warning/ prediction, risk/impact assessment, and mitigation and response), as well as the adaptive actions that occurred within the state in relation to the specific drought events.

The semi-structured telephone interviews were conducted with approximately ten key informants in both Arizona and Georgia with proven expertise in water, climate, and/or drought management (including representatives from state and federal agencies, water and climate related non-governmental organization (NGO) leaders, technical experts, and professional association executives). The interviews probed the actions the state took to implement drought preparedness, how the experts perceived state and CWS management effectiveness in managing the extreme drought events in these states, and what made the states and CWSs more or less adaptable in the face of these droughts. Similar to the archival data, the interviews were coded and analyzed along categorizations of drought preparedness and the adaptive actions that occurred before, during, and after the drought events of interest to this study.

## 3.2 CWS level drought preparedness and adaptive capacity

The CWS assessment focused on the largest systems in both states, primarily (but not solely) concentrated in the urban areas of Phoenix, Tucson, and Atlanta. The largest CWSs were targeted to increase the relevance of the research and because of greater resources at their disposal to mobilize adaptive capacity through drought preparedness measures.

This assessment involved more sophisticated methods. First, the data were collected using an event history calendar (EHC) approach. The novel approach was adapted from life history calendar (LHC) methods, which have been used to collect data on the timing and sequencing of personal events in a more cost effective manner than panel studies (Axinn et al. 1999). While the LHC collects personal data and individuals' histories, aided by recalling

[2] A complete reference list of the documents analyzed and a more in-depth description of the design and instruments used in this research are available from the author upon request.

external events, the EHC focused on CWSs' histories and external event information, aided by recalling personal histories. An important characteristic of the EHC is its ability to simultaneously gather qualitative and quantitative data. Online Resource 1 shows an example of an uncompleted EHC.

The EHC face-to-face interviews focused on senior CWS managers, and in total, the interviews represented 80 percent and 72 percent of the largest systems targeted in Arizona and Georgia, respectively ($n=35$). The temporal data on drought preparedness were obtained by working with the managers to assign numbered values associated with the amount of emphasis placed on the approaches identified in Table 1 during each of the 6-month time periods over the previous decade (0 to 3, or low to high). Managers were encouraged to focus intently on when the numbers were changing, and notes were written in the white space as managers described when, why, and how these approaches were or were not implemented.

The quantitative data were evaluated using panel analysis (generalized estimating equations) to identify statistical patterns between the timing of the approaches' implementation and the onset of droughts. This was done by comparing the reported level of management implementation at a given time (e.g., '2' during winter of 2004) to the Standardized Precipitation Index (SPI) for the CWSs' climate divisions (McKee et al. 1993).[3] Relationships were evaluated systematically across the decade in each state to determine whether the approach corresponded significantly with the timing and magnitude of extreme droughts.[4]

After statistically analyzing patterns of drought preparedness implementation, the qualitative data were used to identify the factors facilitating or inhibiting implementation of these approaches (i.e., dominant bridges and barriers to building adaptive capacity in each state), and to verify and complement the quantitative data from the EHC. Figure 1 illustrates how the study evaluated adaptive capacity and drought preparedness at the state and local CWS scales.

## 4 Findings

### 4.1 State adaptive capacity assessment

#### *4.1.1 Arizona*

The archival research and interviews highlighted the following factors and processes as important influences on Arizona's adaptive capacity.

*Monitoring and early warning/prediction* The Arizona Water Atlas provides comprehensive water use and availability information on seven planning areas. NGOs, universities, agencies, and partnerships, particularly the Southwest's Regional Integrated Sciences and Assessments (RISA), the Climate Assessment for the Southwest (CLIMAS), play a significant role in gathering, synthesizing, and distributing information and studies. There are several online tools made available by the state for CWSs, such as drought status reports and

[3] The SPI is a comparable metric across locations for evaluating climate stress on hydrological processes calculated based on the probability of precipitation for various time scales (e.g., 1, 2, 3, 6, 9, 12, and 24 month intervals). Through a normalization and standardization process, the values can be compared across regions.

[4] The 6-month SPI was used, because it corresponds with the same timeframe on which the management data were collected with the EHC (6-month increments representing 'winter' and 'summer'). In addition, two 'lagged', or delayed response, relationships of the 6-month SPI were evaluated across all systems (i.e., a 6-month lag, and a 12-month lag) to determine if the implementation of the drought preparedness approaches was more immediate or delayed (by one or two lagged periods on the EHC).

**Table 1** Approaches influencing drought preparedness at the CWS level evaluated for their role in building and mobilizing adaptive capacity[a]

| |
|---|
| 1. Supply diversity |
| 2a. Infrastructure – supply |
| 2b. Infrastructure – demand |
| 3. Conservation |
| 4. Conservation-oriented rate-structure |
| 5a. Collaboration – local/regional |
| 5b. Collaboration – State/Fed |
| 5c. Collaboration – other |
| 6. Climate-information and scenarios |
| 7. Uncertainty communication |
| 8. Stakeholder and customer participation |
| 9. Consideration of natural processes |
| 10. Thinking 'outside of the box' and experimentation |
| 11. Long-term drought planning |

[a] A more thorough description of each approach and the predominant literatures (IWRM, AM, or IRP) from which they come is available upon request from the author

AZ Drought Watch. The 2004 Arizona State Drought Preparedness Plan (ASDPP) requires drought monitoring through a state Monitoring Technical Committee (MTC), and supports county-level monitoring through Local Drought Impact Groups (LDIGs). State legislation adopted in 2005 (House Bill 2277) requires all CWSs to have drought plans, which outline

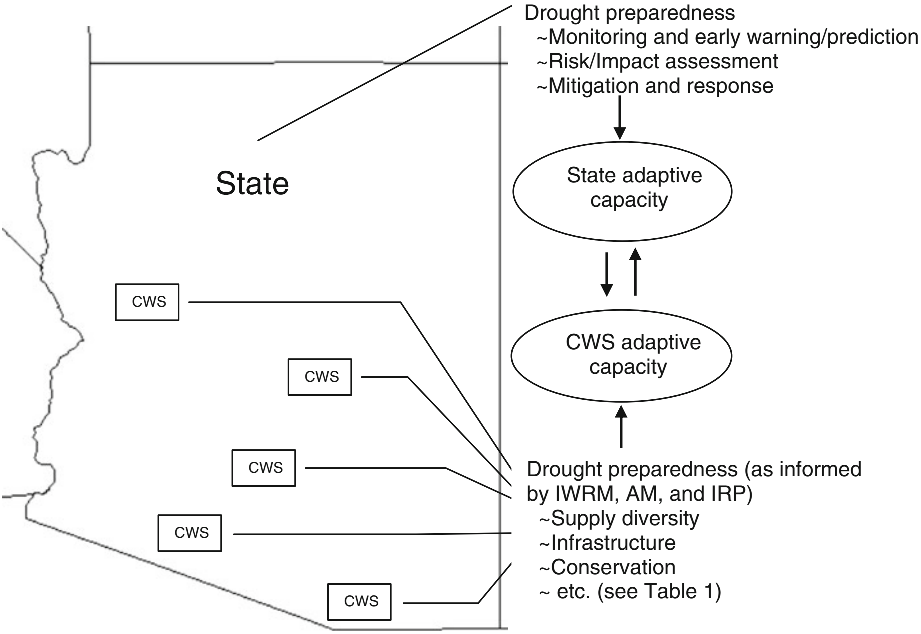


**Fig. 1** Conceptual model showing how drought preparedness and adaptive capacity are evaluated across different spatial scales in this study

locally-relevant triggers and drought stages declared and implemented by local governments during severe droughts. The MTC methodology for determining drought status is based on the SPI and stream flow information, and is frequently updated and improved. After hitting drought triggers, the MTC, LDIGs, and an Interagency Coordinating Group (ICG) examine region-specific triggers to assist with drought alert declarations and local responses according to individual CWS drought plans.

*Risk/Impact assessment* ASDPP identifies historical risks/impacts on the state and regional levels by various sectors, including water resources management. CWSs are required to implement 3-tiered drought plans, parts of which focus on identifying and reducing drought vulnerabilities. LDIGs play a role in local vulnerability and risk assessment, primarily through impacts monitoring and reporting. The Salt River Project (SRP), the U.S. Bureau of Reclamation, the University of Arizona, and several other CWSs began collaborating on climate predictions for the Lower Colorado River during the 2001–2005 drought. The University of Arizona also worked with SRP on tree-ring studies and long-term climate projections. There is strong University and extension service presence (formal and informal) in building drought and climate knowledge, with CLIMAS providing significant support (e.g., online tools, workshops, research collaborations). Researchers and agencies have been actively reaching out to water managers to understand what information is most useable and helpful. Though information and knowledge is readily available, it is a persistent challenge to encourage water managers to seek out such information.

*Mitigation and response* The ASDPP consists of three parts; a technical impacts/vulnerability analysis, a statewide water conservation strategy, and an operational drought plan; all of which help mitigation and response. The ASDPP also lays out the coordination of three groups; the MTC, LDIGs, and ICG. The MTC reports to the ICG twice yearly on drought status recommendations and the ICG meets quarterly, regardless of drought conditions. CWSs are required by the state to have a 3-tiered drought plan; a water supply plan (water strategies, needs, and reporting), a drought preparedness plan (meeting CWS needs during droughts and water shortages), and a water conservation plan (increasing efficiency, and reducing waste). For the drought preparedness plan, systems highlight voluntary and mandatory actions for the four drought levels declared by their local governments, with level 4 being their 'worst-case' scenario. The State of Arizona Emergency Response and Recovery Plan, most recently updated in 2005, highlights drought in its incident annex, which identifies organizations for statewide drought assessment, response, and recovery actions. LDIGs help develop county-level and regional plans in advance of a drought to minimize impacts when droughts occur, and CLIMAS plays an active role in drought mitigation information provisioning. Beyond this, the Governor can evoke mandatory restrictions, which were not declared during the 2001–2005 drought. The ASDPP process has persisted in non-drought years, and endured a 2009 political change in Governors.[5]

### *4.1.2 Georgia*

The archival research and interviews highlighted the following factors and processes as important influences on Georgia's adaptive capacity.

[5] Since conducting this research, budget cuts have affected state drought preparedness measures in Arizona. While the overall ASDPP process remains in place, the cuts indicate the dynamic and potentially fragile nature of building adaptive capacity through drought preparedness.

*Monitoring and early warning/prediction* Universities play a role in gathering, synthesizing, and distributing information and studies. Water-related NGOs and partnerships are active in producing information on water policy, flow regimes, recharge, and drought tracking (e.g., Southeast River Forecast Center). However, water-use reporting for CWSs is only required during drought events. Under the Georgia Drought Management Plan (GDMP), the Georgia Environmental Protection Division (EPD) director, working with the State Climatologist Office, uses a host of indices (percent of normal, SPI, stream flow, soil, groundwater, and reservoir levels) on various timescales (1, 2, 3 12, and 24 months) to monitor and declare droughts in nine climate divisions. Once a trigger is hit, the State Climatologist Office organizes the Drought Response Committee (DRC) to evaluate and make recommendations for response.[6] The GDMP describes the indices and triggers as guidelines to be corroborated by what is occurring 'on the ground' (i.e., the GDMP triggers serve as guidance).

*Risk/Impact assessment* The GDMP alludes to the need for the state, CWSs, and other sectors to conduct future vulnerability assessments, but few if any actually have done so. Local drought planning and assessment is limited, but future requirements are possible, which could include risk/impact assessment. There is some skepticism in the legislative and executive branches regarding the validity of climate change, and therefore, recent attempts to consider climate change have not materialized. Any climate change work in agencies is minimal and not showcased, but state officials are gradually beginning to develop an understanding of the impacts of climate change on water and drought planning. The Southeast's RISA, the Southeast Climate Consortium (SECC), focuses on drought, but mainly in the agricultural sector, and there is minimal university/extension support for water management and climate change. Many local managers in Georgia have yet to identify and understand 'the worst case scenario' (e.g., through tree-ring records), further complicating future drought preparedness and climate change planning.

*Mitigation and response* The 2003 GDMP outlines preparation and response. Officials are supposed to update it every five years, but this has not happened. Georgia EPD takes the lead in creating the DRC, and outlines the drought declaration process, agency organization, pre-drought strategies (state and local), responses (state and local), and indicators/triggers in nine climate divisions. The complete GDMP has not been codified (only the outdoor water use portion has), making implementation of mitigation measures difficult. Stringent pre-drought mitigation strategies at local levels are possible under future rules and regulations,[7] but HB 1281 adopted by the legislature in 2008 disallows CWSs from exceeding state provisions in drought responses and pre-drought strategies. The 1981 Georgia Emergency Management Act includes drought as a hazard for which the Governor can declare a state of emergency and authorize state-level assistance and response. The SECC has not been very active in drought mitigation and response beyond the agricultural sector. During the 2006–2008 drought, measures outlined in the GDMP were deemed insufficient, resulting in the Governor ordering CWSs to reduce water use by 10 percent from previous year levels through a 2007 emergency declaration.

[6] As with Arizona, recent changes in Georgia's drought preparedness approach reflect the dynamism and oftentimes vulnerable nature of building adaptive capacity. Through an executive order in 2011, Georgia's Governor folded the once independent State Climatologist Office into the Governor's executive branch. The Governor also replaced the 12-year-serving State Climatologist.

[7] Officially, Georgia requires water conservation and drought ordinances for CWSs to obtain water withdrawal permits. However, these 'plans' are rarely produced by the CWSs, or not enforced (often overridden) by the State.

### 4.2 CWS adaptive capacity assessment

The results from the generalized estimating equations analysis (i.e., panel analysis) are depicted in Table 2. There are multiple management approaches in each state that show significant relationships with the drought indicators (bolded and thatched in Table 2). Not only are the significant relationships often different in each state across management approaches, but there is variation in both the indicator(s) with which the approaches are associated (the current SPI and/or the lag periods) and the directionality of the relationships (positive meaning the implementation of the approach increases as drought increases and negative meaning the implementation of the approach decreases as drought increases).

The significant relationships in Arizona are negatively associated with droughts (i.e., as drought increases, implementation of the approach decreases), whereas Georgia demonstrates relatively equal numbers of positive and negative significant relationships. This finding is best explained in consultation with the qualitative data.[8]

The negative relationships in Arizona are somewhat anticipated. A few of the relationships may truly be negative with drought, such as with the *communication of uncertainty* (variable 7). Here, the qualitative data show there is a desire to instill confidence and trust over a sense of panic during droughts; hence the negative relationship with uncertainty communication. In other words, managers defer attempts to explain the complex nature of water management and its associated uncertainties to avoid the public second guessing the managers' abilities to meet the communities' water needs.

The qualitative data, however, indicate that most of the relationships are actually not negative, but fall outside of the lag periods evaluated here.[9] That is, positive relationships actually exist with respect to some of the approaches, particularly in the *state coordination* (variable 5b) and *long-term drought-planning* (variable 11). There is also some qualitative evidence in *cui* (variable 5a) and *cross-sector collaboration* (variable 5c) in those systems that are able to find ways to collaborate through long-term city planning initiatives. With variable 5b and 11, processes like the particularly impactful tree-ring research study in the mid-2000s and the Governor's Drought Task Force ultimately resulted in CWS drought conservation and preparedness planning multiple years after the extreme drought period. For these approaches, the droughts seemed to have motivated their implementation, albeit over a longer period of time (i.e., greater than the 12-month lag period evaluated in this study). Finally, with some of the approaches, such as the *collaboration* variables (5a, 5b, 5c) and *supply diversity* (variable 1), the values tend to be generally 'high', irrespective of droughts. In these situations, the negative association is more attributable to coincidence, implying that they already had relatively high levels of the approach preceding the timeframe of this study.[10] This historical emphasis on drought preparedness in Arizona has broader implications for the temporal aspects of adaptive capacity, and is discussed in the next section.

[8] The qualitative data coding exercise classified 30 bridge and 21 barrier categories in both states. A more thorough description of these categories and specific examples from both states are available from the author upon request.

[9] Only one- and two-period lags (i.e., 6-month and 12-month lags) were evaluated, because additional lag periods would have omitted progressively more data at the beginning stages of the timeframe; reducing the power of the results and making it increasingly difficult to identify significant relationships.

[10] Only a 10-year period was investigated. Some approaches might have already been entrenched within a CWS at the beginning this timeframe, making it difficult to detect longer-term relationships between droughts and the implementation of certain management approaches. The qualitative data from the EHC prove valuable in addressing these issues by verifying and augmenting the patterns discovered in the quantitative data.

**Table 2** Relationships between drought preparedness and Standardized Precipitation Index (SPI) drought indices in Arizona and Georgia from 1999–2009; significant (0.10 level) positive relationships are denoted by thatched lines and negative relationships are shaded in grey

| **CWS drought preparedness variables (*dependents*)** | | **Arizona drought index variables (*independents*)** | | | **Georgia drought index variables (*independents*)** | | |
|---|---|---|---|---|---|---|---|
| | | 6-month SPI (current) | 6-month SPI (six-month lag) | 6-month SPI (twelve-month lag) | 6-month SPI (current) | 6-month SPI (six-month lag) | 6-month SPI (twelve-month lag) |
| **1** | Supply diversity | | | | | | |
| **2a** | Infrastructure - supply | | | | | | |
| **2b** | Infrastructure - demand | | | | | | |
| **3** | Conservation | | | | | | |
| **4** | Conservation-oriented rate-structure | | | | | | |
| **5a** | Collaboration - local/regional | | | | | | |
| **5b** | Collaboration - State/Fed | | | | | | |
| **5c** | Collaboration - other | | | | | | |
| **6** | Climate information and scenarios | | | | | | |
| **7** | Uncertainty communication | | | | | | |
| **8** | Stakeholder and customer participation | | | | | | |
| **9** | Consideration of natural processes | | | | | | |
| **10** | Thinking 'outside of the box' and experimentation | | | | | | |
| **11** | Long-term drought planning | | | | | | |

Turning to Georgia, the negative relationship evident in *public and customer participation* (variable 8), is supported by the qualitative data. Here, CWSs report decreased interest in engaging stakeholders in the decision-making process because the stakes are too high and the public's knowledge too low during droughts to justify their involvement. This category also unveils important trust and confidence barriers, similar to *uncertainty communication* (variable 7) in Arizona. Also similar to Arizona, with *local/regional collaboration* (variable 5a), there may be processes established as a result of an earlier drought period, from which the impact on the approach's implementation occurred several years after the drought (suggesting a positive relationship not captured by the time-lags investigated in this research). Here, the most commonly cited processes are the Metropolitan North Georgia Water Planning District (MNGWPD) and the statewide water planning efforts initiated in the early 2000s, which did not affect CWSs' operations until the mid-2000s.

Regarding the positive relationships, there are a number of approaches that show evidence of more immediate implementation (i.e., not lagged), such as *climate information use* (variable 6), and to a lesser extent *cross-sector collaboration* (variable 5c). Both *conservation* (variable 3) and *long-term drought planning* (variable 11) show lagged relationships. The major factors facilitating more immediate relationships with drought in Georgia are research and studies that are carried out through professional organizations and formal regional initiatives as droughts develop (e.g., Georgia Association of Water Professionals and the MNGWPD). These organizations serve as enabling platforms for quick knowledge exchange and collaboration. Leadership is also a very important bridge for implementing many of these approaches during times of drought (this is the case in Arizona too), as well as state and regional regulations and policies.

The qualitative data indicate the best explanation for the positive, yet lagged responses in Georgia, is perception issues. Managers often see water resources and drought cycles as fairly easy to manage and predict (e.g., historically abundant rainfall and relatively short drought periods), and are reluctant to invest time and resources to more consistently implement these approaches. This is particularly evident in the *conservation* (variable 3) and *long-term drought planning* (variable 11) approaches.

## 5 Discussion

### 5.1 Practical implications, heuristics, and applications

The findings from the state and CWS assessments are directly relevant to water management and planning. First, to the extent that comparing between Arizona and Georgia is generalizable to other state drought preparedness efforts, the state assessment findings suggest that adaptive capacity is highest when states and actors within the states:

1. Delegate drought preparedness to the local level;
2. Allow flexibility in triggers, plans, and monitoring;
3. Provide a comprehensive planning and informational support system;
4. Offer iterative regional forums for (or at least remove limitations to) collaborating between systems and locales;
5. Consider climate change in their planning processes; and
6. Establish boundary organizations, such as the RISAs, that are accessible and active in water management and drought planning efforts.[11]

These six elements can serve as important heuristics for states in building adaptive capacity of water management to extreme droughts and climate change. As noted earlier, the relationship between drought preparedness and adaptive capacity has received little empirical attention to date (i.e., both in terms of what actually works in practice and the utility of evaluating drought preparedness as a proxy for climate change management). The guideposts presented here add to previous research by offering a starting point for practitioners to build effective drought preparedness and climate change management initiatives.

[11] This particular finding on the role of boundary organizations in improving adaptation processes is also supported by a recent study by Corfee-Morlot et al. 2011.

The local CWS analyses also have practical implications. In addition to identifying specific bridges and barriers in each state worth taking advantage of or avoiding to build adaptive capacity, there are several applications that one could conceive of from this research to aid in future CWS drought planning. For example, CWSs could systematically compare their patterns of drought preparedness implementation to similar systems' to determine whether they fall behind or are ahead of the curve. Also, by monitoring drought preparedness against drought indicators, managers and officials might better anticipate the extent to which a particular approach may or may not be implemented across CWSs; aiding overall extreme event planning and management. Another application would be for state officials to produce guidelines from these findings to outline good practices for timing and magnitude of implementation for any given approach, and then work with systems to model past behavior to compare where they are to where they want to be.

## 5.2 Theoretical implications: tensions across space and time

More broadly, the findings illustrate tensions and potential tradeoffs across spatial and temporal scales in increasing adaptive capacity through drought preparedness. First, the factors that are important for states in building adaptive capacity to extreme droughts can conflict with what is important for local CWSs in building adaptive capacity to extreme droughts. In the case of Georgia, for instance, determining generic drought responses at the state-level, rather than locally relevant responses, fails to capture and mobilize the system-specific adaptive capacity at the local level; instead relying on crisis management that is reactive rather than proactive. Not only is this less sustainable and efficient, it leaves CWSs feeling frustrated and overlooked, which might not bode well for future state attempts to motivate CWSs into action during a drought emergency.

However, the tension between state and local influences on adaptive capacity is not simply a matter of states disengaging and removing themselves as barriers to CWSs. That is, constraining CWS adaptive capacity might not be universally due to too much regulation, but in some instances too little regulation and direction. Again, in the Georgia case, state regulation through the MNGWPD, drives adaptive capacity building through increased policy certainty and guidance. Arizona, on the other hand, seems to perform well in working through the complexities associated with balancing state regulation and involvement with local flexibility in drought preparedness. Still, there are areas for improvement in Arizona, such as increasing continuity and involvement in LDIGs to build adaptive capacity through stronger state and local CWS linkages.

Thus, in some situations, officials can institute measures perceived to be beneficial for the state, but in fact limit the adaptive capacity of CWSs. This shows that there is a potential tradeoff between structure, regulation, organization, and mobilization of state resources, and flexibility and autonomy of local CWSs. The challenge for building adaptive capacity through management, governance, and institutions in the context of drought preparedness, becomes finding the appropriate balance between structure/guidance/policy certainty (i.e., predictability) and flexibility across scales. To the extent these results are generalizable to other contexts, managers might best build adaptive capacity through 'regulated flexibility', wherein the priority is local preparedness and planning, with states providing the necessary technical, leadership, facilitative, and financial support and resources.

The findings also indicate possible temporal tensions between adaptive capacity to persist and adaptive capacity to transform in the face of extreme droughts and climate change. That is, CWSs may have difficulty simultaneously possessing both temporal aspects of adaptive capacity to a high degree. In Arizona, for example, the EHC quantitative data show highly innovative drought preparedness in CWSs throughout the state. The qualitative data support this finding, pointing to a ‘culture of conservation’ or a ‘conservation ethic’ that has developed within large Arizona CWSs and their customer bases. It is a culture that recognizes the utility of information (including climate information), and is financially committed to long-term planning and infrastructure projects to improve drought preparedness. Managers allude to the arid climate as an underlying motivator for this culture or ethic, but they are also quick to explain that arid conditions have not been the only impetus. In addition to research, long-term and iterative planning, and financial commitments, this culture is also highly motivated by leadership and a collaborative regional attitude.

The ‘culture of conservation’ that has developed in Arizona may not be completely positive for adaptive capacity, however. While exposure to arid conditions and the factors mentioned above may have established a solid conservation ethic, there are still serious barriers that CWSs and their publics face, particularly with respect to the adaptive capacity to transform. The perception prevails within some CWSs and their publics that a conservation ethic is sufficient to address long-term problems and needs; potentially limiting them from responding quickly and changing course when droughts become intense beyond previous experience. In other words, while they are well prepared for current droughts and have built the adaptive capacity to weather these events, lock-in may prevent them from moving beyond a culture of conservation and toward a culture that is well prepared for climate change.

A different adaptive capacity temporal dynamic appears to have developed in Georgia, as shown through the numerous drought preparedness approaches in the EHC analysis that are positively associated with droughts. First, the droughts serve as ‘windows of opportunity’ to increase implementation of the approaches. Because there is less of a culture of conservation in Georgia, there is more immediate room for improving during drought events (i.e., there is more low-hanging fruit). Second, the cyclical nature of these approaches with droughts suggests that while systems in Georgia are able to quickly exercise adaptive capacity and change course, there are impediments to permanently implementing the approaches that build adaptive capacity. In other words, systems are not fully taking advantage of the windows of opportunity. Like Arizona, Georgia CWSs face perception barriers, but these are barriers to instilling a conservation ethic beyond extreme drought periods.

## 6 Conclusion

Looking at drought preparedness across spatial scales in the Arizona and Georgia, adaptive capacity appears highest when states: delegate drought preparedness to the local level; allow flexibility in triggers, plans, and monitoring; provide a comprehensive planning and informational support system; offer iterative regional forums for collaborating between systems and locales; consider climate change in their planning processes; and encourage boundary organizations, such as the RISAs, to be accessible and active in water management and drought planning efforts.

Comparing the state level with the CWS level suggests that well intentioned state drought preparedness could limit the adaptive capacity of local systems. Striking the appropriate balance between structure/regulation (i.e., predictability) and flexibility will likely be a future challenge. To the extent these results are generalizable, it might be best to improve adaptive capacity with ‘regulated flexibility’ through local preparedness and planning, while providing the necessary support and resources at higher scales. Future investigations should not only consider the multiple scales at which adaptive capacity is built and realized, but also how adaptive capacity is interacting between these scales.

Temporal aspects of adaptive capacity also appear to present challenges for adaptation decision making. The findings suggest a potential tradeoff between the adaptive capacity to persist in the face of extreme droughts and climate change and the adaptive capacity to respond quickly and transform. Additional inquiry and policy experimentation could address whether they are mutually exclusive. In the meantime, it might be best for decision makers to conceive of the temporal dimensions of adaptive capacity in layers; first proactively building the layer to improve the ability to swiftly respond to drought crises as they emerge (including being able to take advantage of opportunities and transform when necessary), and second, proactively initiating processes that can instill a longer-term culture of drought preparedness (through institutions, planning initiatives, etc.) to facilitate the preparatory decisions that will protect (but not lock in) critical interests and assets. Being able to navigate between these various tensions could ultimately determine the effectiveness of drought preparedness on adaptive capacity in states and their CWSs.

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