

Jedd, Theresa; Sixt, Gregory N.; Schutz, Anthony; Burbach, Mark

Article — Published Version

Legitimacy in polycentric groundwater governance: Framework conditions identified in Nebraska's Natural Resource Districts

Environmental Policy and Governance

Provided in Cooperation with:

John Wiley & Sons

Suggested Citation: Jedd, Theresa; Sixt, Gregory N.; Schutz, Anthony; Burbach, Mark (2024) :
Legitimacy in polycentric groundwater governance: Framework conditions identified in Nebraska's
Natural Resource Districts, Environmental Policy and Governance, ISSN 1756-9338, Wiley, Hoboken,
NJ, Vol. 35, Iss. 2, pp. 187-200,
<https://doi.org/10.1002/eet.2132>

This Version is available at:

<https://hdl.handle.net/10419/319321>

Standard-Nutzungsbedingungen:

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen
Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle
Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich
machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen
(insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten,
gelten abweichend von diesen Nutzungsbedingungen die in der dort
genannten Lizenz gewährten Nutzungsrechte.

Terms of use:

*Documents in EconStor may be saved and copied for your personal
and scholarly purposes.*

*You are not to copy documents for public or commercial purposes, to
exhibit the documents publicly, to make them publicly available on the
internet, or to distribute or otherwise use the documents in public.*

*If the documents have been made available under an Open Content
Licence (especially Creative Commons Licences), you may exercise
further usage rights as specified in the indicated licence.*



<http://creativecommons.org/licenses/by/4.0/>

Legitimacy in polycentric groundwater governance: Framework conditions identified in Nebraska's Natural Resource Districts

Theresa Jedd¹  | Gregory N. Sixt²  | Anthony Schutz³ | Mark Burbach⁴

¹Department of Governance, Technical University of Munich, Munich, Germany

²Abdul Latif Jameel Water and Food Systems Lab, Massachusetts Institute of Technology, Cambridge, Massachusetts, USA

³College of Law, University of Nebraska-Lincoln, Lincoln, Nebraska, USA

⁴Conservation and Survey Division, School of Natural Resources, University of Nebraska-Lincoln, Lincoln, Nebraska, USA

Correspondence

Theresa Jedd, Department of Governance, Technical University of Munich, Richard-Wagner-Str. 1 80333 Munich, Germany.
Email: theresa.jedd@hfp.tum.de

Funding information

National Science Foundation, Grant/Award Number: 0966093

Abstract

This study considers how and why agricultural groundwater users would limit their own water consumption. We find that voluntary governance arrangements are based on a form of legitimacy that stems from informal social processes. Agricultural irrigation reform in Nebraska, U.S. took place after decades of collaboration in informal social settings; this background of decentralized rulemaking contributed to legitimizing extraction limits in times of water stress. The dimensions of social legitimacy are assessed through triangulation of interview data, integrated management plans, workshop facilitation, and recordings of legal proceedings related to the Natural Resources Districts in the state of Nebraska. These districts initially placed voluntary limits on extraction but evolved to sanction violators for over-consumption. Groundwater rules are accepted because they are set by publicly elected boards, leaders participate in a state-wide leadership training network, and the districts are granted rule-making authority by the state. Our results show that voluntary self-limiting behavior can form the basis for binding legal requirements. The legitimacy of polycentric governance stems from social acceptance, inclusive membership, a prior history of collaboration, and an understanding of rules. The rules themselves are context-specific and self-made. We summarize these elements in an evaluation framework to test whether and how authority in other polycentric groundwater governance arrangements is justified and accepted.

KEYWORDS

groundwater, integrated water resources management, polycentric environmental governance, social legitimacy

1 | INTRODUCTION

Groundwater is critical for food security. Most irrigation in North America (59%) is with groundwater (UN, 2022). In the 20th century, groundwater irrigation was associated with industrialization and economic growth, because it reduced reliance on rainfall and seasonal stream flows and increased crop yields (Rodella et al., 2023). Countries that exploited groundwater resources have grown richer: access

to energy required for pumping is seen as a pathway to economic development (UN, 2022). At the same time, global groundwater reserves are declining because they are withdrawn at a higher rate than they are being replaced (Famiglietti, 2014). Groundwater consumption has surpassed a “planetary boundary,” with more water being withdrawn than is naturally replenished in 47% of the world's land area (Richardson et al., 2023), unjustly affecting portions of the population that have not been significant users of groundwater

This is an open access article under the terms of the [Creative Commons Attribution](https://creativecommons.org/licenses/by/4.0/) License, which permits use, distribution and reproduction in any medium, provided the original work is properly cited.

© 2024 The Author(s). *Environmental Policy and Governance* published by ERP Environment and John Wiley & Sons Ltd.

Change in U.S. acres of irrigated agricultural land by county, 1997-2017

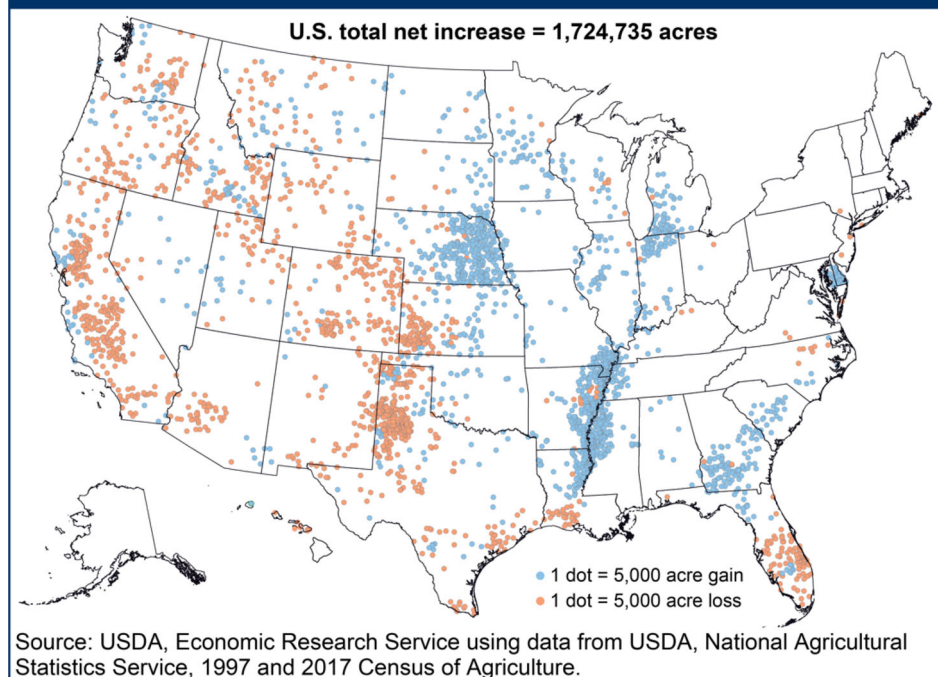


FIGURE 1 The amount of irrigated agriculture in the U.S. is increasing overall, while there is an eastward expansion (Source: U.S. Department of Agriculture Economic Research Service, 2023).

(Neal et al., 2016). This is troubling because, without groundwater, future generations around the world will struggle to find drinking water or grow food during droughts. In the agricultural sector, a promising path to protect groundwater is to involve irrigators directly in setting rules about its use.

Theories of democratic environmental governance and self-rule emphasize the benefits of local input, including a range of stakeholders, and ways of negotiating disagreement about dwindling water resources (Koebele & Crow, 2023). Groundwater governance is an encompassing set of arrangements “that enable decisions to be made, actions taken, and policies enforced” (Roberts et al., 2021, p. 42). It includes “laws, regulations, and customs, as well as the processes of engaging the public sector, the private sector and civil society” (Megdal et al., 2017, p. 719). Multi-stakeholder, multi-level governance arrangements are needed to stop groundwater overextraction because they build a basis for individuals to trust that rules will be collectively followed (Ostrom, 1988; Ostrom, 2010). Unlike surface water delivered from diversions or canal systems, made possible through large publicly owned, state-operated projects, groundwater withdrawal happens largely in the private sector, driven by individual household or farm-level decisions (Shah, 2014). Groundwater extraction developed with minimal government oversight until crises emerged such as in 2014 when California underwent extensive reform of its groundwater governance as a result of extended droughts (Roberts et al., 2021). California's Sustainable Groundwater Management Act has been hailed as a milestone in rulemaking, but less formal rules about groundwater use have longstanding histories in the U.S. These groundwater governance arrangements included measures to reduce demand and consumption, and thus avoid

disastrous declines in water availability that lead to conflict and litigation (Megdal et al., 2017). Many of these informal rules about groundwater use directly involved farmers and their irrigation choices (Ostrom, 2011).

In the U.S., irrigation is shifting eastward (see Figure 1). Farm irrigation decreased in California from 8.8 to 7.8 million acres while increasing from 7 to 8.6 million acres in Nebraska in the decade from 1997 to 2017¹ (USDA ERS, 2023).

Nebraska, like other states in the central portion of the U.S., is becoming a more prominent user of groundwater. Eastward expansion of groundwater withdrawal is due to conversion of rainfed to irrigated cropland; over the High Plains Aquifer, irrigation of wheat, corn, and soybeans is used as a risk reduction strategy against the impacts of climate change (Obembe et al., 2023). At the same time, the additional stressors of heat and changes in rainfall could exacerbate groundwater decline, putting the High Plains Aquifer in peril. Thus, this expansion of groundwater consumption could reduce Nebraska's future drought resilience, making irrigation water less available during extremely dry years.

More is known about where irrigation takes place, but less is known about how it is governed. Regulations about groundwater usage are uneven across the U.S. (Megdal et al., 2015), and it is difficult to implement rules because of the lack of information on consumption rates (Kroepsch, 2024). The variation between states makes it difficult to generalize what makes for “ideal” groundwater governance. Instead, there is a trend of place-based groundwater governance, especially in areas where agriculture is threatened by

¹<https://www.ers.usda.gov/topics/farm-practices-management/irrigation-water-use/>.

drought such as Arizona, Colorado, California, or in states over the High Plains Aquifer of the United States (Blomquist et al., 2010; Burbach et al., 2022; Sixt, McCarthy, et al., 2019; Skurray, 2015; Wiechman et al., 2023).

1.1 | Legitimacy is a key feature of polycentric water governance

Groundwater governance in the U.S. is fragmented, and the authority is shared between states and local agencies (Megdal et al., 2015). This mix of public and private rulemaking across scales is understood as “polycentricity,” in reference to the multiple centers of authority (Ostrom, 1988). Polycentric governance, through its combination of self-made rules and the authority of elections and taxation held by the government, could be key to preventing the collapse of freshwater supplies (Schipanski et al., 2023). Polycentric governance provides a buffer against resource degradation through the installation of rules across scales (Bennett & Satterfield, 2018) especially in places affected by long-term aridity or short-term drought (Petersen-Perlman et al., 2022). It is thought to reduce conflict by increasing negotiation in places like Colorado, USA where water decisions can be highly contentious (Koebele & Crow, 2023). So, beyond highlighting the nuanced nature of fragmented authority, polycentric water governance research considers the quality of interactions, the modes of sharing information and making decisions, and ways to mediate disagreements (Neef, 2009).

Participatory processes potentially reduce conflicts because water users are involved in designing programs and policies. Yet, without background mechanisms for enforcement, which may come from centralized top-down agencies, local control can fall apart (e.g., Gibson et al., 2005). If voluntary, citizen-led arrangements are to be effective, they need to build a credible reputation and be viewed by water users as a legitimate mode of governance. Legitimacy, in a nutshell, means that authority is justified and accepted (Bernstein, 2011). This authority can come from government, society, or a combination of public and private actors (Bernstein, 2011). Legitimacy can be granted by participants when appropriate avenues for deliberation are provided, and local community members have access rights and can also influence rules about water use (e.g., Kuzdas et al. 2015 for Costa Rica).

Polycentric systems of governance rely on a blend of public and private authority to enforce their rules. This authority is not based solely on the state or its implementation of the law. It is granted from the state (traditionally a top-down authority) to societal actors who have a bottom-up social awareness of acceptable behavior. This constellation of authority does not rely solely on the state, or any other single actor for that matter, to make and enforce rules (Carlisle & Gruby, 2017). Polycentric authority is drawn from self-monitoring and collective oversight through multiple institutions simultaneously. It draws upon a threshold of social acceptance, or norms, that prompt group members to consider their actions in relation to others' (Grannovetter in Sikkink, 2024).

1.2 | Polycentric groundwater governance in the U.S.: A system of self-rule

Polycentric water governance has been purported to be more adaptive to water-related crises (Pahl-Wostl & Knieper, 2023). Reed et al. (2018) suggest that this is because environmental management is improved when decision-making authority is shared with the actors who are responsible for implementation. Polycentric water governance arrangements are more capable of adapting to climate change than fragmented or centralized regimes which are comparatively less flexible (Pahl-Wostl & Knieper, 2014). There are connections between climate change and more rapid onset of droughts (Pendergrass et al., 2020), increased anthropogenic demand for water (van Loon et al., 2016), and worsening drought impacts (Wilhite, 2016). As a result, uncertainty in water availability and climatic pressures related to drought can strain groundwater governance institutions because difficult choices need to be made when not all water users' needs can be met (Petersen-Perlman et al., 2022). These prioritizations are set at the state level through water rights appropriation systems. The U.S. does not have a national drought plan, instead addressing water allocation at the state and local levels. There is wide variation in how states plan for drought, with some focusing more on the science of hydrological monitoring and others setting policy guidelines for water conservation (Jedd and Smith, 2023). The feedback effects of increasing temperatures and droughts pose novel challenges including increased demand for groundwater and simultaneous degrading water quality (Petersen-Perlman et al., 2022). Therefore, it is important to ask whether and how polycentric water governance arrangements can hold up to stress.

Polycentric environmental governance is suited to address changing conditions because its redundancy ensures that rules and institutions do not fail during crises (Bennett & Satterfield, 2018). An understanding of how agricultural producers could collectively reduce their consumption would be a leverage point in addressing groundwater overdrafts (Martínez-Valderrama et al., 2023). Elinor Ostrom (2011) suggested that self-governing systems comprised of local users can reduce the strain on water resources from intensified agricultural production.

1.3 | Research question: Can self-rule be self-restricting?

Polycentric governance has a mix of public and private authority which can include flexible and competitively allocated funding from tax revenue (Ostrom, 1988). This multi-dimensional basis for authority can lend the social legitimacy needed to make rules about groundwater extraction (Pahl-Wostl & Knieper, 2014). We focus on how polycentric groundwater governance is legitimated. In other words, we wanted to know why it is accepted. In Nebraska, an agricultural state with a relatively high dependence on irrigation, why would agricultural producers (farmers) set limits on their water use? The taxpayer-funded Nebraska Natural Resources Districts (NRDs) have an

Integrated Management Planning process (NDNR, 2016) which provides a testing ground because of its emphasis on stakeholder involvement. Given the growing dependence of industrialized agriculture on groundwater irrigation, answers to this question could help reduce groundwater depletion in other places.

We begin from the polycentric water governance literature and hone our focus on groundwater with a deeper consideration of the social dimensions that make polycentric governance tick. This study assesses the dimensions of social legitimacy found in collaborative voluntary governance arrangements in Nebraska, U.S., which has a history of local, collaborative water management (Bleed & Babbitt, 2015; Jedd et al., 2022; Sixt, Klerkx, et al., 2019). This study contributes to the call within environmental governance research to better understand the spread of voluntary practices (e.g., a 'norm cascade' in Sikkink, 2024), elaborating on the framework conditions that enable self-governance.

2 | METHODS

We use a 'critical case' approach centered on the processes within the bounds of a single system that has broader significance (Flyvbjerg, 2017; George & Bennett, 2005); Nebraska's agriculture is reliant on groundwater to the extent that allows for logical deductions about other polycentric governance systems for irrigated agriculture. The study was conducted by an interdisciplinary team of researchers in social sciences and natural resource law and management working across disciplinary divides with diverse data sources (similar to Burbach et al., 2022 or Megdal et al., 2017). Data sources include Integrated Management Plan documents, semi-structured interviews, workshop facilitation experience in Nebraska's Natural Resources Districts, and recordings of legal proceedings from the Nebraska Supreme Court. We used the range of data to triangulate the features of this governance system. Triangulation, or the use of more than one method of collecting and analyzing data, is often necessary in studying complex, interdisciplinary topics in environmental governance (O'Neill et al., 2013). The court cases and Integrated Management Plans were helpful in establishing the ability to set limits on groundwater extraction and to sanction overconsumption, and the interviews as to why and how these rules are socially accepted. In all phases of the analysis, we focus on generating thick description that includes actors' perceptions and understandings (Geertz, 1973).

Qualitative studies are capable of generating causal claims about a phenomenon when they pay attention to the "relevant facts" (King et al., 2021) or observations that have a demonstrated connection to the outcome of interest. Throughout the analysis we ground our claims, or present the direct evidence that was used to make our assessment (Knott et al., 2022). The interview quotations presented in Section 4 demonstrate how the data fit into the features of our framework. This is in alignment with Gerring (2012) who shows that qualitative research—when it progresses from generalizing, to recognizing multiple dimensions, to grouping and categorizing—is capable of synthesizing information in a way that makes it possible to build a framework that shows how phenomena are organized.

TABLE 1 Number of interviewees based on their affiliation.

Number of interviews	Type of organization and position
13	Natural Resource District (NRD) managers, staff, and board members
2	Nebraska Association of Resource Districts (NARD)
5	Nebraska Department of Environmental Quality (DEQ)
1	Nebraska Department of Natural Resources
1	Groundwater Foundation (nonprofit organization)
5	University of Nebraska—Lincoln water experts, researchers, and extension agents
1	City of Hastings Utilities
4	Agricultural producers

Note: Some interviewees had more than one (but no more than two) affiliations. In these instances, both affiliations were listed. In total, 35 individuals were interviewed, in 34 interviews (one interview was with two individuals).

Interview data were collected in 34 semi-structured, in-person interviews with 35 decision-makers directly involved in running, overseeing (Nebraska Department of Natural Resources and the Department of Environmental Quality), or supporting (University of Nebraska, Lincoln, the Nebraska Association of Resource Districts) five of Nebraska's NRDs in June 2017 (Table 1, note that one of the interviews was with two decision-makers). Representatives from the following NRDs were interviewed: Central Platte, Lewis and Clark, Little Blue, Lower Niobrara, and Elkhorn. The interview identities are protected with assigned numbers between 100 and 134.

The interview protocol was designed to address water quality and water quantity governance, but in this study, we focus solely on the results that pertain to water quantity.² The interviews were transcribed verbatim. Using open and axial coding, two of the authors devised a schematic to capture the major themes. We created deductive a priori codes from Ostrom's notion of polycentricity, which is congruent with March and Olsen's (1996) "logic of appropriateness" and assumes that social behavior is more than the sum of individuals acting in economically rational terms. The primary codes derived from the literature were: social legitimacy, inclusionary membership, connection to board members, history of collaboration, rewards, self-made rules, and understanding of rules. From these, the data were coded secondarily using these emergent themes as codes. They form the basis for the components of the social legitimacy framework (provided in the results, Table 2).

The Integrated Management Plan documents, and legal proceedings on the implementation of the integrated management plans, were used to check the validity of the results. Additionally, two of the authors have professional experience with NRDs through facilitating leadership workshops and conducting legal scholarship, and one author is an elected member of an NRD board of directors. Several Nebraska Supreme Court cases were reviewed that arose due to conflict between surface water and groundwater users. The cases

²The analysis of the water quality governance results can be found in Sixt et al. (2019a).

TABLE 2 Framework conditions for legitimacy in polycentric groundwater governance.

Core elements Main codes	General components Description of supporting features
Social acceptance	The informal, voluntary, community-oriented practices driven by a sense of obligation to others, including: pressure from peers Influence/wanting to preserve reputation; learning by observing others; and the desire to comply with local norms and customs Cooperative personalities, participants who get along with each other, common values, shared culture Involvement of elders, desire to seek their approval Locally elected voluntary board creates rules, but paid staff implements programs The absence of laws and/or regulations from the state is viewed as a reason for local rule making
Inclusionary membership	Board membership is open to anyone in the district: all willing stakeholders are invited to participate Minimal, or no, separating line between those within the governing process and those outside of it Individuals who would be impacted by new rules are identified and invited to participate in public meetings
Prior history of collaboration	Participants have already collaboratively governed other issues Longevity in natural resource management positions Having faced past droughts together Long-term processes that are seen as stable
Context-specific rules with economic incentive	Avoiding top-down mandates and regulation Using specific rules that are based on particularized local challenges Best management practices (BMPs) are economically feasible Collective cooperation as a demonstration to “outsiders” that water users can identify and share common burdens Stricter rules ramp up when problems exist (e.g. nitrate levels are too high)
Self-made rules	Adaptive management, or flexible rule-making The standards are seen as achievable because they are chosen by the residents of a local area Board of directors are producers themselves Balancing a preference for local rulemaking with the directive to have an Integrated Management Plan Publicly elected board members are part of their communities and regularly interact with water users Agricultural business representatives participate and are viewed as credible sources of information Cost-sharing for equipment, for example, gravity to pivot conversion
Understanding and acceptance of rules	Awareness of the scientific principles behind management practices BMPs become “self-evident” and convincing for action Technically transparent basis for rulemaking No yield benefit from applying excess fertilizer or excess irrigation water Realization that groundwater is drinking water Rules are connected to monitoring Groundwater withdrawal rules change in drought years Stricter rules ramp up when problems exist (e.g. when nitrate levels are too high) Staff are employed for extension services

reviewed were *Hill v. State* (296 Neb. 10, 2017) and *Spear T. Ranch v. Knaub* (271 Neb. 578, 2006). When examining these sources, we looked for evidence about how access is granted to water. We wanted to know if there were differences between surface water rights holders and groundwater access. We also wanted to know who was included in the governing boards. Were decisions made in a majority or a consensus model? We expected to see that there is a way to address associated problems with surface water depletions, given the conflicts between surface water and groundwater users during the 2012 drought.

3 | GROUNDWATER GOVERNANCE IN NEBRASKA

Groundwater is an important component of Nebraska's economy, and agriculture is the highest consuming sector (U.S.G.S., 2021a).

Nebraska has the most irrigated cropland and pasture in the United States (U.S) (Bleed & Babbitt, 2015). Slightly more than 9 million acres of farmland—about 32% of the state's land—are irrigated, mostly from groundwater (Nebraska Association of Resources Districts, 2021; U.S. Department of Agriculture, 2019). Irrigation is a major dimension of agriculture in Nebraska and has led to increased yields and an increase in property value (Ulrich, 2018).

As a result of agricultural demand, groundwater from the High Plains (Ogallala) aquifer is being withdrawn faster than it is being recharged (Figure 2).³ In Nebraska, a large portion of the loss (almost half) was in the Republican River Basin from 2000 to 2009, which it shares with Colorado and Kansas. These losses are due to irrigation withdrawal used to replace decreased rainfall and to compensate for

³<https://www.climate.gov/news-features/featured-images/national-climate-assessment-great-plains%E2%80%9999-ogallala-aquifer-drying-out> Retrieved 3 April 2023.

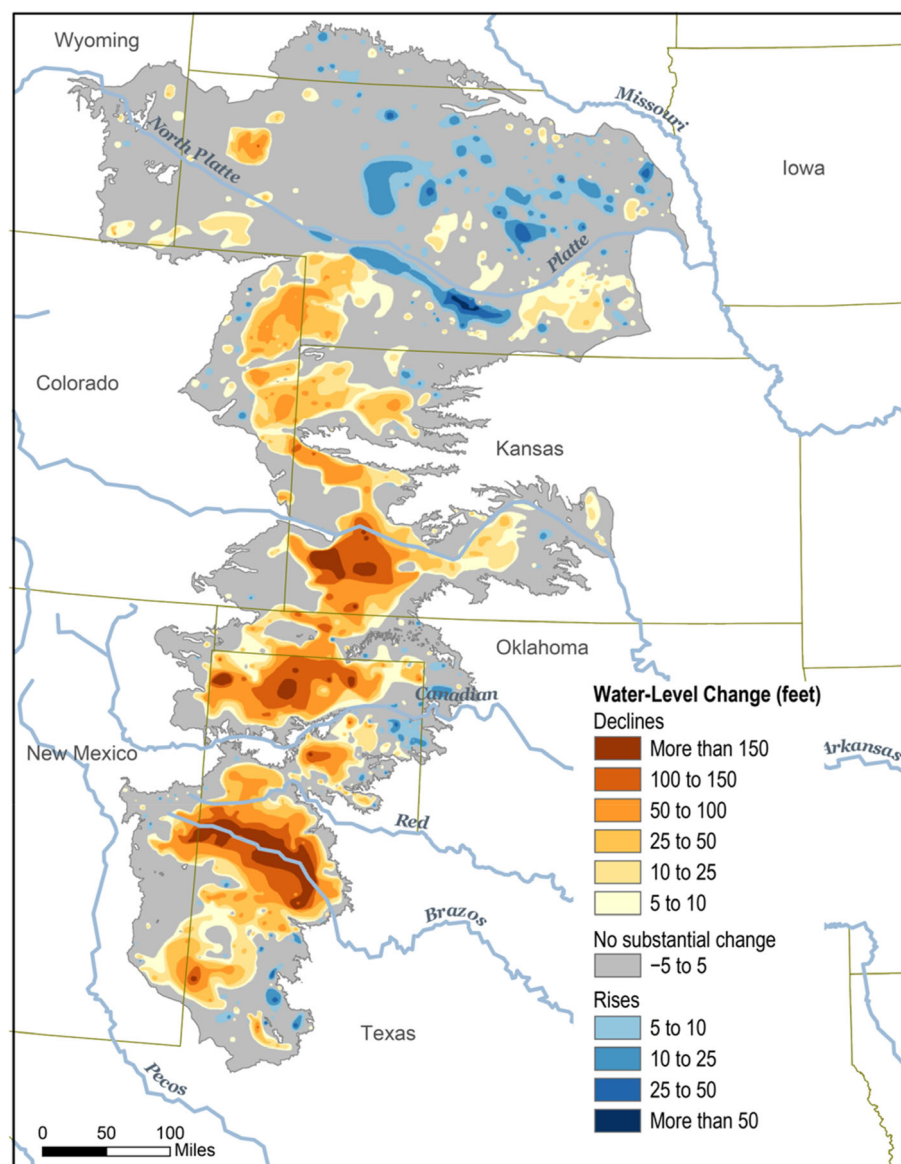


FIGURE 2 Extent of the High Plains Aquifer and water-level change from pre-extraction to 2015 (National Climate Assessment NCA4, 2019).

increased surface water evaporation (Peterson et al., 2020; U.S. Geological Survey, 2021b).

Withdrawal has led to higher levels of groundwater depletion in the western and southern portions of the state, in parts of the state that either tend to be more settled (the Interstate-80 corridor) or receive less rain. The yearly statewide average rainfall is between 13.36 inches in 2012 and 35.50 inches in 1915 (Frankson et al., 2017). The eastern portion of the state tends to be wetter: it receives about twice as much rain (35 inches) as the western part (15 inches) (Shulski, 2018). Droughts plagued the state from February 2002 to September 2008 and again at a peak in the first week of October 2012 with more than 77% of the state in severe drought (National Drought Mitigation Center, 2021). Without groundwater irrigation, the state's agriculture-heavy economy would suffer more than it already does during droughts (Jedd et al., 2022). Despite its reliance on groundwater, Nebraska, in comparison to the other states of the High Plains Aquifer, has experienced less aquifer decline (Sixt, McCarthy, et al., 2019; see also Figure 2).

3.1 | Integrated surface water and groundwater governance

In Nebraska, groundwater and surface water are managed in a somewhat coordinated model, which offers needed flexibility given the growing demand for irrigation coupled with cyclical changes in water availability. The NRDs use an integrated management planning process to coordinate the use of surface water, which is managed by the state, and groundwater, which is managed by NRDs (Peck, 2007). The integrated planning process has resulted in stricter controls for groundwater users, due to conflicts between surface water and groundwater irrigators that were intensified by drought stress. This process was initially required for over-appropriated basins but is now implemented in all NRDs voluntarily (Reed & Abdel-Monem, 2015). Figure 3 shows the status of planning, with required planning in areas that roughly correspond to areas with groundwater decline shown in Figure 2.

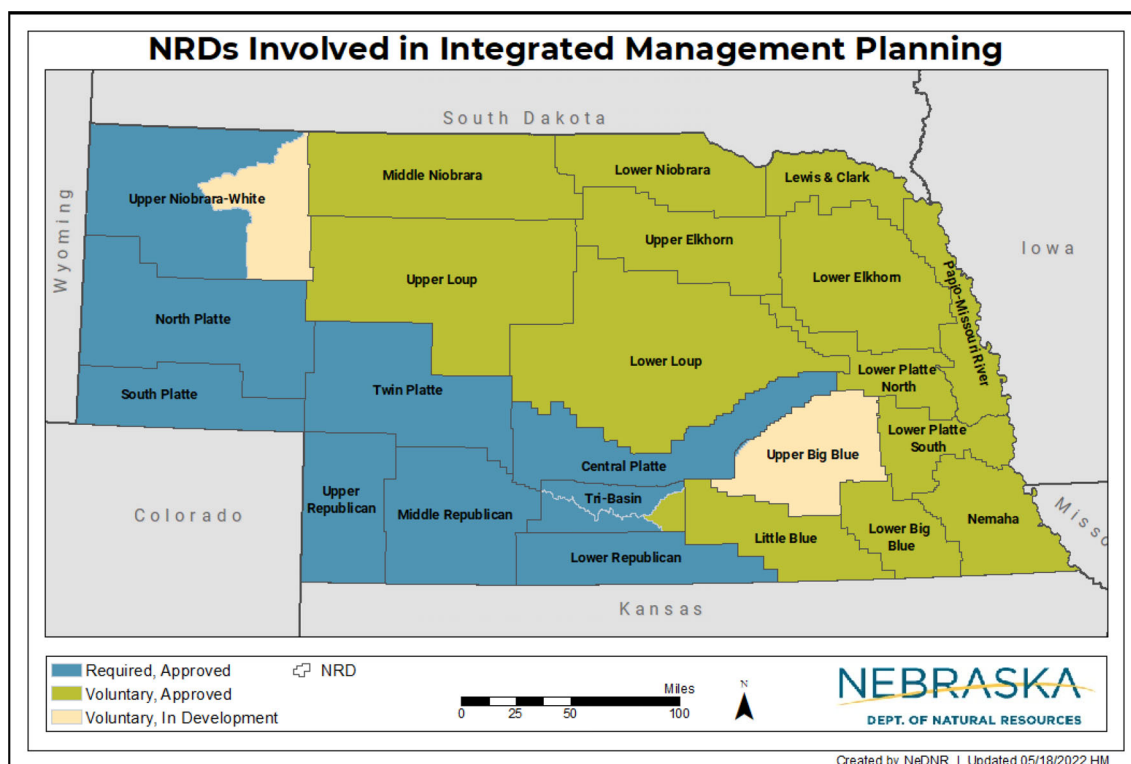


FIGURE 3 Natural Resources Districts with integrated management plans as of May 18, 2022. Source: Nebraska Department of Natural Resources. Reprinted with permission.

The localized model, which works in tandem with state and federal planning and legal mechanisms, is designed to reduce the strain on individual farmers during droughts by collectively setting rules for water use. Like other polycentric forms of governance, it involves public and private stakeholders across levels. Nebraska places responsibility for governing groundwater with the NRDs. They are the “preferred regulators of activities which may contribute to groundwater depletion” (Neb. Rev. Stat. § 46–702 in Nebraska Association of Natural Resources Districts, 2021). NRDs are public-private quasi-governmental entities with an elected Board of Directors. NRDs earn revenue from property and occupation taxes based on irrigation status. While the publicly elected Boards of Directors govern the district's operations, NRD tasks are carried out by professional staff, including a General Manager who has general administrative oversight. The directors, management, staff, and members of the public make decisions about water allocation (Nebraska Association of Natural Resources Districts, 2019).

Some NRDs have more extensive water planning than others. The priorities and approaches to management vary by location. Additionally, the history of cooperation varies between NRDs. The NRD groundwater governance activities are an overlay on the common-law right to withdraw water from beneath one's property. These so-called correlative rights were automatically conferred with property, regardless of how much groundwater was available. This was relatively uncontroversial at the beginning. As scarcity problems emerged, though, NRDs were given statutory authority to regulate withdrawals.

As depletion of groundwater began to affect limited surface waters in a multiyear drought in the early 2000s, the NRDs became involved with the state in integrated surface-groundwater governance (State of Nebraska Department of Natural Resources, 2004).

When water users receive (and trust) weather and climate monitoring information, they can adjust their irrigation practices based on a shared understanding of how much atmospheric water is available—for example, rainfall (te Wierik et al., 2020). Monitoring withdrawal amounts can also inform a network of irrigators of the challenges they may collectively face during the growing season. This information can be provided, for example, with data from well flow meters (North Platte Natural Resources District, 2016). Including climate researchers (who have rainfall data) and extension officers (who can oversee water consumption in the field) in the NRD rulemaking process contributes to “input legitimacy,” which Juerges et al. (2018) define as including multiple types of actors in the rule-making process.

The NRDs make mid-level rules that sit between federal statutes and local-level ordinances. They use collaborative procedures to make rules about groundwater extraction, among rule-making in other areas such as groundwater quality. The boundaries for these local governments were drawn from a combination of watersheds and county-line administrative units. As monitoring technology and capacity have improved, so has rule enforcement. There are directives that include enforceable sanctioning for violations of extraction limits. These sanctions and penalties include mandatory education, cease-and-desist orders, revoking irrigation permits, revoking permission for

groundwater transfers, monetary fines, and eventually a civil misdemeanor for non-compliance [compiled from document review of Upper Republican Order No. 34 Adopting Groundwater Controls (2018), Upper Big Blue NRD Groundwater Management Rules and Regulations (2020), Lower Platte South NRD Groundwater Management Rules and Regulations (2020), and North Platte NRD Rules & Regulations for Enforcement of the Nebraska Ground Water Management and Protection Act and the Nebraska Chemigation Act of 2019]]. Well-head meters that are connected to a monitoring network give the NRD Boards information about when to enforce extraction limits.

4 | RESULTS: GROUNDWATER GOVERNANCE FRAMEWORK CONDITIONS

There is an adage in water governance that you cannot manage what you do not measure (World Meteorological Organization, 2024), which means that information about water availability is required for making rules about water use. We expand upon this adage to say that *you cannot implement rules that are not socially accepted*. All interview participants, to some extent, named elements of social acceptance as a feature of the way that groundwater is governed. There is a sense of obligation to protect water availability for others and for the future. We argue that these dimensions of social acceptance are why the NRDs can claim to legitimately govern groundwater. Our findings, elaborated below, are in line with previous work showing the need for multilevel interactions between states, water suppliers, and water users, especially when state regulators hesitate to unilaterally enforce water restrictions (Kirchhoff & Dilling, 2016). The layering of the ability to sanction overconsumption on top of voluntary compliance procedures is a fundamental feature of polycentric governance.

4.1 | Features of legitimacy in polycentric groundwater governance

In this section, we identify the critical features for establishing the legitimacy of polycentric groundwater governance (See Table 2). The secondary codes contribute to our ability to answer the fundamental question of why farmers would voluntarily agree to reduce their groundwater consumption, even during droughts. These features of polycentric governance arrangements are likely interacting with and influencing each other, but for the sake of analytical clarity, they are presented in a condensed, linear fashion.

First, there must be an overall social acceptance stemming from a sense of obligation to others and the community. As one interviewee stated, “It is hard to look your neighbor in the eye and say ‘that’s your problem, not mine’ (120). This obligation arises because the agricultural water users see themselves as embedded within the NRDs: they are made up of neighbors, peers, competitors, and community members. This social acceptance is the foundation of legitimacy, as it involves peer influence, learning by observing others, and a desire to comply with local norms and customs.

Second, membership needs to be open and inclusive, so that all stakeholders can participate. In essence, this means that there is no clear division between those who are outside the decision-making process and those who are within it. We observed a dissolution of an “us vs. them” distinction because the membership base of NRDs is broad. As an interviewee stated, “I think you have got more people involved so you get more people that are OK with it and less that are ... viewing themselves on the outside looking in” (112).

Third, we found it important that a prior history of collaboration exists when participants have already collaboratively governed other issues. There is longevity in natural resource management positions, and the group has faced past challenges – such as drought – together. The NRDs seek to employ staff who have been working in the region for decades, with strong local ties: “When you go to work conferences here, if you’ve been around for 20 years there is definitely some respect” (122).

Fourth, the rules themselves are context-specific and pertain to very specific areas where problems are located. Their solutions are economically incentivizing, such as improved efficiency with new types of irrigation equipment. Agricultural production was characterized by participants as a challenging endeavor in which profits can be elusive, and “the profits are at the margins” (112). Therefore, the use of farming practices that increase profits, even if they require cooperation, send a signal to state and federal regulators that local water users are capable of setting their own rules. In this setting, the costs incurred are social rather than financial.

Fifth, that the rules are self-made is important in and of itself. This dimension enhances voluntary compliance and increases a sense of self-sufficiency. As one NRD operator put it: “I can’t make anybody do anything. But it is a good thing that I can’t do that because my whole program is based on getting people to do it on their own” (125).

Finally, there is a high level of understanding of the science or rationale behind the rules. University extension services cooperate with the supplier companies to provide information about inputs and water usage, and there is a perception that “the science is getting better” and participants trust that the requirements are effective (for example, that restrictions can reduce the damages to groundwater supplies caused by multi-year droughts). Table 2 contains the key elements we identified in these six dimensions. Detailed notations of each of these framework conditions can be found in Supplementary Material S1, which lists illustrative quotations and summary statements from interviewees.

The results of this research are organized in a way that is consistent with existing frameworks for water and natural resources management (e.g., Eaton et al., 2021; Kliskey et al., 2021). Additionally, these results bring in the history of collaboration and the motivation (sometimes as strong as an economic incentive) to avoid top-down regulation from the state. Studies of polycentric water governance generally portray this separated, overlapping, and socially constructed form of authority in a positive light. These arrangements tend to result in more adaptive governance (Pahl-Wostl & Knieper, 2023), reduced water consumption in order to meet downstream users’ needs (Baldwin et al., 2018), and novel collaboration or information-sharing (Baltutis & Moore, 2019).

4.2 | Scalar and procedural pressures on legitimacy

We note two categories of challenges and the first is scalar. The scale of the governance unit matters; ideally participation should match the scale of the problem (Moss & Newig, 2010). There is interplay between scales, and some problems can emerge from changing the boundaries of a governance program. The higher the scale, the lower the level of possibilities for participation (input legitimacy), which can in turn threaten the output legitimacy (the ability to effectively tackle problems, or simply the rules' effectiveness). In Nebraska, this mismatch can occur within and between the NRDs, the state, the state-defined Basins, Public Power and Irrigation Districts, and management units within the NRDs, among others. It could also occur across state borders, which is particularly notable with Kansas. An overdraft of groundwater can affect neighboring units. If this happens, then one's own reduction in consumption will do little to alleviate the overdraft unless all surrounding water users also reduce their consumption. One way of dealing with the free-rider problem is to rely upon higher rules, yet this is easier said than done.

In basin-wide water governance, top-down initiatives have been criticized for ignoring situational factors and relying on command-and-control rulemaking (e.g. Skurray, 2015 for Australia) and for being less flexible when rapid action is needed, such as during droughts (Western Governor's Association, 2018). Top-down, centralized governance might work in some issue areas with shared problem definitions such as air quality or education (Thiel, 2023) but groundwater is unique and eludes an overarching, national set of rules (Megdal et al., 2015), let alone statewide rules. For example, Nebraska farmers who are relatively less reliant on groundwater irrigation in the eastern part of the state have expressed hesitation to adopt allocation rules because they perceive overdraft to be a problem that happens in the western parts of the state that receive less rainfall (Schutz, 2015).

The second type of challenge is procedural, and it is found in other polycentric environmental governance processes, such as international climate negotiations. For example, not all NGO groups feel that full inclusion is happening (e.g. overrepresentation of some groups such as business and industry and underrepresentation of other groups, including indigenous peoples, women, and people of non-binary gender identities). In these instances, procedural legitimacy is lacking. It is therefore problematic the way that input is taken on board from various groups, or there are no mechanisms to hear different ideas about how to solve a problem (Bäckstrand et al., 2021). Organizations and institutions that do not engage relevant stakeholders and fully understand the power imbalances between them will likely fail to properly incorporate their input (Lukasiewicz & Baldwin, 2017; Morrison et al., 2019).

Integrated planning brings new set of stakeholders in, namely surface water users. The relationship between surface water irrigation districts and the state, or surface water users and groundwater users can become contentious, when groundwater pumping during droughts affects surface water flows (e.g. Spear T. Ranch v. Knaub, 271 Neb. 578, 2006). These tensions create the justification for integrated planning. We observed procedural challenges in the state's

Supreme Court (e.g. Hill v. State, 2017, 296 Neb. 10). Legal challenges tend to occur based on actions taken during droughts or drier parts of the year (i.e., closer to the end of the hydrological year which is September 30th). Conflicts also tend to be located in fully- or over-appropriated hydrologically connected areas, especially near the western and southern state borders where groundwater pumping can impact surface water availability, including for neighboring states (Schutz, 2015; State of Nebraska Department of Natural Resources, 2021). Integrated management planning is beginning to address these challenges but as the lawsuits show, there is still conflict between these types of water users.

Court cases have been inadequate for proactively preventing water decline. In order for a case to be heard by the Nebraska Supreme Court, a plaintiff must first experience harm (e.g. economic loss from water reduction). By the time these losses are incurred, it may be too late to salvage crops, and there can be ecosystem damage such as habitat or species loss. In a Supreme Court case, *Kansas vs. Nebraska and Colorado* (2015), Nebraska had to compensate Kansas for over-pumping hydrologically connected groundwater under the Republican River Compact, designed to protect surface water flows (Jedd et al., 2022). By the time the court case was settled, the ecosystem damage from a drought in 2012 had already led to forest loss due to wildfire, zoonotic diseases in the deer population, and a loss in pheasant and quail bird habitat due to range grasses being cut for emergency cattle feed (Smith, 2012). This is a shortcoming of using the court system to remedy water shortages, as it is an inherent feature of courts to account for loss after damage.

Legislation from the state is also a difficult route to prevent drought damages. Elected officials might hesitate to place limits on water usage because it could be unpopular with voters. Hess et al. (2016) state that demand management can be politically controversial and locally elected officials may avoid putting limits on water consumption for the fear of losing re-election bids. (Hess et al., 2016). Therefore, judicial and legislative procedures leave enforcement gaps in the eyes of agricultural water users.

5 | DISCUSSION AND CONCLUSION

The Integrated Management Planning process in Nebraska overcomes the challenges associated with top-down governance by placing responsibility in the hands of local decision-makers, for example, the boards of the NRDs, who have a vested interest in preventing drought losses before they occur. Polycentric groundwater governance requires a high level of stakeholder participation and the active oversight of elected leaders (Burbach et al., 2020). This is the Board of Directors in each NRD, and the statewide Nebraska Association of Resources Districts. Local resource districts can overcome some of the shortcomings of legislative and court-based approaches.

The results show that voluntary, user-driven rules could evolve to include enforceable (non-voluntary) rules. In other words, the Natural Resources District model shows that when a self-driven rule-making process is legitimate, it has rulemaking authority. The governance

system evolved over time to adjust to water availability, irrigation needs, water quality, and user recognition of the threat posed by drought. In this section, we present the ways in which our results expand upon polycentric governance, the relationship between rural water users and groundwater, the limitations of polycentric governance, and future directions.

5.1 | Expanding dimensions of polycentric groundwater governance

These findings elaborate on what is known about polycentric groundwater governance. Schipanski et al. (2023) suggest that successful polycentric governance, that is, capable of reducing groundwater overdraft, has a shared understanding of problems, creates commitment to conservation through engagement rather than voluntary action, has strong leadership, and supportive governmental policies. Theoretical explanations following Ostrom's lineage suggest that polycentric systems function when civil society and the state “co-produce” scientific knowledge and the rules about the use of natural resources (Miller & Wyborn, 2020). Our results add other dimensions: social acceptance, inclusion, a prior history of collaboration, and economic incentives. These additional characteristics may prevent stakeholders from opting out and choosing other decision-making venues for resolving problems, which others identify as a potential challenge (Morrison et al., 2023).

Social legitimacy includes informal, voluntary, community-oriented practices driven by a sense of obligation to others. Earlier work on which this research builds shows these conditions are present in Nebraska (Bleed & Babbitt, 2015; Jedd et al., 2022; Sixt, Klerkx, et al., 2019). Our results delineate the specific dimensions, or framework conditions, that may apply to other areas experiencing an increase in irrigation. Framework conditions for successful polycentric water governance were identified in this study. They include social legitimacy, inclusive membership, prior history of collaboration, context-specific rules with economic incentives, self-made rules, and an understanding and acceptance of the rules.

A legitimate process has rulemaking authority in the eyes of participants. This form of ‘political commitment,’ or long-term engagement, is identified as a solution to the challenges that climate change poses to groundwater governance (Petersen-Perlman et al., 2022). Actors with long-term engagement in a governance process may be more likely to adopt a cap on extractions, which Grafton et al. (2018) claim is necessary to address declining groundwater supplies. According to Zwickle et al. (2021), rule structures that allow for water use restrictions, though less politically popular, are more effective at reducing groundwater depletion than technological innovation alone. These claims are part of a movement toward improving groundwater governance by setting limits on its use (Rouillard et al., 2021). State-backed caps on consumption go hand-in-hand with voluntary commitments in polycentric groundwater governance (Baldwin et al., 2018).

When paired with technological innovations, polycentric governance arrangements in the agricultural sector push farmers to reduce their irrigation amounts and innovate techniques based on changes in water availability. As mechanized irrigation is prevalent (57% are center pivot systems), it is possible to schedule irrigation based on sensors that detect plant stress, having the potential to make irrigation more efficient, only pumping groundwater when it is critically needed (Bhatti et al., 2022). If water users trust the information about water supply, find that the recommended best practices will save them money (Grafton et al., 2018), and know that there is buy-in among other water users in the district, they may be willing to invest in new equipment, such as timers and perhaps more importantly, to participate in governance arrangements that consider the collective availability of water.

5.2 | Learning at the rural–urban interface

Cities engaging in supply-driven groundwater governance might serve as models for rural areas. Managed groundwater recharge may reduce the need for demand-based restrictions (see Megdal et al., 2017 for the example of Orange County Water District which has used supply-side management to address increasing groundwater consumption and a growing population). Local planners are becoming more inventive in addressing challenges to water supplies. Here, rural water users could learn from urban areas. In other studies of local groundwater management, Hess et al. (2016) found that municipal areas tend to see more coherence in methods to achieve supply increases (additional storage and delivery infrastructure) than demand reduction. This could be done through a range of education, information-sharing, rate re-structuring, and/or metering (Hess et al., 2016). As a result of the variation in demand management implementation (e.g., with caps and/or fees on consumption), localities are bound to see conflict between production, economic growth, and conservation logics. Therefore, it may be more strategic for urban water suppliers to leverage income and profits from water provision toward recharging groundwater supplies.

Following this to a logical analogue in the rural setting, aquifer recharge programs may be a more politically appealing way to keep the focus on boosting supply without having to address more challenging reductions in demand. However, there is a difference in the distance between users and the resource itself. Residents in cities may feel substantively more removed from groundwater resources, while farmers may benefit from groundwater pumping in a way that they perceive more directly. Because rural water users perceive themselves to be closer to groundwater, it may be easier to achieve reductions in water consumption. Therefore, it is worth considering whether the technological “fix” of groundwater recharge is warranted in the agricultural context. This means that the high degree of social legitimacy that we observed may be an inherent feature of successful governance settings that rely on low-technology measures to protect groundwater (i.e. approaches that focus on reducing demand rather than increasing the overall supply).

5.3 | Limitations of polycentric governance and future directions

The Nebraska case leaves some questions that point to shortcomings of a polycentric model. In particular, it is difficult to address cross-border conflicts. When rules are established at the local level, there will inherently be a boundary past which these rules no longer apply. The U.S. Supreme Court cases involving Kansas show that legal conflict has at times been unavoidable. Polycentric governance requires cross-scalar coordination in order to realize gains across district boundaries and jurisdictions. A set of national guidelines for groundwater governance could reduce interstate conflicts.

This study has identified the dimensions of social legitimacy in Nebraska.⁴ Prior research has questioned whether the Nebraska model has been or could be reproduced in another setting: Sixt, Klerkx, et al., 2019 (743) state that “further research is warranted in order to determine whether the NRD system is replicable elsewhere in the U.S. or internationally.” In the absence of national groundwater guidelines, comparison with other states is warranted. States with established groundwater governance systems that rely upon conservation districts include Arizona, California, and Florida (Megdal et al., 2015; Megdal et al., 2017). Testing the framework in these places would strengthen our ability to make general statements about how legitimacy is conferred on polycentric governance arrangements.

There also needs to be more research on the ability to prevent groundwater decline. The literature on environmental governance highlights the importance of establishing institutions that are capable of preventing natural resource degradation (Pickering et al., 2020). Investigation is needed to determine whether moratoria on irrigation well permits can protect groundwater in fully appropriated NRDs (Muñoz-Arriola et al., 2021). Though the National Climate Assessment shows the area of the High Plains Aquifer under Nebraska still has significant saturated thickness compared to the part governed by other states, it is still possible that groundwater decline may be a reality for Nebraska under future climate conditions given the expansion of wells and pumping on the eastern side of the state. Further research is needed to assess whether self-made extraction limits could reduce user conflicts under future droughts, seasonal variations, or decline in water availability due to competing use in a changing climate.

As a note of caution, the framework should be used with caution beyond the agricultural sector. The energy and mining industries are also major users of groundwater. Future research should look outside of the agricultural sector for ways to achieve legitimate groundwater governance. The European Environment Agency, for example, states that industrial production poses a threat to groundwater (EEA, 2022). It is not clear whether multi-national industrial actors are incentivized by the same socially derived values as farmers in a place-based

governance process. Moreover, governance of groundwater in a non-agricultural context may involve additional features that defy the logic of governing through social legitimacy. Despite these caveats, the Nebraska model may offer lessons for other basins where groundwater has historically been plentiful but is now facing drought stresses, intensive irrigated agricultural production, and competing demands for water. Future studies motivated by the need to reduce groundwater overdrafts may start by asking whether the preconditions are present.

5.4 | Conclusion

Nebraska's ease of access to groundwater contributes to agricultural productivity. It has the most irrigated croplands and pastures of all U.S. states, with nearly one-third of its total area under irrigation. Most irrigation is supplied by groundwater from the Northern High Plains (Ogallala) Aquifer. Under rational-economic assumptions, farmers who rely on irrigation would resist rules that affect their use of this aquifer. Yet since the Natural Resources Districts (NRDs) were established in 1972, these local structures have evolved. In addition to voluntary, collaborative rule-making, they have statutory authority to regulate withdrawals and thus, they can proactively prevent aquifer decline during droughts. This research explains why NRDs are an instance of polycentric governance and provides a deeper consideration of why this approach has the ability to reduce groundwater overextraction.

This study supports the claim that polycentric governance of groundwater governance has distinct and identifiable features that could be used in other studies. Using the framework conditions would be a first step to identifying whether socially-legitimated models of polycentric governance can be used to effectively govern groundwater overdraft under future drought conditions. In other words, research should take social values and priorities seriously, asking how *should* groundwater be governed. This speaks to the need to build out normative strains of the institutionalist understanding of polycentric systems (Thiel, 2023).

In Nebraska, regulatory authorities depend upon civil society's willingness to abide by norms and socially accepted rules about using groundwater. Access is often locally determined, and decisions about extraction are also often made by private landowners. Therefore, polycentric arrangements that prompt civil society actors to voluntarily reduce their demand are a promising avenue for reducing unsustainable levels of groundwater consumption. Our results show that social legitimacy is an underpinning feature of polycentric groundwater governance and should not be ignored when setting groundwater rules. The polycentric model of NRDs is a form of self-rule that prioritizes sustainable water use in a state with a majority agricultural economy. This case shows how voluntary water governance can evolve over time to include monitoring, restriction, and enforcement mechanisms when a history of democratic rule, public participation, and self-governance is present. NRDs exercise control by using their authority to make institutional changes and sanction violators for overuse. This

⁴The natural, social, and political circumstances in which the Nebraska system was created may have been exceptionally favorable for cooperation: relatively abundant groundwater supplies, social cohesion, and a unicameral (single-body) state legislature. It is also possible that there are features of the aquifer that lend themselves to stability, and it is coincidental that the polycentric governance system exists in Nebraska. We do not think this is the case but nonetheless needs to be more rigorously tested.

authority is granted and legitimized by publicly elected boards, an ongoing leadership training network, and a history of locally driven rulemaking.

There are shortcomings to the model: in particular, it is difficult to address cross-border issues or legal conflicts between types of water users (surface water and groundwater). In spite of its limitations, the Nebraska model of polycentric groundwater governance may offer lessons for other basins where water resources have historically been relatively plentiful but are now facing drought stresses and the growing demands of intensive irrigated agricultural production. There is no substitute for collective considerations of resource availability. In settings where irrigators cannot innovate their way out of the global groundwater crisis, it is worthwhile to investigate whether and how rules about groundwater overdraft come to be accepted and whether and how that acceptance is maintained over time.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the participants who gave their time for interviews.

FUNDING INFORMATION

Gregory N. Sixt received funding for interview data collection through the National Science Foundation Grant 0966093 for the Integrative Graduate Education and Research Traineeship (IGERT) Program on Water Diplomacy at Tufts University. Theresa Jedd held a postdoctoral fellowship at the National Drought Mitigation Center at the University of Nebraska-Lincoln, School of Natural Resources where some of the initial document analysis was conducted.

CONFLICT OF INTEREST STATEMENT

The authors do not have any conflicts of interest to declare.

ORCID

Theresa Jedd  <https://orcid.org/0000-0001-8192-2864>

Gregory N. Sixt  <https://orcid.org/0000-0003-2839-8164>

REFERENCES

- Bäckstrand, K., Kuyper, J., & Nasiritousi, N. (2021). From collaboration to contestation? Perceptions of legitimacy and effectiveness in post-Paris climate governance. *Earth System Governance*, 9, 100–115.
- Baldwin, E., McCord, P., Dell'Angelo, J., & Evans, T. (2018). Collective action in a polycentric water governance system. *Environmental Policy and Governance*, 28(4), 212–222.
- Baltutis, W. J., & Moore, M. L. (2019). Degrees of change toward polycentric transboundary water governance: exploring the Columbia River and the Lesotho Highlands Water Project. *Ecology and Society*, 24(2), 6. <https://doi.org/10.5751/ES-10852-240206>
- Bennett, N. J., & Satterfield, T. (2018). Environmental governance: A practical framework to guide design, evaluation, and analysis. *Conservation Letters*, 11, e12600.
- Bernstein, S. (2011). Legitimacy in intergovernmental and non-state global governance. *Review of International Political Economy*, 18(1), 17–51.
- Bhatti, S., Heeren, D. M., Shaughnessy, S. A. O., Evett, S. R., Maguire, M. S., Kashyap, S. P., & Neale, C. M. U. (2022). Comparison of stationary and mobile canopy sensing systems for maize and soybean in Nebraska, USA. *Applied Engineering in Agriculture*, 38(2), 331–342.
- Bleed, A., & Babbitt, C. H. (2015). Nebraska's natural resources districts: An assessment of a large-scale locally controlled water governance framework. <https://digitalcommons.unl.edu/wffddocs/79/>
- Blomquist, W., Schlager, E., & Heikkilä, T. (2010). *Common waters, diverging streams: Linking institutions and water management in Arizona, California, and Colorado*. Routledge.
- Burbach, M. E., Eaton, W., Quimby, B., Babbitt, C., & Delozier, J. (2022). Longitudinal assessment of an integrated approach to large-scale common-pool water resource management: A case study of Nebraska's Platte River Basin. *Ecology and Society*, 27(4), 30. <https://doi.org/10.5751/ES-13579-270430>
- Burbach, M. E., Joeckel, R. M., & Matkin, G. S. (2020). 2019 *Nebraska water leaders academy final report* (p. 796). Conservation and Survey Division.
- Carlisle, K., & Gruby, R. L. (2017). Polycentric systems of governance: A theoretical model for the commons. *Policy Studies Journal*, 47, 927–952. <https://doi.org/10.1111/psj.12212>
- Eaton, W. M., Brasier, K. J., Burbach, M. E., Whitmer, W., Engle, E. W., Burnham, M., Quimby, B., Chaudhary, A. K., Whitley, H., Delozier, J., Fowler, L. B., Wutich, A., Bausch, J. C., Beresford, M., Heinrichs, C. C., Burkhart-Kreisel, C., Preisendanz, H. E., Williams, C., Watson, J., & Weigle, J. (2021). A conceptual framework for social, behavioral, and environmental change through stakeholder engagement in water resource management. *Society & Natural Resources*, 34, 1111–1132. <https://doi.org/10.1080/08941920.2021.1936717>
- European Environment Agency, (EEA). (2022). Briefing no. 03/2022: Europe's groundwater – a key resource under pressure. <https://www.eea.europa.eu/publications/europes-groundwater#:~:text=In%20particular%2C%20meeting%20water%20demands,of%20water%20for%20agricultural%20irrigation>
- Famiglietti, J. (2014). The global groundwater crisis. *Nature Climate Change*, 4, 945–948. <https://doi.org/10.1038/nclimate2425>
- Flyvbjerg, B. (2017). Case study. In N. K. Denzin & D. S. Lincoln (Eds.), *The SAGE handbook of qualitative research*. SAGE Publications.
- Frankson, R., Kunkel, K., Stevens, L., & Shulski, M. (2017). Nebraska state climate summary. In NOAA Technical Report NESDIS 149-NE (p. 4). National Centers for Environmental Information.
- Geertz, C. (1973). Thick description: Toward an interpretive theory of culture. In *The interpretation of cultures: Selected essays* (pp. 3–30). Basic Books.
- George, A. L., & Bennett, A. (2005). *Case studies and theory development in the social sciences*. MIT Press.
- Gerring, J. (2012). Mere description. *British Journal of Political Science*, 42(4), 721–746.
- Gibson, C. C., Williams, J. T., & Ostrom, E. (2005). Local enforcement and better forests. *World Development*, 33(2), 273–284. <https://doi.org/10.1016/j.worlddev.2004.07.013>
- Grafton, R. Q., Williams, J., Perry, C. J., Molle, F., Ringler, C., Steduto, P., Udall, B., Wheeler, S. A., Wang, Y., Garrick, D., & Allen, R. G. (2018). The paradox of irrigation efficiency. *Science*, 361(6404), 748–750.
- Hess, D. J., Wold, C. A., Hunter, E., Nay, J., Worland, S., Gilligan, J., & Hornberger, G. M. (2016). Drought, risk, and institutional politics in the American southwest. *Sociological Forum* 31(S1), 807–827. <https://doi.org/10.1111/socf.12274>
- Hill v. State. (2017). 296 Neb. 10. <https://casetext.com/case/greg-hill-of-furnas-cnty-v-state>
- Jedd, T., Schutz, A., & Burbach, M. (2022). Polycentric governance in Nebraska, U.S., for ground and surface water. In J. Rouillard, C. Babbitt, E. Challies, & J.-D. Rinaudo (Eds.), *Water resources allocation and agriculture: Transitioning from open to regulated access*. International Water Association Publishing.

- Jedd, T., & Smith, K. H. (2023). Drought-stricken US states have more comprehensive water-related hazard planning. *Water Resources Management*, 37(2), 601–617.
- Juerges, N., Leahy, J., & Newig, J. (2018). Actor perceptions of polycentricity in wind power governance. *Environmental Policy and Governance*, 28(6), 383–394.
- King, G., Keohane, R. O., & Verba, S. (2021). *Designing social inquiry: Scientific inference in qualitative research, new edition* (2nd ed.). Princeton University Press.
- Kirchhoff, C. J., & Dilling, L. (2016). The role of U.S. states in facilitating effective water governance under stress and change. *Water Resources Research*, 52(4), 2951–2964.
- Kliskey, A., Williams, P., Griffith, D. L., Dale, V. H., Schelly, C., Marshall, A.-M., Gagnon, V. S., Eaton, W. M., & Floress, K. (2021). Thinking big and thinking small: A conceptual framework for best practices in community and stakeholder engagement in food, energy, and water systems. *Sustainability*, 13, 2160. <https://doi.org/10.3390/su13042160>
- Knott, E., Rao, A. H., Summers, K., & Teeger, C. (2022). Interviews in the social sciences. *Nature Reviews Methods Primers*, 2(1), 73.
- Koebele, E. A., & Crow, D. A. (2023). Mitigating conflict with collaboration: Reaching negotiated agreement amidst belief divergence in environmental governance. *Policy Studies Journal*, 51(2), 439–458.
- Kroepsch, A. C. (2024). Monitored but not metered: How groundwater pumping has evaded accounting (and accountability) in the western United States. *Water Alternatives*, 17(2), 348–368.
- Kuzdas, C., Wiek, A., Warner, B., Vignola, R., & Morataya, R. (2015). Integrated and participatory analysis of water governance regimes: The case of the Costa Rican dry tropics. *World Development*, 66, 254–268.
- Lukasiewicz, A., & Baldwin, C. (2017). Voice, power, and history: Ensuring social justice for all stakeholders in water decision-making. *Local Environment*, 22(9), 1042–1060. <https://doi.org/10.1080/13549839.2014.942261>
- March, J. G., & Olsen, J. P. (1996). Institutional perspectives on political institutions. *Governance*, 9(3), 247–264.
- Martínez-Valderrama, J., Olcina, J., Delacámara, G., Guirado, E., & Maestre, F. T. (2023). Complex policy mixes are needed to cope with agricultural water demands under climate change. *Water Resources Management*, 37, 2805–2834. <https://doi.org/10.1007/s11269-023-03481-5>
- Megdal, S. B., Gerlak, A. K., Huang, L. Y., Delano, N., Varady, R. G., & Petersen-Perlman, J. D. (2017). Innovative approaches to collaborative groundwater governance in the United States: Case studies from three high-growth regions in the Sun Belt. *Environmental Management*, 59, 718–735.
- Megdal, S. B., Gerlak, A. K., Varady, R. G., & Huang, L. Y. (2015). Groundwater governance in the United States: Common priorities and challenges. *Groundwater*, 53(5), 677–684.
- Miller, C. A., & Wyborn, C. (2020). Co-production in global sustainability: Histories and theories. *Environmental Science & Policy*, 113, 88–95.
- Morrison, T. H., Adger, W. N., Brown, K., Lemos, M. C., Huitema, D., Phelps, J., Evans, L., Cohen, P., Song, A. M., Turner, R., Quinn, T., & Hughes, T. P. (2019). The black box of power in polycentric environmental governance. *Global Environmental Change*, 57, 101934.
- Morrison, T. H., Bodin, Ö., Cumming, G. S., Lubell, M., Seppelt, R., Seppelt, T., & Weible, C. M. (2023). Building blocks of polycentric governance. *Policy Studies Journal*, 51(3), 475–499.
- Moss, T., & Newig, J. (2010). Multilevel water governance and problems of scale: Setting the stage for a broader debate. *Environmental Management*, 46, 1–6.
- Muñoz-Arriola, F., Abdel-Monem, T., & Amaranto, A. (2021). Common pool resource management: Assessing water resources planning for hydrologically connected surface and groundwater systems. *Hydrology*, 8(51), 15. <https://doi.org/10.3390/hydrology8010051>
- National Drought Mitigation Center. (2021). U.S. Drought Monitor: Time Series. <https://droughtmonitor.unl.edu/DmData/TimeSeries.aspx>
- Neal (Patrick), M. J., Greco, F., Connell, D., & Conrad, J. (2016). The social-environmental justice of groundwater governance. In A. J. Jakeman, O. Barreteau, R. J. Hunt, J. D. Rinaudo, & A. Ross (Eds.), *Integrated groundwater management*. Springer. https://doi.org/10.1007/978-3-319-23576-9_10
- Nebraska Association of Natural Resources Districts. (2019). 2018 NRD Water Management Activities Summary. https://www.nrdnet.org/sites/default/files/groundwater_management_summary_2018.pdf
- Nebraska Association of Natural Resources Districts. (2021). 2020 NRD Water Management Activities Summary. https://www.nrdnet.org/sites/default/files/groundwater_management_summary_2020.pdf
- Nebraska Department of Natural Resources (NDNR). (2016). *Compilation of the statutes regarding the groundwater management and protection act*. Nebraska Department of Natural Resources.
- Neef, A. (2009). Transforming rural water governance: Towards deliberative and polycentric models? *Water Alternatives*, 2(1), 53.
- North Platte Natural Resources District. (2016). Rules and regulations for the Enforcement of the Nebraska Ground Water Management and Protection Act. <https://www.npnrd.org/assets/site/documents/rules-and-regulations/gwma-rules-and-regs-11-14-16.pdf>
- Obembe, O. S., Hendricks, N. P., & Jagadish, S. K. (2023). Changes in groundwater irrigation withdrawals due to climate change in Kansas. *Environmental Research Letters*, 18(9), 94041.
- O'Neill, K., Weinthal, E., Suiseeya, K. R. M., Bernstein, S., Cohn, A., Stone, M. W., & Cashore, B. (2013). Methods and global environmental governance. *Annual Review of Environment and Resources*, 38(1), 441–471.
- Ostrom, E. (1988). Workshop on political theory and policy analysis: Institutional arrangements and the commons dilemma. In F. Ostrom, D. Feeny, & H. Picht (Eds.), *Rethinking institutional analysis and development: Issues, alternatives, and choices* (pp. 103–139). ICS Press.
- Ostrom, E. (2010). Polycentric systems for coping with collective action and global environmental change. *Global Environmental Change*, 20(4), 550–557.
- Ostrom, E. (2011). Reflections on some unsettled problems of irrigation. *American Economic Review*, 101(1), 49–63. <https://doi.org/10.1257/aer.101.1.49>
- Pahl-Wostl, C., & Knieper, C. (2014). The capacity of water governance to deal with the climate change adaptation challenge: Using fuzzy set qualitative comparative analysis to distinguish between polycentric, fragmented and centralized regimes. *Global Environmental Change*, 29, 139–154.
- Pahl-Wostl, C., & Knieper, C. (2023). Pathways towards improved water governance: The role of polycentric governance systems and vertical and horizontal coordination. *Environmental Science & Policy*, 144, 151–161.
- Peck, J. C. (2007). Groundwater management in the high plains aquifer in the USA: Legal problems and innovations. In M. Giordano & K. G. Vilhøth (Eds.), *Groundwater management in the USA: Opportunities and threats to development* (pp. 296–319). CAB International.
- Pendergrass, A. G., Meehl, G. A., Pulwarty, R., Hobbins, M., Hoell, A., AghaKouchak, A., Bonfils, C. J., Gallant, A. J., Hoerling, M., Hoffmann, D., & Kaatz, L. (2020). Flash droughts present a new challenge for subseasonal-to-seasonal prediction. *Nature Climate Change*, 10(3), 191–199.
- Petersen-Perlman, J. D., Aguilar-Barajas, I., & Megdal, S. B. (2022). Drought and groundwater management: Interconnections, challenges and policy responses. *Current Opinion in Environmental Science & Health*, 28, 100364.
- Peterson, S. M., Traylor, J. P., & Guira, M. (2020). Groundwater availability of the Northern High Plains aquifer in Colorado, Kansas, Nebraska, South Dakota, and Wyoming: U.S. Geological Survey Professional Paper, pp. 57.



- Pickering, J., Baekstrand, K., & Schlosberg, D. (2020). Between environmental and ecological democracy: Theory and practice at the democracy environment nexus. *Journal of Environmental Policy & Planning*, 22(1), 1–15. <https://doi.org/10.1080/1523908X.2020.1703276>
- Reed, C., & Abdel-Monem, T. (2015). An assessment of the Nebraska integrated management planning process: A report from the University of Nebraska Public Policy Center funded by the Nebraska Department of Natural Resources.
- Reed, M. S., Vella, S., Challies, E., de Vente, J., Frewer, L., Hohenwallner-Ries, D., Huber, T., Neumann, R. N., Oughton, E. A., del Ceno, J. S., & van Delden, H. (2018). A theory of participation: What makes stakeholder and public engagement in environmental management work? *Restoration Ecology*, 26(S1), S7–S17.
- Richardson, K., Steffen, W., Lucht, W., Bendtsen, J., Cornell, S. E., Donges, J. F., Drüke, M., Fetzer, I., Bala, G., von Bloh, W., Feulner, G., Fiedler, S., Gerten, D., Gleeson, T., Hofmann, M., Huiskamp, W., Kumm, M., Mohan, C., Nogués-Bravo, D., ... Rockström, J. (2023). Earth beyond six of nine planetary boundaries. *Science Advances*, 9, eadh2458. <https://doi.org/10.1126/sciadv.adh2458>
- Roberts, M., Milman, A., & Blomquist, W. (2021). The sustainable groundwater management act (SGMA): California's prescription for common challenges of groundwater governance. In J. Baird & R. Plummer (Eds.), *Water resilience*. Springer. https://doi.org/10.1007/978-3-030-48110-0_3
- Rodella, A.-S., Zaveri, E., & Bertone, F. (2023). *The hidden wealth of nations: The economics of groundwater in times of climate change*. World Bank.
- Rouillard, J., Babbitt, C., Pulido-Velazquez, M., & Rinaudo, J. D. (2021). Transitioning out of open access: A closer look at institutions for Management of Groundwater Rights in France, California, and Spain. *Water Resources Research*, 57(4), e2020WR028951.
- Schipanski, M. E., Sanderson, M. R., Méndez-Barrientos, L. E., Kremen, A., Gowda, P., Porter, D., Wagner, K., West, C., Rice, C. W., Marsalis, M., & Guerrero, B. (2023). Moving from measurement to governance of shared groundwater resources. *Nature Water*, 1(1), 30–36.
- Schutz, A. B. (2015). Defining sustainability in Nebraska's Republican River basin: The LB 1057 task force. *Texas A&M Law Review*, 3, 771.
- Shah, T. (2014). *Groundwater governance and irrigated agriculture* (p. 69). Global Water Partnership (GWP).
- Shulski, M. (2018). Nebraska's changing climate – Highlights from the 4th National Climate Assessment. University of Nebraska–Lincoln Institute of Agriculture and Natural Resources Crop Watch. <https://cropwatch.unl.edu/2018/nebraska-changing-climate>
- Sikkink, K. (2024). How international relations theory on norm cascades can inform the politics of climate change. *PS. Political Science & Politics*, 57(1), 36–39.
- Sixt, G. N., Klerkx, L., Aiken, J. D., & Griffin, T. S. (2019). Nebraska's natural Resource District system: Collaborative approaches to adaptive groundwater quality governance. *Water Alternatives*, 12(2), 676–698.
- Sixt, G. N., McCarthy, A. C., Portney, K. E., & Griffin, T. S. (2019). Water diplomacy at the macro scale: Agricultural groundwater governance in the High Plains aquifer region of the United States. In S. Islam & K. M. Smith (Eds.), *Interdisciplinary collaboration for water diplomacy: A principled and pragmatic approach*. Routledge.
- Skurray, J. H. (2015). The scope for collective action in a large groundwater basin: An institutional analysis of aquifer governance in Western Australia. *Ecological Economics*, 114, 128–140.
- Smith, K. (2012). *Expect more impacts as Nebraska drought rolls into second year*. University of Nebraska.
- Spear T. Ranch vs. Knaub. (2006). 271 Neb. 578. <https://casetext.com/case/spear-t-ranch-v-knaub>
- State of Nebraska Department of Natural Resources. (2004). Order designating overappropriated river basins, subbasins, or reaches, and describing hydrologically connected geographic area. Signed by Director Roger K. Patterson. <https://dnr.nebraska.gov/sites/dnr.nebraska.gov/files/doc/water-planning/upper-platte/orders/OverappropriatedOrder9-15-04.pdf>
- State of Nebraska Department of Natural Resources (NeDNR). (2021). Annual review of availability of hydrologically connected water supplies. Published by the Nebraska Department of Natural Resources. https://dnr.nebraska.gov/sites/dnr.nebraska.gov/files/doc/water-planning/statewide/FAB/2021AnnualReport/20201229_FAB2021_Final.pdf
- te Wierik, S. A., Gupta, J., Cammeraat, E. L., & Artzy-Randrup, Y. A. (2020). The need for green and atmospheric water governance. *Wiley Interdisciplinary Reviews: Water*, 7(2), e1406.
- Thiel, A. (2023). Polycentric governing and polycentric governance. In F. Gadinger & J. A. Scholte (Eds.), *Polycentrism: How governing works today*. Oxford University Press.
- U.S. Department of Agriculture. (2019). 2018 Irrigation and Water Management Survey: 2017 Census of Agriculture; Volume 3, Special Studies, Part 1. AC-17-22-1. https://www.nass.usda.gov/Publications/AgCensus/2017/Online_Resources/Farm_and_Ranch_Irrigation_Survey/fris.pdf
- U.S. Department of Agriculture Economic Research Service (ERS). (2023). Change in U.S. acres of irrigated agricultural land by county, 1997–2017. <https://www.ers.usda.gov/webdocs/charts/62561/19972017map.png?v=2849.1>
- U.S. Geological Survey. (2021a). Water use data for Nebraska (Refresh Date June 2018). https://waterdata.usgs.gov/ne/nwis/water_use?format=html_table&rdb_compression=file&wu_area=State+Total&wu_year=ALL&wu_category=ALL&wu_category_nms=--ALL%2BCat egories
- U.S. Geological Survey. (2021b). USGS: High plains aquifer groundwater levels continue to decline. Release date June 16. <https://www.usgs.gov/news/usgs-high-plains-aquifer-groundwater-levels-continue-decline>
- Ulrich, L. (2018). Nebraska's irrigation history: It's complicated. In *Growing a healthy future* (Vol. 7). University of Nebraska Institute of Agriculture and Natural Resources.
- United Nations (UN). (2022). *The United Nations world water development report 2022: Groundwater: Making the invisible visible*. UNESCO.
- Van Loon, A. F., Gleeson, T., Clark, J., Van Dijk, A. I., Stahl, K., Hannaford, J., Di Baldassarre, G., Teuling, A. J., Tallaksen, L. M., Uijlenhoet, R., & Hannah, D. M. (2016). Drought in the Anthropocene. *Nature Geoscience*, 9(2), 89–91.
- Western Governors' Association. (2018). *Water resource management in the west*. Western Governors' Association Policy Resolution.
- Wiechman, A., Vicario, S. A., & Koebele, E. A. (2023). The role of intermediate collaborative forums in polycentric environmental governance. *Journal of Public Administration Research and Theory*, 34(2), 196–210.
- Wilhite, D. (2016). Managing drought risk in a changing climate. *Climate Research*, 70, 99–102.
- World Meteorological Organization, (2024). *State of global water resources 2023 report* WMO-No. 1362. Geneva, Switzerland. WMO.
- Zwickle, A., Feltman, B. C., Brady, A. J., Kendall, A. D., & Hyndman, D. W. (2021). Sustainable irrigation through local collaborative governance: Evidence for a structural fix in Kansas. *Environmental Science & Policy*, 124, 517–526.

SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: Jedd, T., Sixt, G. N., Schutz, A., & Burbach, M. (2025). Legitimacy in polycentric groundwater governance: Framework conditions identified in Nebraska's Natural Resource Districts. *Environmental Policy and Governance*, 35(2), 187–200. <https://doi.org/10.1002/eet.2132>