SUSTAINING WATER RESOURCES AND COMMUNITIES THROUGH LOCAL COLLABORATIVE GOVERNANCE

By

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ABSTRACT

Water is one of the essential ingredients for life on earth and touches every aspect of our lives. Growing concern for equitably providing safe water now and into the future is an increasingly salient for individuals, communities, governments, and researchers as water scarcity continues to be a growing issue. In this dissertation I focus on the role of local collaborative governance institutions as a strategy for incorporating stakeholders into decision-making processes to manage resources. Chapter 1 uses the Institutional Analysis and Development Framework to understand agricultural producers' motivations to collaboratively govern groundwater in Kansas, how they measure the success of collaborative efforts, and how they have adapted as individuals and a community under conditions of voluntary and collective withdrawal restrictions. Chapter 2 uses the Integrative Framework for Collaborative Governance to understand why Michigan water users have not chosen to collaboratively govern shared water resources despite being able to do so since the state's implementation of the 2008 Great Lakes-St. Lawrence River Basin Water Resources Compact. Chapter 3 outlines a new research agenda for incorporating the construct of structural power within the Social-Ecological Systems Framework.

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Introduction

Water is one of the essential ingredients for life on earth (National Aeronautics and Space Administration, 2024). Water touches every aspect of our lives, and indeed, life is unimaginable without it. Even in our quest to find life on other celestial bodies in the solar system – such as Jupiter's moon Europa - the presence of water is a key criterion (Chappell, 2023). The United Nations has made Clean Water and Sanitation its 6th Sustainable Development Goal, because clean water "is essential not only to health, but also to poverty reduction, food security, peace and human rights, ecosystems and education" (United Nations, 2023).

In terms of ecosystems services, water is a keystone for providing freshwater, irrigation, and is the basis for all fisheries. Another key component is regulating this resource, based upon the impact of climate and weather, supporting all ecosystems (from which we derive countless benefits), and enabling cultural values as well as recreational activities (that are centered on water to flourish). However, population growth and intensification of pressures on water resources across multiple sectors are adversely impacting the ecosystem services provided by the water that we need and expect (e.g., Salehi, 2022; Mishra et al., 2021; Vasseghian et al., 2021; Kilic, 2020); Mekonnen and Gerbens-Leenes, 2020).

The growing concern for equitably providing water now and into the future has inspired researchers to identify effective ways of doing so. Heberlein (2012) outlines three general approaches for addressing environmental problems such as growing water scarcity: cognitive, technological, and structural. Cognitive fixes emphasize using education as a tool for modifying individuals' behaviors so that they no longer contribute to a problem. Technological fixes focus on implementing advancements in technology to ameliorate a problem without having to alter underlying behaviors. Structural fixes center on fundamentally altering the basic socioeconomic coordinates that determine behavior – often through policy changes.

In this dissertation, I focus on structural fixes as a method for sustaining vital water resources. Specifically, the research I present here investigates the role that local collaborative governance institutions can play in managing water to satisfy environmental, social, and economic needs now while conserving resources for the future.

Chapter 1 is titled *Mapping Motivations and Measuring Success: Implementing the Institutional Analysis and Development Framework for the Collaborative Governance of Groundwater.* In this chapter I use the Institutional Analysis and Development Framework (IAD)

to understand agricultural producers' motivations to collaboratively govern groundwater in Kansas, and how they measure the success of their collaborative efforts. Using semi-structured interviews, I collected qualitative data to show the social and economic impacts that voluntary irrigation restrictions have had on producers. Kansas producers rely on groundwater from the High Plains Aquifer as the primary source of irrigation, but water levels have been declining for decades. Grassroots pressure from producers led the state to adopt the Local Enhanced Management Areas (LEMA) Act in 2012, which recognized producers' ability to make policies to manage shared groundwater resources. The first LEMA was formed in 2013, where producers imposed a collective cut in withdrawals that resulted in a 31% reduction in average pumping over a 10-year period. While previous research has found that rates of groundwater loss have declined since the implementation of this LEMA, this study delves deeper into the factors that led to the formation and success of the area and broadens our understanding of how producers evaluate the success of collaboration. Using semi-structured interviews based upon the IAD, I found that producers effectively adapted to using less water by reevaluating how much water is necessary to grow crops, adopting water saving technologies including soil moisture monitors, and altering the types of crops grown. I also found that producers were driven to collaborate primarily by a desire to extend the aquifer's lifespan, minimize regulatory oversight, preserve a sense of agricultural identity and place attachment to their farms and farming community, and provide opportunities for future generations to inherit farming operations. By identifying both the antecedents and outcomes of self-organized local collaboration, this analysis can help reduce the barrier of uncertainty for other producers to co-manage their water resources.

Chapter 2 is titled *Rights, Norms, and the Adoption of Collaborative Water Governance Institutions: A Michigan Case Study.* Legal rights and norms play a key role in stabilizing natural resource governance systems by establishing rules that individuals and organizations follow and expect from others. While providing necessary stability for a governance regime, rights and norms may also inhibit important adaptations of governance systems in response to changing environmental, political, social, and economic conditions. This research focuses on changes in Michigan water policy that created the opportunity for water users to collaboratively govern shared water resources at the watershed scale. While water users have had the ability to form collaborative institutions since the state's implementation of the 2008 Great Lakes-St. Lawrence River Basin Water Resources Compact, no institutions have formed to date. I hypothesize that

the lack of collaboration can be explained in terms of prevailing water rights and established norms in Michigan's water user communities. Using the concepts of uncertainty, interdependence, consequential incentives, and leadership – as outlined in the Integrative Framework for Collaborative Governance – I operationalize the constructs of rights and norms to test hypothesis. I created a survey that was sent to all large-quantity water users in the state to understand why they have not formed collaborative institutions. Results show that the norm of individualistic water use, based on expected water abundance, diminishes willingness to participate. I also find that water users who do not currently talk with others, nor believe that having conversations about water management will improve relationships, and who do not think water users should work together to manage water express less willingness to collaborate. By identifying barriers for collaboration, this research can help policymakers and other interested parties incentive water users to collaborate in Michigan. Moreover, the focus on rights and norms – as measured using the Institutional Analysis and Development Framework – offers researchers and policymakers a lens through which to understand collaborative institutions in other situations, helping to guide evaluation and identify possibilities for improvements.

The third and final chapter is titled *Institutional Genesis: Incorporating Structural Power in the Social-Ecological Systems Framework.* The collaborative governance of common pool resources has become widely accepted by researchers focused on collective action in social-ecological systems as an effective strategy for sustaining common pool resources and the socioeconomic activities predicated upon them. Developing frameworks which accurately depict the causal relationships between institutions and the social, economic, political, and ecological systems within which they are embedded is crucial for theoretical understanding and the practical efficacy of governance. The Social-Ecological Systems Framework (SES) created by Ostrom and subsequently expanded upon by others is of particular importance, because it provides the most comprehensive and flexible constellation of operationalized concepts connected by empirically verifiable relationships. A problem with the SES, however, is the insufficient incorporation of power into the framework. While researchers have previously attempted to incorporate the notion of power into the SES, this article proposes a new approach for doing so that opens novel avenues for future research by emphasizing that how collaborative institutions originally form dictates power structures within the institutions, which in turn affects policies and actions that emerge from it. Emerson and Nabatchi outline three processes by which

institutions come into existence, and which affect structural power: self-initiated, independently convened, and externally directed. I argue that the SES framework should incorporate these processes to reflect the different power structures associated with them. Doing so entails new and exciting questions proposed and pursued by scientists working in collaborative governance research.

Together, these three chapters help policymakers and researchers better understand what motivates water users to collaborate, how they evaluate the performance of collaborative efforts across social, economic, and environmental metrics, and offers new avenues of research linking power to social-ecological systems frameworks. Chapter 1 was funded by a National Science Foundation Grant focused on the Nexus of Food, Water and Energy systems. Chapter 2 was jointly funded by Michigan Sea Grant and the Michigan Department of Environment Great Lakes and Energy. Chapter 3 was not externally funded and constitutes an independent study.

Mapping Motivations and Measuring Success

Abstract

I use the Institutional Analysis and Development (IAD) Framework to understand agricultural producers' motivations to collaboratively govern groundwater in Kansas and how they measure the success of these collaborative efforts. I collected qualitative data to show the social and economic impacts that voluntary irrigation restrictions have had on individual farmers. Kansas producers rely on groundwater from the High Plains Aquifer as the primary source of irrigation, but water levels have been declining for decades. Grassroots pressure from producers led the state to adopt the Local Enhanced Management Areas (LEMA) Act in 2012, which recognized producers' ability to make policies to manage shared groundwater resources. The first LEMA was formed in 2013, where producers imposed a collective cut in withdrawals that resulted in a 31% reduction in average pumping over a 10-year period. While previous research has found that rates of groundwater loss have declined since the implementation of this LEMA, this study delves deeper into the factors that led to the formation and success of the area and broadens our understanding of how producers evaluate the success of collaboration. Using semi-structured interviews based upon the IAD, I found that producers effectively adapted to using less water by reevaluating how much water is necessary to grow crops, adopting water saving technologies including soil moisture monitors, and altering the types of crops grown. I also found that producers were driven to collaborate primarily by a desire to extend the aquifer's lifespan, minimize regulatory oversight, preserve a sense of agricultural identity and place attachment to their farms and farming community, and provide opportunities for future generations to inherit farming operations. By identifying both the antecedents and outcomes of self-organized local collaboration, this analysis can help reduce the barrier of uncertainty for other producers to co-manage their water resources.

Introduction

Agricultural Water Scarcity and Collaborative Governance

Water scarcity is a pressing problem around the world (Rosa et al., 2020). Approximately 80% of the human population faces water insecurity (Scanlon et al., 2023), and one-third of individuals or companies that rely on water as an input for their economic production face threats to continued water access in the near future (Richter et al., 2017). This growing water scarcity is largely driven by irrigated agriculture, which is the primary source of water demand and consumption globally (Elliott et al., 2014; Smidt et al., 2019). Large-scale industrial agriculture is defined by intensive water application to increase productivity, where utilizing surface and groundwater resources to supplement natural rainfall is often necessary for production (Alauddin and Quiggin, 2008). In the United States, 90% of consumptive water withdrawals are for irrigated agriculture (Sanderson and Frey, 2015).

The concept of collaborative governance has increasingly been invoked as a model of institutional arrangement to address issues of scarcity associated with common pool resources like water (Eaton et al., 2022). Elinor Ostrom popularized collaborative governance as a way to manage common pool resources beyond state control or the free market (e.g., Ostrom, 2010; Ostrom 1990). A defining feature of collaborative governance is the assertion that resource users can and should participate in developing and implementing policies for managing shared resources (Ansell and Gash, 2008; Ran and Qu, 2019). Including resource users in the governance process helps ensure that policies fit the environmental, socioeconomic, and cultural realities of the people who will be subject to its policies (e.g., Torfing, 2019; Carlisle and Gruby, 2019).

Collaborative governance arrangements primarily emerge through two avenues: top-down, and bottom-up. Top-down collaboration occurs when federal or state governments create policies that compel water users to work together with the intent of sustainably managing shared resources, while bottom-up collaboration occurs when resource users organize at the grassroots level to form governing bodies that are then recognized by higher levels of government (e.g., Eckerberg et al., 2015; Koontz and Newig, 2014). While there is value to both forms of collaboration (Watson, 2014), researchers have identified several advantages of bottom-up collaboration – in particular, facilitating better institutional fit and promoting greater community buy-in compared to top-down approaches directed by state authorities (An, 2021).

Research on the collaborative governance of common pool resources has found that, within appropriate conditions, resource users will alter behaviors through collaboration even in the absence of an external authority that compels collective action (Piazza, 2021). To explain why resource users may be motivated to form bottom-up collaborative governance institutions, Emerson and Nabatchi (2015) outline four interconnected drivers: uncertainty, interdependence, consequential incentives, and leadership. Uncertainty exists when the actions of resource users no longer result in the expected outcomes based on previous experiences, because changes in the underlying social-ecological system cause unexpected results from these actions. Such uncertainty can motivate collaboration if resource users believe that working together, rather than acting separately, is a viable strategy to identify and mitigate uncertainty. Furthermore, the likelihood of resource users working together increases if they recognize that each person's resource use affects, and is affected by, the use of others. Interdependence means that resource users acknowledge the fact that they are dealing with a common pool resource, where each user's action affects both the shared resource and others' ability to use it. Recognition of interdependence may promote collaboration if resource users perceive that working together is the best way to manage their shared resources. Additionally, if resource users perceive consequential incentives from working together to manage shared resources, they are more likely to collaborate. In other words, if working together may produce more desirable outcomes for individuals and the commonly held resource than acting individually, then resource users are incentivized to collaborate. Finally, bottom-up collaboration requires one or more individuals to initiate the establishment of collaborative governance institutions. Without such leaders setting the process in motion, it is unlikely that collaborative governance institutions will form, even given favorable conditions of uncertainty, interdependence, and consequential incentives.

This research investigates the development of a bottom-up collaborative water governance institution in Kansas to identify the motivations that led agricultural producers to initiate collaboration, as well as how they measure the success of the institution according to categories identified in the IAD. The success of this institution in reaching its conservation goals has since led nearby collectives of growers to attempt to replicate it. However, it may be the case that there are other important measures of success that need to be considered for both evaluating the LEMA as well as wise implementation elsewhere. Finally, I seek to understand how

producers, as individuals and as a community, have adapted in response to the transition from acting as independent water users to a more collaborative arrangement.

Local Collaborative Governance in Kansas

Agriculture is a major component of the Kansas economy. In 2018 agriculture and associated industries (e.g., food processing and distribution, fertilizers, and pesticides, etc.) accounted for nearly 13% of the state's workforce, and over 40% of total statewide Gross Domestic Product (Kansas Department of Agriculture, 2018a). Kansas exports approximately $4.8 billion of agricultural products annually, is the number one producer of wheat and sorghum in the U.S. as of 2020 and is ranked third in terms of cattle production and beef processing as of 2020 (Kansas Department of Commerce, 2023). Land values in Kansas are also closely tied to groundwater availability, with agricultural land values averaging 55% higher for irrigated acreage, combining to a total value of approximately $5 billion for irrigated lands in the state (Sampson et al., 2019).

Agricultural productivity in Kansas is threatened by rapid declines in groundwater availability (e.g., Whitmore et al., 2023; Buchanan et al., 2023; Haacker et al., 2015) because intense pumping has reduced the long-term viability of irrigation (Cotterman et al., 2018). Kansas is highly dependent on the High Plains Aquifer (HPA), with 97% of irrigation water in the state coming from the HPA (Smidt et al., 2016). Rates of groundwater extraction from the HPA in Kansas since the 1970s have been significantly greater than recharge rates, resulting in groundwater loss that was evident both to agricultural producers at the field level (i.e., loss of well capacity) and state and university groundwater modelers (Brauer et al., 2017; Deines et al., 2021; Pfeiffer et al., 2014). Without readily available alternative sources of water for irrigation, the depletion of the HPA threatens the future of irrigated agriculture in Kansas (Butler and Johnson, 2024).

This issue has motivated agricultural producers and policymakers to design and implement strategies that reduce short-term water consumption to ensure long-term water availability, while striving for the economic viability of producers now and into the future. In 2012, the Kansas legislature enacted the Local Enhanced Management Areas Act in response to grassroots efforts by agricultural producers who wanted to help resolve water scarcity issues at the local level and have the state government recognize their authority to make management decisions as a collective of water users (Cruse et al., 2016). Producers in Sheridan and Thomas

Counties recognized the imminent threat of water scarcity in their region and elected to impose upon themselves a 20% reduction in irrigation averaged over a 5-year period (Pfeiffer and Lin, 2014). Under this plan, water users have 55 inches of water to apply to their state-certified irrigated acreage that they can use in any way they see fit over a 5-year period. Moreover, the Act created a binding regulatory order to reduce water use, which was overseen by the Kansas Department of Water Resources (DWR-KDA) and gave producers the confidence that everyone was adhering to the same set of rules. This area became the first Local Enhanced Management Area (LEMA), the Sheridan 6 (SD-6) LEMA (Sanderson and Frey, 2015).

Under the 2012 Local Enhanced Management Areas Act, for a LEMA to be recognized by the state, a majority of the Groundwater Management District (GMD) Board members associated with the region must vote to approve its adoption (Kansas Department of Agriculture, 2016). GMD Board members are elected officials from the agricultural community who hold public meetings to understand the desires and concerns of represented producers, and who make decisions – such as whether to institute a LEMA – based on stakeholder input (Bossert, 1993). Once approved by the GMD Board and Chief Engineer of the Division of Water Resources in the Kansas Department of Agriculture, decisions made by a LEMA have the force of law (Golden and Guerrero, 2017). If a water user fails to follow policies created by the LEMA, the Chief Engineer has the power to enforce any corrective measure approved by the LEMA (Kansas Department of Agriculture, 2018b).

The Sheridan 6 (SD-6) LEMA exemplifies a bottom-up collaborative governance institution initiated by, and composed of, agricultural producers, the authority of which is explicitly recognized by state authorities. It also represents a paradigm shift in how water resources are managed in the state. Kansas has historically operated according to Prior Appropriation, which is based on the idea of "first in time, first in right" (Griggs, 2021). In practice, this means that when the total quantity of water allocated by the state through permits is not available, 'senior' rights holders – those who obtained rights first – can use the entirety of their allocations, while more 'junior' rights holders – those who obtained rights later in time – are unable to use all of the water they technically have a right to. However, under the SD-6 LEMA, all rights holders agreed to proportionally reduce water use regardless of the relative seniority of their water rights.

Numerous studies have found that the SD-6 LEMA was successful at slowing the rate of aquifer decline (e.g., Whitmore et al., 2023; Glose et al., 2022; Zwickle et al., 2021; Deines et al., 2019, 2021; Golden and Guerrero, 2017; Steiner et al., 2021). However, environmental success is only one outcome of interest. Even if the LEMA resulted in reduced rates of groundwater decline, it is important to understand the social and economic impacts that this policy has had on producers and their livelihoods, because if users cannot adapt to a smaller water budget, then individual and regional economies will suffer. While questions about environmental impacts of the LEMA can be answered with groundwater data and models, I used a qualitative approach to understand first-hand farmers' perspectives on the social and economic impacts of LEMA.

This Study

In this study, I use the Institutional Analysis Development (IAD) framework to understand the effects of the SD-6 LEMA on groundwater resources, the water user community, and how individual water users adapted to a smaller water budget (Figure 1).

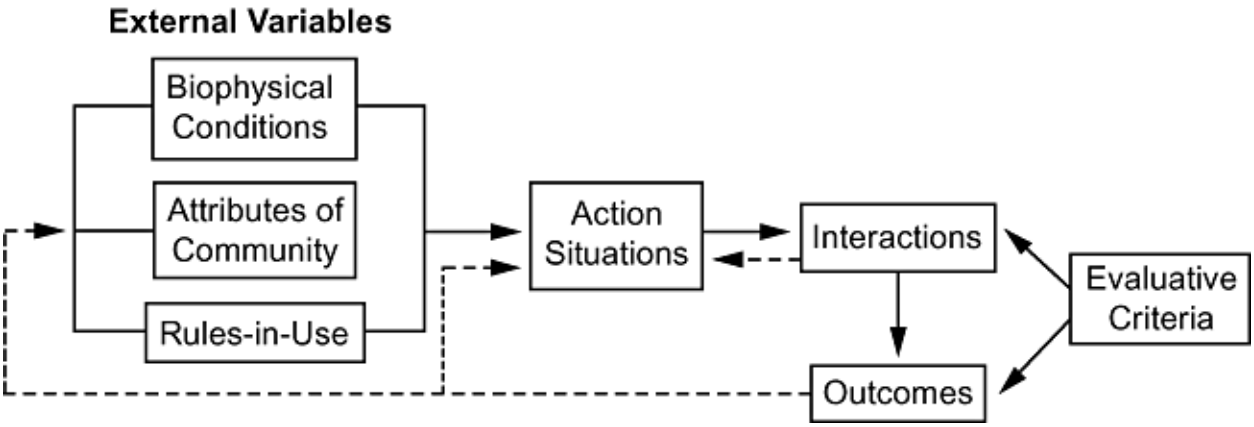

Figure 1. Institutional Analysis and Development Framework (Ostrom, 2011).

The IAD framework was developed by Ostrom (2005) to model collaborative governance institutions as decision making nodes within a larger system defined by biophysical conditions, attributes of the resource user community, and the rules-in-use that define resource access and use. I apply the IAD framework to understand both how the external variables – biophysical conditions, attributes of the water user community, and rules-in-use – gave rise to the SD-6 LEMA (here depicted as the action situation), as well as how the outcomes of actions taken by the LEMA have affected the external variables. It is important to note that "rules-in-use" can be

analyzed at three levels: constitutional (e.g., federal or state laws), collective choice (e.g., agreements among resource users about how resources are allocated), and operational (e.g., private decisions made by individuals regarding their resource use) (Ostrom, 2005). In this research, all three levels are relevant to understand how the SD-6 LEMA works, and how water users behave within it and are investigated during the interview process.

I investigated the following research questions to understand the conditions that gave rise to the SD-6 LEMA, and how water users evaluate the success of collaborative efforts:

RQ1. What were Kansas producers' motivations for establishing a LEMA?

I posit that agricultural producers in Kansas were motivated to form a LEMA for several reasons: to preserve their identity as members of a farming community (Valizadeh et al., 2020), to ensure that they can pass their land and business on to future generations (Fischer and Sanderson, 2022), and to take responsibility for a water scarcity issue that their individual and collective actions have (at least partially) created (Ataei et al., 2022).

RQ2. How do producers define the success of the SD-6 LEMA? Do they believe that it has been successful, and if so, why?

The SD-6 LEMA was first initiated from 2013 to 2017, and then renewed for 2018-2022 and again for 2023-2027 (Kansas Department of Agriculture, 2023). Given this history of renewal, I posit that producers believe that the LEMA has been successful. I explore several reasons for why this may be the case, including: improved relationships between water users (Jager et al., 2020), changes in water use rules that encourage resource sustainability (Pahl-Wostl, 2019), maintaining the economic productivity of producers (Ghosh and Ghost, 2023), and producers having the ability to adapt individual practices in ways that seem most rational to them (Gilmore et al., 2022).

RQ3. How have producers adapted at the field level to withdrawal reductions enacted through the LEMA?

I posit that producers have adapted farming practices under LEMA policy in the following ways: maintaining the same irrigated acreage while applying less water per acre, switching to less water-intensive crops, and/or adjusting cropping schedules (Deines et al., 2021). I also expect that producers adopted technologies that increase irrigation efficiency, such as soil moisture probes (Whitmore et al., 2023).

Methods

Sample & Recruitment

This research took place in the summer of 2021. The target population was agricultural producers within the SD-6 LEMA boundary. Through an open records request to the Kansas Department of Water Resources, the names, addresses and contact information for all water rights holders in the LEMA were obtained. To recruit interview participants, letters explaining this research were mailed to all water rights holders in the LEMA inviting them to participate, followed by two reminder letters at one-week intervals. Additionally, snowball sampling was utilized when participants offered to encourage other producers to be interviewed. Sampling efforts ceased after the final reminder letter and when participants could no longer suggest additional friends/acquaintances to contact. Producers were offered $100 for their participation.

There are 59 irrigators operating within the SD-6 LEMA. Nineteen producers (32%) ultimately participated in this study. Since I was only able to obtain the names and contact information for water rights holders in the LEMA, it is not possible to determine the extent to which research participants are representative of the larger population. Without available demographic information for the entire population regarding, for example, length of time farming, age, the number of acres they farm, whether they own or rent the land they work, the relative seniority of their water rights and other relevant information, it is difficult to know whether and to what extent the results of this research may be biased.

Data Collection and Analysis

I conducted 19 phone interviews during the summer of 2021. It was necessary to conduct interviews remotely due to COVID-19 related travel restrictions. Before the interviews began, participants signed a waiver granting permission to be recorded. On average, interviews lasted approximately one hour, and were audio recorded using Rev (2023) for later coding and data analysis. I coded transcripts in Dedoose using a combination of deductive and inductive codes. Following Rabiee (2004), the data analysis process occurred over three phases: familiarization, code application, and interpretation.

Additionally, I conducted intercoder reliability checks to ensure that the clarity of codes resulted in similar applications across multiple researchers. Following O'Connor and Joffe (2020) approximately 25% of transcripts (5/19) were independently coded by two researchers using codes developed by the primary researcher. After transcripts were independently coded,

the researchers compared and discussed their code application until an interpretive logic was generally agreed upon. The primary researcher then coded the entire set of transcripts. Analyzing data involved identifying coded material, at the sentence level, that was relevant for answering each research question. Finally, a detailed reading and interpretation of coded material was conducted to offer answers to research questions.

Instrument

I used the Institutional Analysis and Development Framework (IAD) to design a semi-structured interview guide (Table 1). Producers were also asked about their support for the LEMA, how they measure the success of the institution, if they think that it has been successful, and how they adapted farming operations under LEMA rules. These questions supplement those created using the IAD, which does not integrate resource users' first-person perspectives of a collaborative governance institution and its impacts.

Table 1. IAD variable and their corresponding interview questions.

	Interview Questions
Biophysical Conditions	Has your farming practice, or other farmers you know, been impacted by groundwater scarcity? If so, can you please explain these impacts?
	Describe, if any, indicators of groundwater scarcity you have observed.
	Have you noticed changes in rainfall patterns in recent years?
	Do you think the Kansas Geological Survey accurately models groundwater conditions where you farm, and across Kansas as a whole? Why or why not?
	How many farmers do you know in the Sheridan LEMA?
Attributes of Community	Do you think farmers in the Sheridan LEMA share similar views about the condition of water resources?
	Do you think that most farmers in your region support the LEMA? Why or why not?
	Is your water right senior or junior?
Rules-in-Use	Do you own, rent, or lease farmland?
	What crops do you typically plant, and has this changed after the establishment of the LEMA?

Table 1 (cont'd)

	Have you adopted farming practices after the establishment of LEMA, and if so, how? (intensive & extensive).
	Management strategies (row spacing, density of planting, soil moisture sensors, etc.).
	Has your water use/acre changed since the establishment of the LEMA?
	What kind of irrigation technology do you use?
	Has the LEMA changed how you perceive water resources?
	Has the establishment of the LEMA reduced energy costs and/or inputs?
	Would you say that you are better off after the establishment of the LEMA? Your neighbors? Your children (do you expect them to take up farming after you?). – stress, happiness, other ways I have not mentioned?
	Have your profits increased or decreased since the establishment of the LEMA?
	Perceptions of LEMA effectiveness (is it working in the interest of farmers? – procedural fairness, trust, etc.).
	Are you personally active in water governance?
	To what extent do you think the State is responsible for managing groundwater for long-term availability? To what extent do you think this is farmers' responsibility?
Perceptions of Success	Do you think that the LEMA has been a success?
	How do you measure the 'success' of the LEMA?

Results

RQ1. What were Kansas producers' motivations for establishing the LEMA?

Respondents were highly motivated by the fact that they perceived water scarcity as an immediate problem that needed to be addressed if they were to continue irrigating. Nearly all participants reported that increasing water scarcity was obvious to them, and the community at large, because their wells had gradually lost pumping capacity through the years. They did not

need external information from the state or universities to convince them that there was an issue, because it was immediately apparent in their daily operations.

Fifteen participants (79%) explicitly stated that overuse from irrigation was the principal driver of declining water levels, and that the cumulative effect of withdrawals was depleting the aquifer. Moreover, nearly half of participants (47%) noted that since the LEMA has been implemented, they have noticed that their capacities had ceased to decline, indicating a stabilization of groundwater levels. Three participants even said that well capacity had slightly increased from the lowest point before LEMA was enacted.

Participants were also asked about changes in climate that may impact water use in the LEMA region, with nine producers (47%) describing their perceived changes. Two participants (11%) commented that annual precipitation and temperature had changed since they began farming but said that weather is always variable and not necessarily due to climate change. Four participants (21%) said that the growing season has shifted so that planting now begins earlier in spring and harvest lasts later into the fall. Finally, three participants (16%) said that the climate was drier in general, making irrigation even more essential. These participants said that they now refer to their region as "Kansiowa" - because they perceive their temperature and rainfall patterns to be more like those in Iowa.

Finally, while there was general acceptance among producers that water scarcity was a real issue based on the loss of well capacity, two participants (11%) said they were not convinced that the LEMA was the proper solution until they attended educational presentations by members of the Kansas Department of Water Resources explaining the hydrological models used to justify the 20% reductions proposed by the LEMA statute. Ultimately, education efforts on the part of the state helped create trust in the models used for regulatory purposes. As one participant said, "we all knew there was a problem" but seeing how modeling work helped the water user community to visualize the issue "really resonated with me."

RQ2. How do producers define the success of the SD-6 LEMA? Do producers believe that the LEMA has been successful, and if so, why?

All participants except for one (95%) said that they support the LEMA, believe that it is successful, and will continue to support it into the future. The lone dissenter argued that the LEMA was not a good policy because it amounted to an uncompensated taking by the state, where water users gave up a percentage of their property right without any monetary benefit in

return. Those in favor of the LEMA gave a variety of reasons for their support: their recognition that preserving water into the future was a personal and collective responsibility, their desire to pass farming operations onto descendants, their ability to maintain their profitability despite water reductions, the important role of agriculture in supporting the economy of local communities, retaining high land values, and the fact that the LEMA allows users' discretion for how they will use their allotted 55 inches of water over 5 years.

Fifteen participants (79%) also said that they support the LEMA because they recognized that irrigation is the primary driver of aquifer decline, and ten (53%) said that the only reasonable way to address aquifer decline is collective reductions in total water withdrawals. These participants stated that producers need to take responsibility for their actions and change behaviors if they are going to be part of the solution rather than the problem. Eleven of these participants also said that they support LEMA because they desire to retain power over water resource management decisions within the community, rather than having the state impose rules upon them. Respondents said that each producers' situation is different, and that top-down measures created at the state level would likely fail to appreciate this fact. They argued that if producers governed water resources themselves it would lead to better outcomes for individuals and the community.

Thirteen producers (68%) talked about inheriting their land and farming operations from previous family generations. They were willing to adopt the LEMA and water restrictions because they wanted to pass their land and operations to younger generations in their family. These participants described a desire to continue their farming heritage into the future and saw the ability to irrigate as key for the survival of farming operations, such that if their children and grandchildren will have the option to continue this tradition it is essential to reduce water consumption now to better ensure availability in years to come.

Twelve of the nineteen participants (63%) described how their profitability under LEMA has been unaffected, and none explicitly mentioned a reduction in profitability. This was a strong motivating factor for the renewal of the LEMA and participants expressed support for renewing the LEMA into the future. Since water users have been able to use less water while maintaining profitability, they are able to extend the life of the aquifer while remaining economically viable.

Eight participants (42%) mentioned the LEMA was necessary because agricultural production is the economic foundation for their communities. Without money generated from

agriculture and spent in communities, non-agriculturally related businesses (e.g., restaurants) and agriculturally based businesses (e.g., implement and chemical dealers) would not be able to exist. Participants said that the ability to extend the life of the aquifer to ensure the viability of irrigated agriculture into the future simultaneously helped ensure the sustainability of local communities.

Five participants (26%) talked about the close linkage between land values and available irrigation water. A piece of land that can be irrigated is worth far more than land where only dryland agriculture is possible. The LEMA was seen as a good thing because it helped ensure that land values remain high by preserving the aquifer upon which irrigation in the region is dependent.

Finally, three participants (16%) said that the flexibility of water application built into the LEMA is one of the policy's most important components, and that flexibility helped create buy-in within the farming community. The fact that water users in the LEMA have discretion about how they will use their allotted 55 inches over a five-year period is a risk mitigation strategy that lets them adjust water use given unpredictable climatic conditions such as rainfall and temperature. The participants who emphasized the importance of this flexibility said that without it, fewer water users would likely have endorsed the LEMA.

RQ3. How have producers adapted at the field-level to withdrawal reductions enacted through the LEMA?

Participants described three important changes in the water user community during the process of developing and implementing the LEMA: change in perception of water rights, greater willingness to have conversations about water use, and education.

The most important change in the LEMA community was how producers thought about water rights. Six participants (32%) talked about the fact that they respect individuals' water rights, but that effectively addressing aquifer decline required a shift in perspective towards a more collective approach to management because it was clear that individuals' actions impacted others. These participants argued that since members of the SD-6 LEMA had their water allocations reduced proportionally it resulted in a sense that everyone was being treated fairly. Proportionally reducing water allocations is a novel phenomenon in the SD-6 LEMA, where state water law had previously operated according to Prior Appropriation Doctrine where more senior right holders (those who had been granted water use earlier in time than others) can use their full water allotment in times of scarcity while more junior right holders must cut back.

Four participants (21%) mentioned that producers tend to be more willing to speak with each other about their water use since implementation of LEMA. One of these participants said that this used to be a taboo subject, but now producers openly discuss their watering schedules, how much water they have used, and other similar topics. This participant also said that he now felt "we are in this together" to "save our water", whereas in the past water users were "more in competition with each other."

Participants also described several changes that occurred at the operational level after the adoption of LEMA, and how they adjusted to working with a smaller water budget. These changes include a shift in perception about how much water is necessary for irrigation and altered strategies for irrigation scheduling, crop types and planting schedules.

Fifteen participants (79%) talked about how farming within the LEMA changed their perceptions of water. Six of these participants talked about the fact that they were surprised at how easy it was to adapt to water restrictions and learned that they did not actually need as much water to operate effectively as they had previously thought. Although participants said that they needed to be more careful and calculated with water uses, they realized that they were wasting water before the LEMA by using more than what was necessary to raise healthy crops. Some of the ways that the other nine participants described altering their irrigation practices included turning off systems when it is raining and using soil moisture probes to be more precise and timelier with each application.

Participants also talked about adapting to water restrictions by changing the types of crops that they grow and their planting strategies throughout the season. Roughly half (53%) of participants said that they had not changed the types of crops that they grow because they realized that they could meet their water reduction targets by watering the same crops less. However, five participants (26%) said that they had begun to include soybeans and wheat in their crop rotations, rather than growing only corn, because they are less water intensive. Two participants (11%) mentioned that new genetic varieties of corn that require less water have been a valuable advancement that has allowed them to continue focusing on corn production.

Discussion

Overall, producers expressed support for the SD-6 LEMA, now and into the future. There was common recognition that groundwater levels were rapidly declining, that immediate action was needed for producers to continue irrigating, and that irrigation was the main driver of

increasing water scarcity. Most participants expressed the idea that the solution was clear: irrigation needed to be reduced to extend the usable lifetime of the aquifer. The immediacy of the problem, combined with the fact that the LEMA design was perceived as relatively fair in that it proportionally reduces all producers' water allocation, ultimately coalesced into the grassroots movement from which the LEMA grew – especially because it offered an avenue for water users to make decisions at the local level, rather than relying on state regulators.

Recognizing the problem and taking responsibility for the collective reduction in water use was the first step towards creating the SD-6 LEMA, but there is an important point of institutional design that encouraged collaboration: fairness. The decision was made that the rules for the SD-6 LEMA would mandate a 20% reduction in water use for every water user. Kansas operates under the law of prior appropriation, meaning that in times of scarcity more junior right holders bear all the costs of reduction while more senior right holders can utilize their full allotment. If the LEMA were to follow the logic of prior appropriation, it is unlikely that it would have been successful because the burden of reductions would have fallen heavily on some and not at all on others; it is unlikely that those upon which the burden fell would approve of the policy because it would have effectively made farming impossible. The LEMA represents a paradigm shift in the trend of how water allocations are treated in Kansas, indicating that the success of local collaborative governance institutions may have to stray from historical legal precedent and embrace innovation.

Producers said that they witnessed the fruits of their actions as their well capacities visibly stabilized. This gave them confidence that they had made the right decision to implement the LEMA and that it should continue to be renewed. Producers gave several reasons as to why it was important to extend the life of the aquifer, primarily: for future generations to inherit viable farming operations and preserving land values. Understanding these cultural and economic factors sheds light on what local collaborative governance success looks like to the resource users embedded in the system. Although the IAD and other conceptual frameworks used to evaluate the success of collaborative governance institutions provide key insights into relationships between institutions and environmental, social, and economic variables, they often fail to capture the first-person perspectives of resource users who operate within these institutions. These first-person perspectives are essential for understanding why resource users

create (or don't create) collaborative governance institutions, as well as provide evidence of success for various governance designs.

Furthermore, the process of creating the SD-6 LEMA helped water users build a sense of camaraderie as their mindset shifted towards collective water management. While previously producers had perceived water use as an individual concern, now there is greater transparency and the sense that "we are in this together." Shared motivation is essential for members of collaborative governance institutions to work effectively together (Emerson et al. 2012), and the LEMA exemplifies the development of shared motivation through open dialogue about key aspects of water management.

Conclusion

Contributions to Theory: The Role of Fairness in Good Policy Design

The Sheridan 6 LEMA in Kansas offers a positive example of how local collaborative governance institutions can effectively resolve common pool resource problems. While the specific design of institutions should be congruent with local contexts, the LEMA embodies collaboration principles that can be applied elsewhere. First, fairness was a key feature of the LEMA that generated a great deal of buy-in for water users to adopt an innovative water governance strategy. By imposing an equal reduction in water allocations, rather than relying on prior appropriation doctrine, LEMA policy was perceived as an attempt to sustain water for everyone. Other locations considering the implementation of a collaborative water governance institution should consider fairness as vital to create resource user buy-in. In this case, part of ensuring fairness was modifying prevailing rules of water allocations in times of water-use reductions; regardless of whether such rules need to be altered in other cases, this study shows the value of considering the relationship between water allocations and institutional formation.

Moreover, participants in this research described several motivating factors that researchers can expect to apply in other locations. The primary drivers of collaboration were maintaining agricultural revenue and in-community spending, preserving land values, and retaining the option of passing viable family farms onto descendants by ensuring irrigation remains possible. Understanding these motivations may help researchers better investigate perceived success of local governance institutions by having a clear idea about how producers measure success, provide advocates for adopting such institutions with communication strategies

to increase community buy-in, and offer regulatory agencies greater insight into what drives water users' behaviors.

This research points toward the value of expanding our understanding of why resource users are motivated to form collaborative governance institutions at the local level, and how they evaluate its performance. The SD-6 LEMA represents an instance of self-originating collaboration, but it is important to note that collaboration is initiated by other means, such as state mandate; it may be that certain findings from this study are more likely to be relevant in other cases of self-originating institutions compared to cases where collaboration began another way.

However, other findings are applicable to collaborative governance institutions because of certain commonalities they share. This study indicates that the perceived fairness of the LEMA rules played an encouraging role in its formation, which may be an important factor in other instances where resource users have voluntarily created an institution, or places where collaboration is being considered. Brisbois and de Loe's (2016) systematic review of articles examining the role of power in collaborative resource governance highlights the impact of power relations in either facilitating or foiling collaborative efforts. The prior appropriation doctrine that had prevailed in Kansas established significant power disparities between senior and junior water rights holders, and a key factor in the formation of LEMA was the fact that water users elected to equally reduce water consumption regardless of the relative seniority of their water rights.

In cases where collaboration began as a state mandate, fairness will likely play less of a role because participation is mandatory. For example, the 2014 Sustainable Groundwater Management Act (SGMA) in California was established by the state legislature to stabilize groundwater in over drafted basins by compelling water users to collaboratively create sustainable groundwater management plans (Espinoza el al., 2023). Under conditions of state mandated collaboration, however, it may still be worthwhile to consider how those affected by law and policy implementation perceive the fairness of the rules they must follow. It may be in policymakers' interest to design laws and institutions aiming to sustain resources in ways that minimize the costs users bear and maximize the benefits they may take advantage of. Of course, this ideal is difficult to realize in practice considering the complexity of resource management issues and the diversity of interested parties involved. Nevertheless, meaningful insights may be

gained through understanding fairness in these conditions and using this knowledge to inform policy making.

Contributions to Practice: Measuring Institutional Success

Agricultural producers in the Sheridan 6 LEMA were confronted with the fact that their groundwater use needed to evolve if they were going to meaningfully confront the threat of increasingly scarce resources. The LEMA represented a way for producers to fairly reduce individual and collective withdrawals to extend the period of usable groundwater and do it in such a way that they could adapt and remain economically viable. This research sought to understand how LEMA participants evaluate its success now that it has been in place and twice renewed since 2013.

In addition to finding that research participants considered the LEMA successful because rates of groundwater decline have lessened since its adoption, they also discussed measures of success in broader economic and cultural terms. Participants' economic metrics for evaluating the success of LEMA are, unsurprisingly, tied closely to their ability to irrigate now and into the future. At the individual level, participants said that the LEMA has proven successful because they have been able to adapt in ways that allow them to remain economically viable. Relatedly, at the community level, participants explained that agricultural productivity is the cornerstone of local economies, and a measure of the LEMA's success is their confidence that their communities can continue benefiting from irrigated agriculture.

Participants also described cultural values that acted as measures for judging the relative success of the LEMA. At the individual level several participants described how many agricultural producers in the area had inherited their lands from previous generations and that they desire to have the option of passing their property - including water rights – on to descendants. A measure of the LEMA's success is its ability to help sustain a culture that exists in the region and is lived through LEMA members and their community. Not only is water a key input in the economic realities of agricultural production, but water users in this study want to preserve their culture and way of life.

This work is important because it makes a case that collaborative water governance through the LEMA was successful beyond simple environmental measures. The LEMA was successful, according to participants, because it helps them to preserve their identity as agricultural producers, their communities, and ways of life. As with all communities, the

Sheridan 6 LEMA represents a unique case and generalization of findings from this research to other cases should be done carefully. Specifically, understanding individual and community values is essential to why collaboration exists where and when it does, how collaborative institutions adapt and maintain themselves, and why some do not exist where we might expect them to.

The specific economic and cultural values cited by LEMA participants will be found in other locations that share similar demographics: midwestern US agricultural communities facing the threat of groundwater scarcity, that are of a certain size and cultural composition, that have the necessary social cohesion and leadership to organize a collaborative governance institution, and the ability to design and implement a plan for how it will operate. Given the geographic area of the central and western United States experiencing groundwater shortages, many communities fall under these criteria.

These findings can also be generalized by similarities in collaborative governance efforts, even if they are situated in communities with different demographics from the ones studied here. Consider interstate compacts like the Rio Grande or Great Lakes Compacts where the rules governing water cover diverse communities in and between each of the states involved, water sharing agreements amongst municipalities, states and nations, and rules that balance how interested parties can interact with shared resources from individual to global scales. It would be inappropriate to expect that expressions of economic and cultural values that are vital to the success of the LEMA would be the same as those expressed by such very different communities.

Considering the economic and cultural values of resource users is important both for cases like the SD-6 LEMA where the institution developed from the bottom up, as well as cases where users are mandated to participate by law (e.g., SGMA in California). Policymakers responsible for designing collaborative governance institutions would likely prefer to minimize the costs associated with implementation and maximize its efficacy regarding the goals it was created to achieve. For example, if a policy is particularly hard to bear economically or offends persons' sense of self and culture, some of those affected may risk behaving in ways that stray from intended policy, and thereby require state enforcement to compel adjustments in users' behaviors. It may be better for policymakers to think critically about how potential policies will impact the economic and cultural values of communities affected because attempting to design

good (as perceived by those affected) at the front end may save unnecessary governmental resources and efforts to try and correct the effects of bad policy.

Future Research

I hypothesize that the fairness of an institution and the fairness of the rules it creates, as perceived by the impacted resource users, will directly affect their willingness to participate. Fairness is a complex concept that can be defined socially, economically, politically, and means something different depending on a stakeholder's perspective. Identifying and testing measurable definitions of fairness in collaboration is an ongoing and rich field of study (e.g., Roozee et al., 2024; Annahar et al., 2023; York and Yazar, 2022). This research revealed that the Sheridan-6 LEMA's innovative approach to equally reduce users' water allocations, and thereby stray from the previous precedent of prior appropriation doctrine, was a key design feature for making the institution feasible for water users. Exploring relationships between water allocations and the initiation, operation, adaptation, and failings of institutions offers substantial opportunities for improving the design and implementation of collaborative institutions.

Rights, Norms, and Collaborative Water Governance Institutions: A Michigan Case Study

Abstract

Legal rights and norms play a key role in stabilizing natural resource governance systems by establishing rules that individuals and organizations follow and expect from others. While providing necessary stability for a governance regime, rights and norms may also inhibit important adaptations of governance systems in response to changing environmental, political, social, and economic conditions. This research focuses on changes in Michigan water policy that created the opportunity for water users to collaboratively govern shared water resources at the watershed scale. While water users have had the ability to form collaborative institutions since the state's implementation of the 2008 Great Lakes-St. Lawrence River Basin Water Resources Compact, no institutions have formed to date. I hypothesize that the lack of collaboration can be explained in terms of prevailing water rights and established norms in Michigan's water user communities. Using the concepts of uncertainty, interdependence, consequential incentives, and trust – as outlined in the Integrative Framework for Collaborative Governance – I operationalize the constructs of rights and norms to test my hypothesis. I created a survey that was sent to all large-quantity water users in the state to understand why they have not formed collaborative institutions. Results show that the norm of individualistic water use, based on expected water abundance, diminishes willingness to participate. By identifying barriers for collaboration, this research can help policymakers and other interested parties incentive water users to collaborate in Michigan. Moreover, the focus on rights and norms – as measured using the Institutional Analysis and Development Framework – offers researchers and policymakers a lens through which to understand collaborative institutions in other situations, helping to guide evaluation and identify possibilities for improvements.

Introduction

Rights, norms, and collaborative governance

Systems of governance created to manage water resources cannot be fully understood without considering the legal rights and social norms that structure how resource users interact with resources and each other (Muir et al., 2023). Rights determine who may access a resource, what resource users may or may not do, and obligations associated with being a resource user (e.g., Dade et al., 2022; Tenzing et al., 2021; Sikor et al., 2017). Like rights, norms partially structure how people interact with resources. While rights are grounded in law, as well as administrative and judicial interpretations, norms, on the other hand, more broadly refer to customary social behaviors that resource users perform and can expect from others (Oniki et al., 2020).

While rights and norms stabilize governance systems, they can also inhibit important adaptations. Collaborative governance is increasingly cited as a potentially powerful strategy for sustaining common pool resources and the socio-economic systems predicated upon them (e.g., Ulibarri et al., 2023; Jimenez et al., 2020). Transitioning towards collaborative governance may be difficult, however, if prevailing rights and norms create barriers to change. The relative strength of rights and norms in determining whether collaborative governance institutions form depends on the process by which transitions towards collaboration occur. Emerson and Nabatchi (2015) identify two ways that collaboration may be initiated: self-origination from bottom-up organization by resource users, and external mandate by state authorities.

Under self-originated conditions, rights and norms play a stronger role in determining whether collaboration occurs than in cases of mandated collaboration. Self-originated collaboration implies that resource users voluntarily choose to collaborate and seek to create the legal and normative space to do so – either within the current structure of rights and norms, or by altering them. If there are certain rights and/or norms in place that sufficiently deter resource users from voluntarily collaborating with each other to manage shared resources, then they are unlikely to do so. On the other hand, if the state mandates resource users to collaborate, then they must adapt behaviors regardless of previous rights and norms and adjust to new rights and norms within the new governance regime they are subject to.

While the ideas of self-originated and state-mandated collaboration may be useful constructs for describing how collaborative governance institutions are formed, there are other

instances where the process of initiating collaboration does not easily fit into either category. This research focuses on collaborative water governance in Michigan, where changes in state policy enable water users to voluntarily collaborate in efforts to manage shared resources. This case is unlike self-origination in that the ability for resource users to collaborate came from actions taken by the state legislature rather than collective action by water users. The case is also unlike scenarios where collaboration is state mandated because water users can voluntarily choose to collaborate or not without legal consequence. In this case, *facilitating* collaboration is critical. The current lack of collaboration indicates that there is not a proper incentive structure to encourage water users' voluntary adoption of collaborative institutions. The state is actively seeking strategies to motivate the establishment of collaboration through self-origination.

Collaborative water governance in Michigan

This research investigates collaborative water governance in Michigan, or rather, the lack thereof. Specifically, I seek to understand why water resource users have not formed collaborative governance institutions even though they have been able to do so since the state's implementation of the 2008 Great Lakes-St. Lawrence River Basin Water Resources Compact (Compact). In 2008, Michigan became a signatory to the Compact with the intent of promoting intergovernmental cooperation between the eight Great Lakes states, two Canadian provinces, and Tribal governments to "protect, conserve, restore, improve and effectively manage the Waters and Water Dependent Natural Resources of the Basin" (MCL 324.34201). Under this agreement, states are responsible for monitoring and restricting, where necessary, large quantity water withdrawals to protect hydrologically based ecosystems.

Michigan's implementation of the Compact resulted in caps on cumulative withdrawals in designated water management areas (WMAs), where caps are based on water levels necessary to support characteristic fish populations (MCL 324.32701). Scientists at Michigan's Department of Natural Resources defined characteristic fish populations as those species expected to exist in certain stream types (Reeves et al., 2010). Michigan's legislature then established flow standards for each stream type according to ideal conditions for characteristic fish populations. A WMA is labeled zone A when water is relatively abundant, through B and C zones which indicate increasingly scarce conditions, down to zone D which signals that no more withdrawals can be approved because it would adversely impact fish populations (Steinman et al., 2011).

Figure 2. below shows current C and D zones in Michigan, indicating locations where water scarcity is currently preventing further withdrawals (zone D) or where water levels are approaching the maximum number of cumulative withdrawals (zone C).

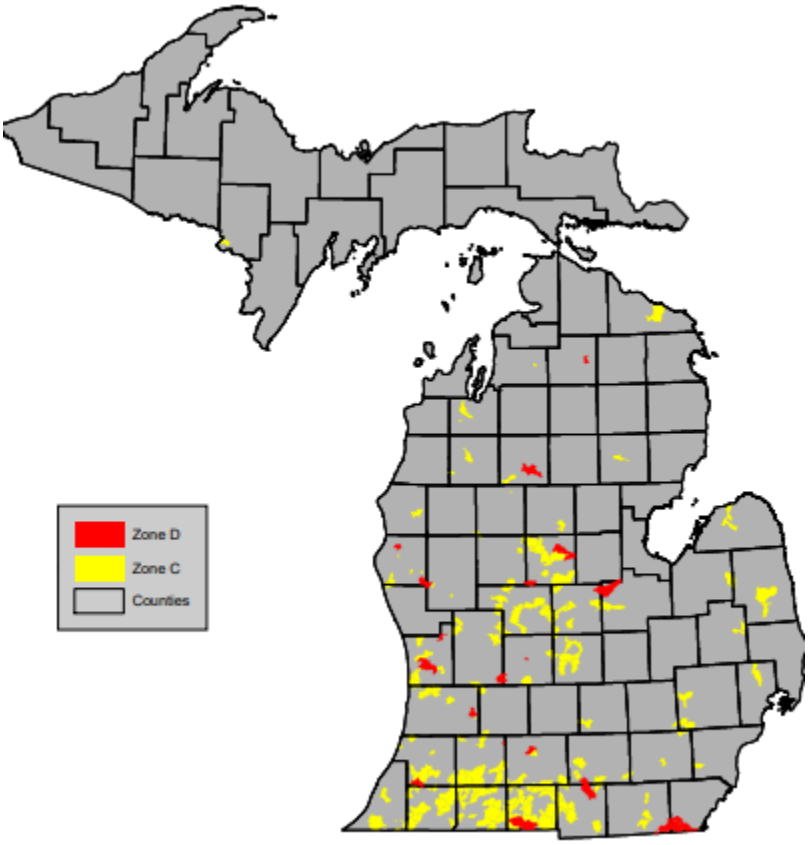

Figure 2. Map of C and D zones in Michigan generated from the Water Withdrawal Assessment Tool. (O'Neil, 2024).

Additionally, Michigan water law states that:

"All persons making large quantity withdrawals within a watershed are encouraged to establish a water users committee to evaluate the status of current water resources, water use, and trends in water use within the watershed and to assist in long-term water resources planning. A water users committee may be composed of all registrants, permit holders, and local government officials within the watershed" (Mich. Comp. Laws § 324.32725).

Water Users Committees (WUCs) were conceived as a planning and conflict resolution mechanism inspired by the idea that collaborative governance institutions can be an effective vehicle for sustaining shared water resources and the socio-economic activities predicated upon

them. Given the caps on withdrawals established by Michigan's implementation of the Compact, policy makers foresaw a potential for increased conflicts resulting from competition over resources effectively made scarcer by law. WUCs are intended to offer water users the option of managing water within withdrawal limits without relying on courts or state regulators to adjudicate disputes, which also reduces administrative and judicial burdens for the state. Additionally, by allowing each collaborative institution to make decisions about water within the WMA, WUCs offer greater flexibility in decision-making so that water users can better ensure local rules are congruent with their particular social, economic, and environmental circumstances.

Moreover, as environmental, social, and economic conditions change, WUCs may enable water users to adapt management practices more efficiently and effectively than courts or state authorities. Adaptive collaboration has been shown to be a successful approach for achieving more sustainable water usage while avoiding the financial and social costs typically associated with decreased withdrawals (Zwickle et al., 2021). There is also evidence suggesting that when conflicts do arise among competing users, adaptive collaboration can reduce the likelihood that disagreements will escalate to the point of litigation (Chaffin et al., 2014).

Can the lack of collaboration in Michigan, despite the potential benefits water users might gain from working tougher, be explained by prevailing rights and norms? Michigan water rights are founded in Riparian Doctrine, which is descended from English Common Law (Paganelli, 2007) and rest on the assumption that resources are abundant enough to meet societal demands without adversely impacting hydrological systems (Huffman, 2009). Riparian Doctrine regulates water use through the notions of correlative rights and reasonable use. The principle of correlative rights states that water users have "limited but more or less equal rights" to use water (Vermeylen, 2010). These rights are qualified by reasonable use, where "the primary right of a riparian proprietor is to receive protection for his reasonable use" of resources "from an unreasonable use by another" (Tauer, 2011). What is considered reasonable versus unreasonable has evolved through court decisions. For example, a proposed water withdrawal for irrigation would be considered unreasonable if it would interfere with private drinking wells of adjacent properties (Michigan Department of Environment, Great Lakes, and Energy, 2018).

Combined, the history of correlative rights and reasonable use in Michigan has created a legal and normative landscape that lends itself to an individualistic, rather than community-based, approach to water use and management. Concretely, the only duty that water users have towards one another is avoiding unreasonable interference with others' reasonable use (Lautenberger and Norris, 2016). Although caps on total withdrawals may heighten tensions between water users over resources made scarce through policy, this may not incentivize collaboration but rather entrench individualism.

Research Hypotheses

To understand why no WUCs have formed in Michigan, I use the Integrative Framework for Collaborative Governance (IFCG), created by Emerson et al. (2012) to operationalize the constructs of rights and norms, and explore how they may be preventing water users from collaborating. Emerson et al. identify four types of drivers that motivate resource users to initiate collaboration: uncertainty, interdependence, consequential incentives, and trust. Without the existence of all these motivational factors, it is unlikely that resource users will voluntarily collaborate to manage shared resources in Michigan.

This study poses four hypotheses, presented below:

Hypothesis 1 (uncertainty construct): Perceptions of water scarcity will significantly predict water users' likelihood of participating in a WUC. The more abundant they perceive resources, the less likely they are to join a WUC.

Resource users' degree of motivation to form collaborative governance institutions is related to their perceptions of resource abundance/scarcity (e.g., Bardhan, 1993; Araral, 2009; Blanco, Lopez, and Villamayor-Tomas, 2015; Uphoff et al., 1990). Users need to perceive resources as sufficiently scarce for them to believe that there is a problem that warrants being addressed collaboratively. I predict that the perception of water abundance is a norm in the water user community, and that it will remain so into the future. The scarcer water users perceive water to be, the more likely they are to express willingness to join a WUC.

Hypothesis 2 (interdependence construct): The degree to which water users treat water management as a collective, rather than an individual enterprise, will significantly predict their likelihood of participating in a WUC. The lower the degree of collectivity, the less likely they are to join a WUC.

Due to Michigan's history of correlative rights and reasonable use, I predict that water users are more likely to perceive water use as an independent, rather than interdependent, concern. Communication between resource users is one indicator that the usage of a resource is perceived to be interdependent (Osborne et al., 2019), where actors rely on one another for resolving common pool resource issues. I predict that (a) water users who report more communication with others about managing shared water resources, and (b) who report that water users *should* communicate more about water management, will have a greater likelihood of expressing willingness to join a WUC.

Hypothesis 3 (consequential incentives construct): Water users' beliefs about the positive or negative impacts that communicating with other users about water management may have will significantly predict their likelihood of joining a WUC. The more water users believe that conversations will have a positive impact on shared water resources, the more likely they will be to join a WUC.

I expect that water users do not perceive consequential incentives for collaborating. I expect the norm is that water users do not perceive benefits to be gained, or problems to be avoided, from communicating about water management and may even believe that attempts to collaborate will have negative impacts. For example, water users may believe that attempting to work together may introduce new conflicts that otherwise would not have occurred if they continued managing water separately. I predict that water users who believe that conversations will improve, and not harm, relationships will be more likely to report a greater willingness to join a WUC.

Hypothesis 4 (trust construct): The degree to which water users trust themselves, other water users, and the state to manage shared water resources responsibly will predict their likelihood of joining a WUC. The more highly water users trust themselves, other water users and the state, the more likely they are to express willingness to join a WUC.

Trust is critical for the success of collaborative governance institutions (Hickey et al., 2023). If water users are going to voluntarily form a WUC – and thereby sacrifice a degree of autonomy for the sake of the group – they will need to trust themselves, other water users, and the state to act as responsible water managers. I predict that water users who report higher levels of trust across these metrics will be more likely to report a greater willingness to join a WUC.

Methods

Sampling frame

I obtained contact information for Michigan large-quantity water users from two sources: the Michigan Department of Agriculture and Rural Development (MDARD), and the Michigan Department of Environment, Great Lakes, and Energy (EGLE). MDARD is the state agency responsible for food and agricultural sectors in Michigan, and provided contact information for agricultural producers that use irrigation, and those who raise livestock. EGLE is the state agency responsible for permitting and monitoring all other non-agricultural water users, and provided information for these users, which included: public water supply, power generation, industry, mining companies, fire protection, lake augmentation, water bottling, HVAC, snowmaking and more.

Data collection

To explore why Michigan water users have not formed WUCs, I designed a survey to test my hypotheses using the IFCG framework. The survey was sent to all registered large-quantity water users in Michigan (those that have the capacity to use at least 100,000 per day) (Michigan Department of Environment, Great Lakes, and Energy, 2024). The survey was developed in Qualtrics and sent electronically.

Invitations to participate in the survey were sent to 1,788 agricultural producers and 1,531 non-agricultural water users in the fall of 2022. An initial email was sent that explained the intent of the research and provided a link to the survey. This email was followed by three follow-up emails to maximize rates of participation. Survey respondents were offered the chance to win one of ten $100 gift cards as an incentive.

Survey Instrument

Considering that no WUCs have been formed, a proxy dependent variable was used to predict water users' *willingness to participate* in WUCs based on the hypothetical scenario described below:

Imagine that a water user in your watershed was denied a new withdrawal and approached you to join a WUC. How likely is it that you would agree to participate? (1, not at all likely – 5, extremely likely)

The independent variables featured in the survey test the four hypotheses described above. The measures used to test each hypothesis are presented in Table 2.

Table 2. Independent variables and response options used to test hypotheses.

Construct	Item	Response Options
Scarcity (H1)	How abundant or scarce do you think water resources are in your watershed?	1 (very abundant) – 5 (very scarce)
	How abundant or scarce do you think water resources are in Michigan in general?	1 (very abundant) – 5 (very scarce)
	To what extent do you believe that water resources in the future will become scarcer in your watershed?	1 (not at all) – 5 (extremely)
	To what extent do you believe that water resources in the future will become scarcer in Michigan in general?	1 (not at all) – 5 (extremely)
Interdependence (H2)	How often do you talk to other water users in your watershed about your water management?	1 (not at all) – 5 (very often)
	To what extent do you believe your ability to use water depends on how others use water?	1 (not at all) – 5 (a great deal)
	How much do you think that water users currently work together to make water management decisions?	1 (not at all) – 5 (a great deal)
	To what extent do you think water users *should* work together to make water management decisions with others in their watershed?	1 (not at all) – 5 (a lot)
	To what extent do you think water users *should* work together to make water management decisions with the state of Michigan?	1 (not at all) – 5 (a great deal)

Table 2 (cont'd)

Consequential Incentives (H3)	To what extent do you think having conversations with other water users in your watershed about water management could improve relationships with them?	1 (not at all) – 5 (a great deal)
	To what extent do you think having conversations with other water users in your watershed about water management could harm relationships with them?	1 (not at all) – 5 (a great deal)
Responsible Use (H4)	Do you believe that you use water responsibly?	1 (definitely not) – 5 (definitely yes)
	Do you believe that other water users in your watershed use water responsibly?	1 (definitely not) – 5 (definitely yes)
	Do you believe that water users in Michigan use water responsibly?	1 (definitely not) – 5 (definitely yes)
	To what extent do you trust the state of Michigan to manage water effectively?	1 (not at all) – 5 (extremely)

Data Analysis

I performed descriptive analyses to summarize findings and identify important patterns in the data. To test the impact of scarcity, interdependence, consequential incentives, and trust constructs on collaborative intention I ran a series of stepwise linear regressions made up of three models.

The first model included the following demographic controls: (1) whether the water user was an agricultural producer or non-agricultural water user (*water user type*), (2) whether the water user had been denied a proposed withdrawal or not (*permit denial*), and (3) whether a water user's proposed withdrawal required a site-specific review or not (*site-specific review*).

The second model included the controls that were not directly related to research questions, but which may have a moderating effect: (1) water users' degree of self-reported water policy knowledge (*policy knowledge*), (2) water user's familiarity with the water

withdrawal assessment tool (*WWAT familiarity*), (3) water user's trust in the water withdrawal assessment tool (*WWAT trust*), (4) and water user's knowledge of the state's definition of adverse resource impacts (*ARI knowledge*).

The third model consisted of the four constructs that were tested (i.e., scarcity, interdependence, consequential incentives, and trust).

After these stepwise linear regressions were performed for each construct, a final stepwise linear regression was performed. This regression maintained the first two control models described, while the third model included all the independent variables found to significantly predict water users' willingness to collaborate from the four independent construct models.

An important limitation of these regressions is the inability to control for the zone in which a water user resides. Contact information from MDARD and EGLE did not include the location where a water user operates, and a survey question asking whether water users know what zone they are in revealed that a very small percentage (8%) of respondents had this knowledge.

Results

Demographics

A total of 1024 large-quantity water users responded to the survey, accounting for 31% of all large-quantity water users in Michigan. Of these respondents, 520 (50.7%) were agricultural producers and 504 (49.3%) were non-agricultural producers. Table 3 shows the number and proportion of water user types who participated in this study. Additionally, Michigan's diverse agriculture was reflected in the sample, with survey respondents identifying 34 kinds of agricultural products that they grow (Table 4). It is important to note that respondents could select more than one kind of agricultural product.

Table 3. Number and Proportion of Water User Types in the Study.

Water User Type	N	% of Respondents
Irrigation for Agriculture	520	50.7
Irrigation for Non-Agriculture (e.g., golf courses)	189	18.4
Public Water Supply	84	8.2
Industry	71	6.9

Table 3 (cont'd)

Livestock Production	40	3.9
Fire Protection	32	3.1
Mining	19	1.9
Snowmaking	12	1.2
Dewatering	11	1.1
Heating, Air Conditioning, and Ventilation	10	1.0
* Other	36	3.6
Total	1024	100

** Eight other water user types each represented less than 1% of respondents*

Table 4. Types of crops produced by large-quantity water users in this study (respondents could choose multiple crops).

Crop Type	Number of Growers	Crop Type	Number of Growers
Apples	49	Hops	1
Asparagus	19	Horticulture	31
Beef	38	Maple syrup	3
Blueberries	47	Nursery and landscape	37
Cabbage	12	Onions	8
Carrots	10	Peaches	21
Celery	8	Pork	15
Cherries	28	Potatoes	50
Chestnuts	4	Poultry	5
Christmas trees	15	Pumpkins and squash	34
Corn	278	Snap beans	29
Cucumbers	22	Soybeans	231
Dairy	25	Sugar beets	18
Dry edible beans	32	Sweet corn	29
Eggs	4	Tomatoes	26

Table 4 (cont'd)

Grapes	13	Wheat	110
Honey	2	Wood	2

Descriptive statistics

Descriptive analysis of the dependent variable reveals that Michigan water users were only somewhat likely to express willingness to collaboratively govern shared water resources through a WUC (M = 2.36, SD = 0.95).

Several important findings emerge from the descriptive analyses of the independent variables that compose each of the four constructs underlying the hypotheses (Table 5).

In terms of *scarcity*, results show that water users perceive current water resources in their watershed (M = 2.04, SD = 0.84) and Michigan as abundant (M = 2.15, SD = 0.75) and expect water resources in their watershed (M = 2.25, SD = 1.01) and Michigan to remain abundant into the future (M = 2.40, SD = 0.99).

Regarding *interdependence*, water users rarely speak with others about water management (M = 2.06, SD = 0.96) and think that water users currently work together to manage shared resources only a little bit (M = 1.94, SD = 0.79). However, they also believe that their ability to use water depends on others a moderate amount (M = 2.88, SD = 1.18), and that water users should work with other water users (M = 3.08, SD = 1.02), and with the state (M = 2.93, SD = 1.11), a moderate amount to manage shared resources.

In terms of *consequential incentives*, water users think that having conversations about water management with other water users could improve relationships a moderate amount (M = 2.51, SD = 1.00), and that having these conversations will not harm relationships (M = 1.84, SD = 0.93).

Finally, regarding *trust*, water users believed that they themselves use water responsibly (M = 4,53, SD = 0.65), that others in their watershed (M = 3.80, SD = 0.77) and others in Michigan likely do so as well (M = 3.47, SD = 0.76), but that the state of Michigan probably does not (M = 2.42, SD = 1.00).

Table 5. Means and standard deviations for independent variables.

Construct	Item	Mean	SD
Scarcity (H1)	How abundant or scarce do you think water resources are in your watershed?	2.04	0.84
	How abundant or scarce do you think water resources are in Michigan in general?	2.15	0.75
	To what extent do you believe that water resources in the future will become scarcer in your watershed?	2.25	1.01
	To what extent do you believe that water resources in the future will become scarcer in Michigan in general?	2.40	0.99
Interdependence (H2)	How often do you talk to other water users in your watershed about your water management?	2.06	0.96
	To what extent do you believe your ability to use water depends on how others use water?	2.88	1.18
	How much do you think that water users currently work together to make water management decisions?	1.94	0.79
	To what extent do you think water users *should* work together to make water management decisions with others in their watershed?	3.08	1.02
	To what extent do you think water users *should* work together to make water management decisions with the state of Michigan?	2.93	1.11
Consequential Incentives (H3)	To what extent do you think having conversations with others about water management could improve relationships?	2.51	1.00
	To what extent do you think having conversations with others about water management could harm your relationships?	1.84	0.93

Table 5 (cont'd)

Trust (H4)	Do you believe that you use water responsibly?	4.53	0.65
	Do you believe that other water users in your watershed use water responsibly?	3.80	0.77
	Do you believe that water users in Michigan use water responsibly?	3.47	0.76
	To what extent do you trust the state of Michigan to manage water effectively?	2.42	1.00

Study Measures

H_1: Perceptions of water scarcity will significantly predict water users' likelihood of participating in a WUC.

The following four items comprising the *scarcity* measure were entered as predictors in a stepwise linear regression with *willingness to collaborate* as the DV: (1) water users' perceptions of current water availability in their watershed (*current watershed availability*), (2) current water availability in Michigan (*current Michigan availability*), (3) perceptions of the extent that water scarcity will increase in their watershed (*future watershed scarcity*), and (4) perceptions of the extent that water scarcity will increase in Michigan (*future Michigan scarcity*).

After controlling for all the demographic and moderating variables in Model 2, the only item shown to have a significant impact on a respondent's reported willingness to join a WUC was their perception of water scarcity in the state in the future ($\beta = .203$, $p = .015$). The scarcer water users believe resources will become in Michigan in the future, the more likely they are to express willingness to join a WUC. (Table 6).

Table 6. Linear Regression Results for Uncertainty Construct.

	A	B	C
Water user type	.107	.069	.063
	(-.077)	(-.090)	(-.092)
Permit denial	.071	.045*	.070
	(-.091)	(-.104)	(-.093)

Table 6 (cont'd)

Site-specific review	.267	.341	.346
	(.054)	(-.046)	(-.045)
Policy knowledge		.088	.123
		(.089)	(.079)
WWAT familiarity		.421	.300
		(.044)	(.056)
WWAT trust		.020*	.109
		(.116)	(.082)
ARI knowledge		.613	.666
		(.027)	(.023)
Current watershed availability			.072
			(-.123)
Current Michigan availability			.915
			(.007)
Future watershed scarcity			.900
			(-.011)
Future Michigan scarcity			.015*
			(.203)
R-squared	.024	.055	.087
Adjusted R-squared	.018	.040	.064

Standard errors are reported in parentheses

**, * indicates $p < .01$, and $p < .05$ respectively

H_2: The degree to which water users treat water management as a collective, rather than an individual enterprise, will significantly predict their likelihood of participating in a WUC.

The following five items comprising the *interdependence* measure were entered as predictors in a stepwise linear regression with *willingness to collaborate* as the DV: (1) the extent to which water users currently talk with other water users in their watershed about resource management (*talk with others*), (2) water users' perceptions about the extent to which

their ability to access and use water depends on how others use water (*water codependence*), (3) water users' perceptions about the extent to which they currently cooperate with others to manage water resources (*current cooperation*), (4) water users' perceptions about the extent to which they should cooperate with other water users to manage resources (*should cooperate (water users)*), and (5) water users' perceptions about the extent to which they should cooperate with the state to manage water resources (*should cooperate (with state)*).

After controlling for all the demographic and moderating variables in Model 2, two items are shown to have a significant impact on a respondent's willingness to join a WUC. I found that the extent to which water users currently talk with other water users in their watershed about resource management significantly predicts their willingness to participate in a WUC ($\beta = .143$, $p = .006$). The more water users currently talk with others, the more likely they are to be willing to join a WUC. Additionally, water users' perceptions about the extent to which they should cooperate with other water users to manage resources significantly predicts their willingness to join a WUC ($\beta = .246$, $p = .000$). The more water users think they should cooperatively manage water, the more likely they are to be willing to join a WUC (Table 7).

Table 7. Linear Regression Results for Interdependence Construct.

	A	B	C
Water user type	.088	.076	.077
	(-.082)	(-.088)	(-.086)
Permit denial	.047*	.041*	.234
	(-.101)	(-.107)	(-.060)
Site-specific review	.501	.563	.663
	(-.033)	(-.028)	(-.020)
Policy knowledge		.046*	.188
		(.104)	(.065)
WWAT familiarity		.368	.081
		(.049)	(.091)
WWAT trust		.059	.492
		(.095)	(.035)
ARI knowledge		.369	.500
		(.048)	(-.036)

Table 7 (cont'd)

Talk with others			.006**
			(.143)
Water codependence			.453
			(-.038)
Current cooperation			.185
			(.065)
Should cooperate (water users)			.001**
			(.246)
Should cooperate (with state)			.400
			(.054)
R-squared	.024	.061	.170
Adjusted R-squared	.018	.047	.147

Standard errors are reported in parentheses

**, * indicates $p < .01$, and $p < .05$ respectively

H_3: Water users' beliefs about the positive or negative impacts of communicating with other users about water management will significantly predict their likelihood of joining a WUC.

The following two items comprising the *consequential incentives* measure were entered as predictors in a stepwise linear regression with *willingness to collaborate* as the DV: (1) water users' perceptions of the extent to which they think that having conversations with other water users would improve relationships (*improve relationships*), and (2) water users' perceptions of the extent to which they think that having conversations with other water users would harm relationships (*harm relationships*).

After controlling for all the demographic and moderating variables in Model 2, the only item shown to have a significant impact on a respondent's reported willingness to join a WUC was their perceptions of the extent to which they think that having conversations with other water users would improve relationships ($\beta = .368, p = .001$). The more water users believe that having conversations would improve relationships, the more they were willing to join a WUC. (Table 8).

Table 8. Linear Regression Results for Consequential Incentives Construct.

	A	B	C
Water user type	.055	.039*	.024**
	(-.090)	(-.100)	(-.102)
Permit denial	.055	.035*	.171
	(-.095)	(-.107)	(-.065)
Site-specific review	.348	.398	.264
	(-.045)	(-.040)	(-.049)
Policy knowledge		.055	.084
		(.098)	(.082)
WWAT familiarity		.321	.218
		(.053)	(.061)
WWAT trust		.019**	.271
		(.115)	(.051)
ARI knowledge		.592	.648
		(.028)	(.022)
Improve relationships			.001**
			(.368)
Harm relationships			.433
			(.034)
R-squared	.026	.062	.196
Adjusted R-squared	.020	.048	.180

Standard errors are reported in parentheses

**, * indicates $p < .01$, and $p < .05$ respectively

H_4: The degree to which water users trust themselves, other water users, and the state to manage shared water resources responsibly will predict their likelihood of joining a WUC.

The following four items comprising the *responsible use* measure were entered as predictors into a stepwise linear regression with *willingness to collaborate* as the DV: (1) the extent to which water users believe that they personally use water responsibly (*personal* responsibility) (2) the extent to which water users believe that others in their watershed use water

responsibly (*others in watershed are responsible*), (3) the extent to which water users believe that Michigan water users use water responsibly (*others in Michigan are responsible*), and (4) the extent to which water users believe that the state manages water effectively (*state management*).

After controlling for all the demographic and moderating variables in Model 2, I found that none of the items comprising the struct construct significantly predict water users' willingness to join a WUC (Table 9).

Table 9. Linear Regression Results for Trust Construct.

	A	B	C
Water user type	.158	.125	.132
	(-.067)	(-.075)	(-.078)
Permit denial	.058	.045*	.037*
	(-.094)	(-.103)	(-.108)
Site-specific review	.225	.316	.405
	(-.059)	(-.048)	(-.041)
Policy knowledge		.051	.056
		(.100)	(.099)
WWAT familiarity		.296	.291
		(.056)	(.057)
WWAT trust		.052	.168
		(.097)	(.077)
ARI knowledge		.602	.688
		(.028)	(.021)
Personal responsibility			.429
			(-.041)
Others in watershed are responsible			.650
			(.029)
Others in Michigan are responsible			.329
			(.058)

Table 9 (cont'd)

State management			.274
			(.060)
R-squared	.024	.057	.065
Adjusted R-squared	.018	.042	.042

Standard errors are reported in parentheses

**, * indicates $p < .01$, and $p < .05$ respectively

Regression testing IFCG constructs

To understand why Michigan water users have not collaborated through WUCs, I attempted to measure their (lack of) motivations in terms of the scarcity, interdependence, consequential incentives, and trust constructs outlined in the IFCG. The five IFCG items found to be significant predictors of water users' willingness to join a WUC through the four construct regressions were entered as predictors into a stepwise linear regression with *willingness to collaborate* as the DV.

After controlling for all the demographic and moderating variables in Model 2, I found that all these variables remain significant predictors of water users' willingness to participate in a WUC (Table 10).

In terms of the scarcity construct, I found that water users' willingness to join a WUC was significantly impacted by their perceptions about the current degree of water availability in their watershed (β = -.116, p = .015). The scarcer they perceive water to be in their watershed, the less likely they were to express willingness to join a WUC. Additionally, water users' perceptions of the extent to which water scarcity is likely to increase in Michigan in the future significantly predicted their willingness to participate in a WUC (β = .107, p = .031). Water users who believed that water was likely to become scarcer in Michigan in the future were more likely to express willingness to join a WUC.

In terms of the interdependence construct, I found that the extent to which water users currently talk with others in their watershed about comanaging resources significantly impacts their willingness to join a WUC (β = .107, p = .035). The more respondents reported talking with other water users in their watershed about resource management, the more likely they were to

report a greater willingness to join a WUC. Moreover, the extent to which water users thought they should talk with others about collaborative water management significantly and positively correlated with their willingness to participate in a WUC (β = .111, p = .045).

In terms of the consequential incentives construct, I found that the extent to which water users believe that having conversations with others in their watershed about water management would improve relationships significantly impacts willingness to join a WUC (β = .254, p = .001). The greater the extent to which respondents thought that having these conversations would improve relationships, the more likely they were to express greater willingness to join a WUC.

None of the survey items I used to operationalize the trust construct proved significant predictors of water users' willingness to participate in a WUC.

Table 10. Linear Regression Results for Testing IFCG Constructs.

	A	B	C
Water user type	.146	.101	.143
	(-.069)	(-.081)	(-.069)
Permit denial	.055	.040*	.276
	(-.096)	(-.106)	(-.052)
Site-specific review	.241	.325	.266
	(-.057)	(-.048)	(-.050)
Policy knowledge		.101	.272
		(.085)	(.053)
WWAT familiarity		.356	.179
		(.050)	(.069)
WWAT trust		.028*	.377
		(.110)	(.043)
ARI knowledge		.580	.760
		(.030)	(-.016)
Current watershed availability			.015*
			(-.116)
Future Michigan scarcity			.031*
			(.107)

Table 10 (cont'd)

Talk with others			.035*
			(.107)
Should cooperate (water users)			.045*
			(.111)
Improve relationships			.001**
			(.254)
R-squared	.024	.055	.209
Adjusted R-squared	.018	.040	.187

Standard errors are reported in parentheses

**, * indicates $p < .01$, and $p < .05$ respectively

Discussion

This research investigates why Michigan water users have not formed collaborative watershed governance groups despite their ability to do so since 2008. I hypothesized that rights and norms in Michigan's water user community are preventing the adoption of collaborative institutions, and I test this hypothesis by operationalizing the constructs of rights and norms using the categories of motivational factors found in the Integrative Framework for Collaborative Governance. Since Michigan water law allows, but does not require, water users to collaboratively govern shared watershed resources, it is important to understand their motivations – or lack thereof – for collaborating. Below I discuss the results of the four hypotheses.

Hypothesis 1: Perceptions of water scarcity will significantly predict water users' likelihood of participating in a WUC.

Michigan has historically been a water-rich state, where members of the water user community could expect resources to remain plentiful and available for use. However, as pressures on water resources have increased, the risk of scarcity – both locally and across the state in general – continues to increase. Research shows that willingness to participate in

collaboration falls on a bell-curve, with willingness being the lowest on either end (too scarce or too abundant), and highest between these end points.

Our findings indicate that Michigan water users perceive resources as abundant, and therefore do not believe that scarcity is a salient risk. Water users' perceptions that water is currently abundant in their watershed and in Michigan, and their expectation that resources will remain abundant into the future, may be a norm so strongly ingrained in Michigan's water user community that the treat of scarcity appears quite unlikely. The lack of perceived abundance is likely a major factor explaining why water users do not believe that voluntary collaboration is necessary, hence the lack of WUCs in the state.

More generally, findings support the idea that voluntary collaboration is unlikely to occur if resources are perceived as too abundant to warrant forming collaborative groups to resolve a problem not perceived to exist. In cases where resources are perceived as abundant and collaboration remains voluntary, it is likely that strong incentives need to be in place to overcome the lack of urgency created by perceptions of abundance. Alternatively, if water is perceived to be abundant it may be the case that policies should mandate collaboration, rather than relying on the voluntary actions of resource users, if collaboration is going to occur at all.
Hypothesis 2: The degree to which water users treat water management as a collective enterprise will significantly predict their likelihood of participating in a WUC.

Given the body of riparian law that developed in Michigan based on historic conditions of water resource abundance, water rights entailed very little obligation on the part of users to co-manage resources. The only substantive obligation water users must observe is avoiding unreasonable interference with other water users' reasonable use. For this reason, I expected that water users who participate in more pro-collaborative behaviors are more likely to report willingness to participate in a WUC. Indeed, I found that water users who spoke to others about water management, who thought that there was currently a high degree of cooperation among water users, and who thought water users *should* cooperate, were more likely to be willing to collaborate.

This link between pro-collaborative behaviors and attitudes and willingness to participate in WUCs may represent a leverage point for encouraging the adoption of WUCs. Facilitating conversations among water users about shared resources, without explicitly asking water users to form WUCs, could provide researchers and the state with a starting point for building dialogue

between resource users. Strengthening conversations about water resources in this way could reduce perceived barriers that may currently be associated with forming WUCs.

However, perceived interdependence and willingness to participate in a WUC were not significantly related. This lack of relationship may be due to different definitions of interdependence. From a social-ecological systems perspective, the very nature of surface and groundwater being a common pool resource implies that resource users are interconnected. However, from a rights perspective, water users are not necessarily interconnected because each individual water rights holder has a recognized ability to use a certain permitted amount. Even if water users may recognize their interconnectedness from a social-ecological systems perspective, the nature of water rights in Michigan protects their ability to use water in the case of interference from others.

The difference between definitions of interdependence – the social-ecological perspective and that of water rights in Michigan – becomes more complicated with the fact that the state has set caps on cumulative withdrawals in watersheds. Effectively this creates a new type of potential conflict between water users and state law and changes the rights of water users. No longer are the duties of water users limited to refraining from the unreasonable interference with other water users' reasonable use, but from avoiding adverse resource impacts by overdraft. Caps on cumulative withdrawals create a new, legal, form of interdependence between water users who are now responsible for collectively avoiding excess withdrawals. It remains an open question whether this institutional setup will incentivize the formation of WUCs.

Hypothesis 3: Water users' beliefs about communicating with other users about water management will significantly predict their likelihood of joining a WUC.

Communication is a fundamental component within collaborative governance institutions, essential for developing shared norms of reciprocity and trust among participants (Ulibarri and Scott, 2017). Moreover, improved communication is linked to more deliberative modes of interaction that are aimed at collective problem solving rather than actors exercising individual power through negotiation or bargaining (Newig et al., 2018). This was the case in my data, where water users who believed that increased communication with others about watershed management would improve relationships were more likely to report greater willingness to participate in a WUC.

The IFCG identifies the existence of consequential incentives as a key factor for motivating collaboration. Findings suggest that the potential for improving relationships between water users through communicating about shared resources management is one such incentive. This suggests another example where facilitating communication in water user communities may be a way to build relationships between water users that are key for successful collaboration. By placing the emphasis on finding mutually beneficial outcomes made possible through communication, it is possible that collaboration will appear more desirable to water users. If water users can recognize avenues for realizing individual and community benefits through dialogue and working together in an informal way, then water users may be more inclined to form collaborative groups.

Hypothesis 4: The degree to which water users trust themselves, other water users, and the state to manage shared water resources responsibly will predict their likelihood of joining a WUC.

I expected that for water users to voluntarily collaborate trust between potential WUC members, and between water users and the state would be required. Here, I operationalize the construct of trust as water users' perceptions that potential WUC participants manage water responsibly. More specifically, I measured the extent to which water users trust themselves, other water users, and the state to manage water responsibly.

Collaborators need to trust each other to create shared values and goals, and foster legitimacy in collective decision-making (Bianchi et al., 2021). In this context, where water users may be voluntarily transitioning from individual to collective decision-making, it is important that they trust relevant actors to manage water resources responsibly (Muff et al., 2020). Without this trust, it is unlikely that individuals will be willing to sacrifice their power of individual decision-making to collaborate with others who are believed to be irresponsible water users.

However, I found that willingness to participate in a WUC was not predicted by the perceived responsibility of personal water management, the water management of other water users, nor water management by the state. It may be the case that my operationalization of the construct of trust was not appropriate for the context of this study. This is discussed in further detail below.

Research Limitations

The most important limitation of this study was the fact that I substituted trust for the leadership construct in the IFCG. I made the choice to do this because no WUCs have been

formed, and therefore there are no official 'leaders' or examples of leadership that could be tapped into. However, I could have tried to operationalize the construct of leadership even in the absence of WUCs.

After making the decision to substitute leadership with trust, I then operationalized trust as 'trust in responsible management.' I expect that trust is key if Michigan water users are going to voluntarily transition from independent to collaborative water use, making it important for researchers to properly measure this construct. Trust is a multifaceted concept (Sohns et al., 2021), and it may be that frames other than the one I selected are perceived as more important to Michigan water users. For instance, Hamm et al. (2016) describe six distinct, through interrelated, ways of defining trust: dispositional trust, care, competence, confidence, procedural fairness, and salient values similarity. It may be the case that other trust frames beyond the one used in this research are more relevant predictors of water users' willingness to participate in WUCs.

Future research on the role of trust as a predictor of willingness to participate in WUCs could explore a more comprehensive set of trust frames to identify what is most salient for water users. Moreover, future research could seek to operationalize the construct of leadership and test whether it is a significant predictor of water users' willingness to participate in WUCs.

Conclusion

This paper investigated why Michigan water users have not formed collaborative watershed governance groups despite having the ability to do so since 2008. I predicted that certain rights and norms which exist in the water user community are preventing transitions from individualistic to collaborative governance. I tested hypotheses using the concepts of uncertainty, interdependence, consequential incentives, and trust as outlined by the IFCG.

While theory predicts that as resource conditions transition from relatively abundant to relatively scarce and users become less certain about their ability to access and use resources that they will become more likely to collaborate. However, I found that Michigan water users do not report a greater willingness to collaborate even as some watersheds have begun to become water stressed according to the Water Withdrawal Assessment Too. It may be the case that water users in Michigan still perceive water resources – both locally and state-wide, now and into the future – as being abundant, and that there is little need to form voluntary collaborative groups to manage an abundant resource.

The right for water users to use resources in Michigan does not legally depend on working with other water users, in the sense that once an individual receives a registration, they can use their allotted amount almost completely independently of other water users or state regulatory oversight. Therefore, it is perhaps unsurprising that their perceived lack of interdependence is reflected in their unwillingness to participate in a WUC. However, I find that those water users who currently communicate with other water users about water management, and who believe that water users should work together to manage shared resources, are more likely to express willingness to collaborate.

Facilitating communication in water user communities about water management with the intent of building trusting relationships between water users and highlighting potential benefits that can arise from working together, can help set the stage for WUC adoption. Beginning with informal processes that encourage communication in a low stake setting, while helping water users to recognize mutually beneficial gains from doing so, will make WUCs appear less foreign and intimidating, and instead as a vehicle for cooperative, sustainable, and community-driven water management.

Additionally, I found that my operationalization of trust through the lens of responsible water use failed to predict willingness to participate in WUCs. Future research would benefit from exploring measures for trust in this context. Identifying what trust means to water users, as well as the form(s) of trust that need to exist to encourage WUC participation, will be important if Michigan water users are ever going to voluntarily collaborate. This is especially true for researchers and state actors interested in facilitating the formation of WUCs, because they will have clearer insight on how to build trust in water user communities.

This research shows that rights and norms are crucial for understanding the development – or lack thereof – of local collaborative governance institutions, and that my approach using the Integrative Framework for Collaborative Governance yielded valuable insights. In the context of WUCs in Michigan, I identified several leverage points that can be used to encourage collaboration, as well as barriers that need to be addressed if they are going to voluntarily collaborate. Perhaps the most significant barrier I found is strong perceptions of resource abundance. This problem is particularly wicked because in some places water is abundant in both an environmental and legal sense, in others it is abundant in an environmental sense but not legally, and in still others it is scarce in both senses. This situation echoes Ostrom's statement

that there are no panaceas for resolving common pool governance issues (Ostrom, 2007), and means that the process of developing WUCs will be different case by case.

This work can help guide policymakers, water users and other parties interested in promoting WUCs. Focusing on how rights and norms create or inhibit motivations to collaborate helps identify and leverage specific sources of willingness to collaborate and identify existing barriers. Whether institutions arise through self-initiated organization such as the 2012 Local Enhanced Management Areas in Kansas (e.g., Steiner et al., 2021; Perez-Quesada and Hendricks, 2021), state mandated collaboration such as the 2014 Sustainable Groundwater Management Act in California (e.g., Dobbin and Lubell, 2021; Lubell et al., 2020), or more unique scenarios like that of Michigan, understanding how rights and norms facilitate or inhibit transitions to collaboration is important for evaluating how institutions are structured and function, as well as how they can be improved.

Institutional Genesis: Structural Power and the Social-Ecological Systems Framework

Abstract

The collaborative governance of common pool resources has become widely accepted by researchers focused on collective action in social-ecological systems. Collaboration has proven an effective strategy for sustaining diverse common pool resources and the socioeconomic activities predicated upon them. Developing frameworks which accurately depict the causal relationships between institutions and the social, economic, political, and ecological systems within which they are embedded is crucial for theoretical understanding and the practical efficacy of governance. The Social-Ecological Systems Framework (SESF) created by Ostrom and subsequently expanded upon by others is of particular importance. The SESF provides the most comprehensive and flexible constellation of constructs connected by empirically verifiable relationships. A problem with the SESF, however, is the insufficient incorporation of power into the framework. While researchers have previously attempted to incorporate the notion of power into the SESF, this chapter proposes a new approach for doing so. This approach opens novel avenues for future research by emphasizing that how collaborative institutions originally form dictates the nature of power structures within them. This in turn affects policies and actions that emerge from it. Emerson and Nabatchi outline three processes by which institutions come into existence, and which differentially affect structural power: self-initiated, independently convened, and externally directed. I argue that the SESF can be improved by incorporating these modes of institutional genesis and the different power structures associated with them. Doing so entails new and exciting questions to be proposed and pursued by scientists working in the field of collaborative governance research.

Introduction

Collaborative Governance Frameworks: A Brief History

Conceptual frameworks play a key role in the social sciences. Frameworks identify essential elements of a system and arrange these variables into visible relationships that help researchers analyze phenomena from a similar theoretical perspective (McGinnis and Ostrom, 2014). The purpose of a framework, then, is to guide research by grounding inquiries in well-established theoretical constructs, thereby allowing multiple investigations to contribute towards a common understanding (Adom et al., 2018). Without the use of frameworks, there is a risk of researchers "speaking different languages" by conceiving of systems in distinct and perhaps incompatible ways; this makes it difficult for diverse projects focused on similar phenomena to contribute towards the creation of a more holistic theory and practical applications (Van der Waldt, 2020).

In common pool resource management, there has been an evolution in the frameworks used to conceptualize institutional arrangements for governing commons. In his seminal 1968 article *The Tragedy of the Commons,* Hardin presents readers with a hypothetical scenario where cattle ranchers grazed their herds in a commonly shared pasture range. He describes how each rancher is incentivized to increase their herd for private gain, but in doing so, they each contribute to the pasture's degradation. Eventually, by following the logic of individual profit maximization, the pasture will be overgrazed to the detriment of everyone involved. Hardin proceeds to argue that the only way these ranchers – and by extension, all resource users dependent on common pool resources – can avoid overconsumption or pollution is by ceding individual decision-making rights to the state, thereby ensuring that laws can be developed in recognition for the need of "mutual coercion mutually agreed upon" (Hardin, 1968).

Concretely, Hardin argued that the sustainability of the commons can only be achieved through top-down state regulation and resource privatization (Frischmann et al., 2019). This sort of governance, Hardin believes, is necessary for overcoming the incentives each user has for maximizing personal short-term profits to the detriment of shared resources. However, state-centric governance that relies on privatization has been found to harbor its own dilemmas, including, for example, rent-seeking behaviors, governmental corruption, and the creation of unaccounted externalities (e.g., Leitheiser et al., 2022; Papadimitropoulos, 2017).

Elinor Ostrom pioneered an alternative position for thinking about the governance of common pool resources by conceiving of institutional arrangements other than the narrow set of options emphasized by Hardin (Ostrom 1990; Ostrom, 1999; Ostrom 2010). While Hardin claimed that there is a need for privatization and strong state regulation to avoid a tragedy of the commons, Ostrom's research showed that when resource users themselves create and participate in "flexible, inclusive and locally governed institutions", it is possible to achieve environmentally sustainable socioeconomic practices (Forsyth and Johnson, 2014, 8). This idea has commonly come to be known as collaborative governance.

To develop her idea of collaborative governance, Ostrom challenged the notion of human rationality underpinning Hardin's view of the tragedy of the commons. Hardin's parable about herdsmen inevitably destroying their shared pastureland as a logical consequence of individuals exercising rational economic choice within the context of a common pool resource asserts that, ultimately, humans seek to maximize short-term personal gain to the detriment of (a) other people now and into the future, and (b) to themselves in the future (Oakes, 2016). In this frame, it is considered 'rational' for actors to behave this way because they believe that if they do not maximize their own resource appropriation in the short-term, others will, and they will suffer for it.

However, through theoretical and empirical work, Ostrom showed how communities of resource users have instituted systems for managing common pool resources that are "better than rational" as Hardin would understand it (Ostrom, 1998, 3). This is accomplished by operating according to a different mode of rationality where "reciprocity, reputation, and trust" have enabled them to "overcome the strong temptations of short-run self-interest" (Ostrom, 1998, 3). These findings helped to inspire the creation of the Social-Ecological Systems Framework (SESF). The SESF aimed to standardize the concepts and language researchers interested in common pool resources and social dilemmas use, both to guide context-specific work from a general starting point, as well as make these findings more generalizable and useful for developing collaborative governance theory (Ostrom, 2009).

This Chapter

The purpose of this chapter is threefold:

First, I present the SESF and highlight how it helped to advance collaborative governance theory. I also identify and discuss some of the main critiques that researchers have leveled against the framework.

Second, I introduce the concept of structural power to represent the political dynamics inherent to natural resource governance. Furthermore, I draw upon Emerson and Nabatchi's (2012) work describing how structural power is related to different processes by which institutions are formed – a process I refer to as institutional genesis.

Finally, I outline new avenues of research that become available through updating the SESF using the concept of structural power as a function of institutional genesis. Doing this, I hope to contribute towards a new chapter of collaborative governance research and practice.

The Social-Ecological Systems Framework

Advancing Social-Ecological Systems Governance Theory

The Social-Ecological Systems Framework (SESF) was developed to help researchers develop a shared language, set of concepts, and framework for designing social-ecological systems governance research and organizing their findings (Ostrom, 2009). Doing so helped to formalize and make more sophisticated the science of social-ecological systems governance. The SESF acts as a diagnostic tool for understanding the source(s) of social-ecological problems and possible solutions to these problems, while providing a common ground and language for researchers to make research generalizable (e.g., Ostrom and Cox, 2010; Schluter et al., 2019). The diagnostic nature of the SESF enables researchers to both specify in detail what makes a particular social-ecological problem (and potential solutions to the problem) distinct, while simultaneously enabling the generalization of findings from each case to larger theoretical implications for social-ecological systems governance (Basurto, Gelcich, and Ostrom, 2013).

The SESF is composed of two tiers of variables, where the first-tier variables (Figure 3) act as constructs that are further decomposed into second-tier dimensions that can be operationalized within research projects (Table 11). The first-tier variables are Resource systems, Resource units, Governance systems, Actors, and Action situations (McGinnis and Ostrom, 2014). The resource system refers to the type of common pool resource being governed (e.g., forests, pasturelands, freshwater, etc.) and is characterized by such metrics as its size and the clarity of the resource boundary. Resource units refers to the extractible and consumable parts of a resource system (e.g., a tree in a forest, an area of pastureland, the number of gallons of water).

Governance systems refer to the organizations and rules that structure how resource users interact with resources and with each other. Actors refers to individuals involved in governing and using resources and are characterized by measures such as number of relevant actors, their demographic makeup, and the types of relationships (e.g., cooperative, conflicting) that exist between actors. Lastly, Action Situations refer to the interactions between actors to jointly affect the outcomes of resource governance processes.

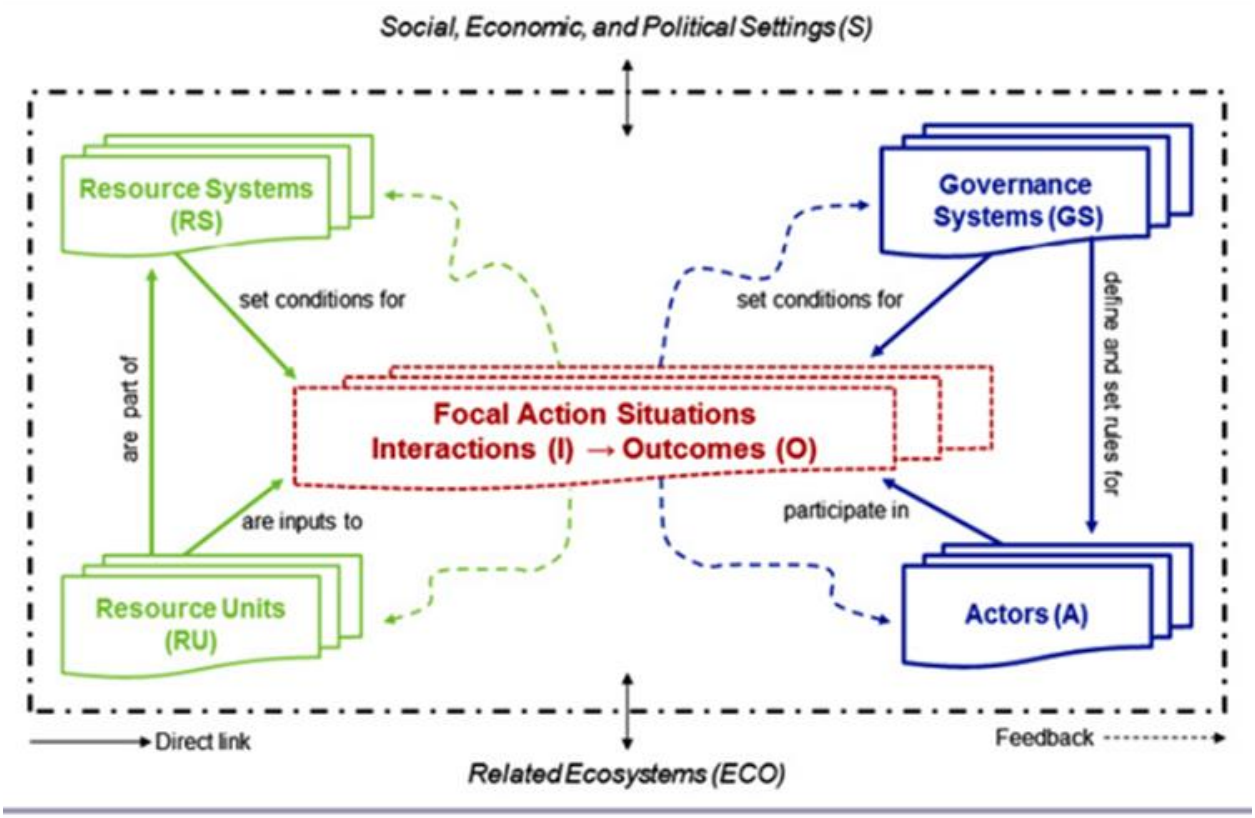

Figure 3: Social-Ecological Systems Framework (McGinnis and Ostrom, 2014).

Table 11. SESF first- and second-tier variables (McGinnis and Ostrom, 2014).

First-tier variables	Second-tier variables
Social, economic, and political settings (S)	Economic development
	Demographic trends
	Political stability
	Other governance systems
	Markets

Table 11 (cont'd)

	Media organizations
	Technology
Resource systems (RS)	Sector (e.g., water, forest, pasture)
	Clarity of system boundary
	Size of resource system
	Human-constructed facilities
	Productivity of system
	Equilibrium properties
	Predictability of system dynamics
	Storage characteristics
	Location
Governance systems (GS)	Government organizations
	Non-government organizations
	Network structure
	Property-rights system
	Operational-choice rules
	Collective-choice rules
	Constitutional-choice rules
	Monitoring and sanctioning rules
Resource units (RU)	Resource unit mobility
	Growth or replacement rate
	Interaction among resource units
	Economic value
	Number of units
	Distinctive characteristics
	Spatial and temporal distribution
Actors (A)	Number of relevant actors
	Socioeconomic attributes
	History or past experiences

Table 11 (cont'd)

	Location
	Leadership/entrepreneurship
	Norms(trust-reciprocity)/social capital
	Knowledge of SES/mental models
	Importance of resource (dependence)
	Technologies available
Action situations	Harvesting
	Information sharing
	Deliberation processes
	Conflicts
	Investment activities
	Lobbying activities
	Self-organizing activities
	Networking activities
	Monitoring activities
	Evaluative criteria
	Social performance measures
	Ecological performance measures
	Externalities to other SESs
Related ecosystems (ECO)	Climate patterns
	Pollution patterns
	Flows into and out of focal SES

The SESF has proven to be perhaps the most conceptually comprehensive framework in the social-ecological systems governance literature and is unique in that it treats social and ecological components as equally important for defining systems' structure and function (Johnson et al., 2019). The multitiered structure of the framework provides enough flexibility that it can be modified to fit different types of resources and social dilemmas while enabling the generalizability of findings to other situations (Partelow, 2018). By characterizing complex

social-ecological systems using first-tier variables that are arranged in a network of causal relationships, and which consist of multiple second-tier dimensions, the SESF acts as a boundary object that facilitates interdisciplinary knowledge co-creation between researchers from diverse disciplinary backgrounds (e.g., Guimaraes et al., 2018; Hertz and Schluter, 2015).

In practice, the SESF has been used to understand a diversity of social-ecological systems governance problems. These include fisheries (e.g., Blythe et al., 2017; Basurto, Gelcich, and Ostrom., 2013), forests (e.g., Schmitt-Harsh and Mincey, 2020; Xie et al., 2019; Guimaraes et al., 2018), food systems (Kopainsky et al., 2015), irrigation systems (Cox, 2014), lakes (Nagendra and Ostrom, 2014), soil carbon (Amin et al., 2020), freshwater (e.g., Baudoin and Arenas, 2020; Flynn and Davidson, 2016), national parks and biosphere reserves (e.g., Ferreria et al., 2019; Gurney et al., 2019), methanation projects (Arfaoui et al., 2022), cooperative approaches to rural electrification (Holstenkamp, 2019), and payments for ecosystem services (Bennett and Gosnell, 2015).

Critiques of the SESF

Despite the theoretical and empirical advancements achieved through the SESF, researchers have identified several limitations of the SESF. Nagel and Partelow (2022) reviewed 51 studies where researchers used the SESF and found that they were often unclear how to apply it in ways that made their results generalizable to other cases. Moreover, Fabinyni et al. (2015) notes that the SESF puts excessive emphasis on human adaptation to environmental change and less on environmental change due to human activities. Delgado-Serrano and Ramos (2015) describe how the SESF originally failed to acknowledge the fact that a diversity of actors may be involved in governing common pool resources beyond direct users, and that the SESF should reflect a broader array of actors who have direct influence on the social-ecological system in question (e.g., researchers, government officials, etc.) (Delgado-Serrano and Ramos, 2015).

Most important for this chapter, however, is the fact that the SESF inadequately represents the concept of power (Thiel, Adamseged, and Baake, 2015). Power plays a key role in shaping relationships between actors, which in turn affects resource management policies and outcomes (e.g., Calderon-Conteras and White, 2020; Clement, 2013). Natural resource management is not an apolitical matter, and it is important for the SESF – or any framework – to incorporate this concept (Rutting et al., 2022). Indeed, it is difficult to overstate the role that power plays in resource governance. Power determines who designs the structure of institutions

(Epstein et al., 2020), who determines how problems are framed (Ingalls and Stedman, 2016), and who can participate in decision-making within the institution (e.g., Mendez et al., 2019; Wiegleb and Bruns, 2018).

Structural Power and Institutional Genesis

Defining Structural Power

Power and institutions are closely related (e.g., Coy et al., 2021; Clement, 2010). Brisbois and de Loe (2016) identify three types of power at play in natural resource governance: instrumental, discursive, and structural. Instrumental power is perhaps the most readily observable aspect of power and refers to the measurable use of force or financial, technical, and social resources in competition with others. Discursive power deals with the ability of certain actors to shape social norms and values in their interest through dialogue and other forms of communication. Lastly, structural power refers to how the form of an institution privileges certain interests over others in terms of ability to frame issues, make and implement decisions, and more generally influence the purpose and actions of an institution.

I focus here on the integration of structural power into the SESF because this form of power partially determines how instrumental and discursive power are manifest within and by an institution. Structural power defines who has power to participate in governance in the first place and who does not, which in turn dictates who has *power over* others, who has the *power to* steer institutions toward specified goals, and who has *power within* an institution to mobilize resource to achieve desired outcomes (Partelow and Manlosa, 2023).

Integrating structural power within the SESF enables researchers to conceptually capture the dynamic landscape of empowerment/disempowerment within a social-ecological system, and thereby understand the organization and actions of an institution as a function of the empowered interests at its helm. Focusing on structural power in this way further allows researchers to analyze how power interacts with specific variables already featured in the SESF, and how power ultimately helps shape a social-ecological system.

To integrate structural power into the SESF, it is necessary to characterize types of structural power based on how institutions came into being – a process that I call institutional genesis. The way that power is structured within an institution depends on the circumstances that brought the institution about. The following section details three modes of institutional genesis, and the type of power structures likely to be associated with each.

How Institutional Genesis Shapes Structural Power

Emerson and Nabatchi (2015) describe three ways that collaborative governance institutions can develop in their book *Collaborative Governance Regimes.* These modes of institutional genesis include:

"… self-initiated, independently convened, or externally directed. In self-initiated [institutions], participants come together after being inspired and galvanized by a set of core stakeholders. In independently convened [institutions], an autonomous third party assembles participants and designs processes for interaction. In externally directed [institutions], outside entities with sufficient authority or resources incentivize or mandate participants to work together in a preset manner."

Self-initiated institutions are most like the cases originally described by Ostrom used to argue for local collaboration as a means of sustaining resources against Hardin's position of state-centric governance and privatization. In self-initiated collaborations, resource users begin organizing independently of state agencies, and therefore may be in a better position to articulate the purpose, scope, and logistical operations of an institution than if a collaboration was externally imposed. When resource users self-initiate collaborations, we might say they have the most "power" – relative to other genesis modes – in sense of being most able to structure the purpose of the institution.

Villamayor-Tomas and Garcia-Lopez (2018) conducted a meta-analysis of 81 community-based natural resource management regimes worldwide to understand how social movements contribute to the structure and mission of institutions. A key takeaway from their work is that that social movements often acted as catalysts for shifting power over resource decisions towards more local jurisdictions; these institutions were able to capture power to advocate a resource management position that emphasized benefits and protections to local interests.

Independently convened collaborative governance institutions do not easily fit into the top-down versus bottom-up dichotomy that is often invoked to describe how institutions form and are uncommon in the literature on collaborative governance (Douglas et al., 2020). Independently convened collaborative situations are defined by the fact that external actors – such as professional facilitators – design processes and platforms that help potential collaborators engage in conversations necessary for initiating collaborative institutions (Swette et al., 2023). In

cases of independently convened collaborative institutions, it is more difficult to generalize about how diverse actors' powers will be structured within an institution. Unlike the organizational structure that grows organically through self-initiation, or one thoughtfully crafted through policy, the outcomes of convention and facilitation processes require negotiating with diverse interests and building bridges between them.

Lastly, externally directed collaboration occurs when state authorities mandate that resource users work together to manage shared resources. In these cases, structural power is generated through law created by state authorities rather than from the bottom-up mobilization of resource users. While it is possible for laws mandating collaboration to be written in ways that are perceived as beneficial or fair to resource users, it is also possible that certain interests are privileged while others are minimized or excluded. An example of state-mandated collaboration is the 2014 Sustainable Groundwater Management Act (SGMA) in California, which was established by the state legislature to stabilize groundwater in over drafted basins by compelling water users to collaboratively create sustainable groundwater management plans (Espinoza el al., 2023). As explained below, the intent of SGMA is to maintain the agricultural sector as a strong presence in global markets while altering practices to extend the life of groundwater resources; the structure of this policy ultimately privileges large water users in the sense that the purpose of collaboration is to use water in ways that support agricultural interests.

Characterizing types of structural power that are associated with each mode of institutional genesis is key for incorporating these concepts into the SESF. Specifically, the mode of institutional genesis at least partially determines (1) who can participate in resource governance, (2) who has power over others in making decisions, (3) who has the power to set agendas and steer the institution, and (4) who has power within the institution to mobilize resources to accomplish goals.

The following section considers how the SESF can be improved by incorporating the concept of structural power as a function of how institutions are formed. Specifically, I consider which Tier 1 and Tier 2 variables are likely to be impacted, and the nature of these impacts based on the mode of institutional genesis.

Incorporating Structural Power in the SESF

Outline of a New Research Agenda

Considering that the SESF is primarily a diagnostic tool used to identify and help address problems in social-ecological systems (McKay et al., 2020), incorporating the concept of structural power as a function of institutional genesis, can help to explain the developmental process of institutional formation. This perspective can improve our understanding of why an institution is structured and functions in a particular way, what actors are enabled to participate in governance, the policies and actions enacted by the institution, and how the institution affects the larger social-ecological system within which it is embedded.

More specifically, applying the lens of structural power to the SESF reveals how institutional genesis directly affects, and is affected by, the *social* components of a given social-ecological system, which then indirectly affects the ecological components. Concretely, then, the SESF components affected by the incorporation of structural power are the following first-tier categories and their underlying second-tier variables: (1) Social, economic, and political settings; (2) Governance systems; (3) Actors; and (4) Action situations. The important challenge is understanding and elaborating how these features of the SESF are affected by the mode of institutional genesis. How does the way that collaboration begins – self-initiated, independently convened, or externally mandated – affect the social components of the SESF? It is precisely here that new avenues of research come into view.

Table 12 below displays a set of possible, though not exhaustive, research questions that emerge from integrating institutional genesis into the SESF. I present this set of questions because they touch on common questions well-established in the literature. The point I hope to make by discussing these illustrative cases through the lens of institutional genesis is that the SESF becomes a more useful diagnostic tool when we think about how power is structured in institutions. This lens can be applied to all of the tier-1 and tier-2 variables already found in the SESF and offers researchers a language for understanding the role of institutional power dynamics in shaping social-ecological systems.

Table 12. Research Questions Combining Institutional Genesis and the SESF.

First-Tier Construct	Second-Tier Variable	Research Questions
Social, economic, and political settings	Economic development	Do economic characteristics affect the mode of institutional genesis?
Governance systems	Monitoring and sanctioning rules	Does the mode of institutional genesis affect the kinds of monitoring and sanctioning rules enacted by institutions?
Actors	Number of relevant actors	Does the number of *types* (degree of heterogeneity) of actors predict the mode of institutional genesis?

Research Examples Integrating Institutional Genesis and SESF

Below I give examples of research that has been conducted on each of the research questions in Table 2. I highlight both externally directed and self-initiated cases for each question to show that the mode of institutional genesis affects how power is structured, and how these different power structures affect variables of interest in social-ecological systems. I do not here consider cases of independently convened collaborations because, as stated above, they are still rare in the literature (Douglas et al., 2020).

Do economic characteristics affect the mode of institutional genesis?

The 2014 Sustainable Groundwater Management Act (SGMA) in California represents a case of externally directed collaboration. The state passed legislation requiring water users to form groundwater sustainability agencies (GSAs) to manage resources with the goal of achieving sustainable yields (Miro and Famiglietti, 2018). The principal reason for enacting SGMA is the fact that groundwater throughout the state is being overdrawn, leading to aquifer declines that threaten the future of irrigation in California (Langridge and Van Schmidt, 2020). California's agricultural sector has been structured for participation in global markets – highlighting the tension between the desire for economic growth and long-term water sustainability (Veeck et al.,

2020). Bernacchi et al. (2020) find that the continued emphasis on economic growth has resulted in GSAs being structured so that agricultural producers hold more decision-making power than other stakeholders – such as disadvantaged communities (defined by the authors as <80% of the statewide annual median household income by census tract).

This case of state-mandated collaboration in California structures power in such a way that water users whose businesses are geared towards economic development and competition in global markets have more power that other stakeholders who may be interested in managing water towards other goals. SGMA represents an externally directed collaboration that exemplifies how this form of institutional genesis offers less power to resource users to structure institutions, as well as how state mandated collaboration weighs the interests of some stakeholders over others.

Michigan's Wester Upper Peninsula (UP) Food Systems Collaborative represents an opposite case, where collaborative processes were self-initiated, aim to serve local markets, and are structured to be more inclusive of stakeholders (Christensen, 2020). Collaborative local food systems in the Western UP have emerged not only to supply communities with local produce and encourage entrepreneurship but have emerged to fill economic gaps left over from post-industrial mining in the region (Lu and Carter, 2023). Moreover, unlike the SGMA policy in California that aims to support agriculture's continued participation in global markets, the purpose of Michigan's western UP food systems collaborative is to "create a supportive, interconnected, and equitable food system across the region through service and stewardship for the wellbeing of our earth, air, and water, and all living beings" (Western UP Food Systems Collaborative, 2022).

This case supports the argument that economic self-initiated collaboration may be more likely to occur in conditions where economies aim for supporting and enriching the local community rather than competing in larger/global markets. Unlike the SGMA's support for entrenched agricultural interests, the Western UP food systems collaborative reflects grassroots efforts to create a system that revitalizes communities as they reorient local economies.

Does the mode of institutional genesis affect the kinds of monitoring and sanctioning rules implemented by institutions?

In 2012, the Kansas legislature passed the Local Enhanced Management Areas (LEMA) Act in response to grassroots organization by agricultural producers to address rapidly declining aquifers (Cruse et al., 2016). Producers in Sheridan and Thomas Counties recognized the

imminent threat of water scarcity and elected to impose upon themselves a 20% reduction in collective withdrawals averaged over a 5-year period (Butler et al., 2023). The legislature put producers' plans into law, and the state's Division of Water Resources monitors and enforces this agreement (Sanderson and Frey, 2015). If a water user fails to follow policies created by the LEMA, the Chief Engineer can enforce any corrective measure approved by the LEMA (Kansas Department of Agriculture, 2018). Not only does the state enforce rules created by producers themselves, but the LEMA also represents a paradigm shift in how water is managed in the state. Kansas historically operated according to Prior Appropriation, based on the idea of "first in time, first in right" (Griggs, 2021). In practice, this means that when the total quantity of water allocated by the state through permits is not available, 'senior' rights holders – those who obtained rights first – can use the entirety of their allocations, while more 'junior' rights holders – those who obtained rights later in time – are unable to use all the water they technically have a right to. However, under the LEMA, all rights holders agreed to proportionally reduce water use regardless of the relative seniority of their water rights.

One of the 8 institutional design principles outlined by Ostrom (1990) is that rules for governing resources match local needs and conditions. Since producers in the LEMA were able to construct monitoring and sanctioning rules themselves by taking the initiative to collaborate, they were able to ensure that these rules fit their circumstances and intentions. An important metric for evaluating an institution is the extent to which it is perceived as being procedurally just. Alexander (2021) defines procedural justice as referring to decision-making processes, how these processes work, who is recognized as having a stake in governance, and who can participate. The LEMA may be viewed as procedurally just because producers have a strong ability to affect the rules that impact them.

In Michigan, the state's adoption and implementation of the 2008 Great Lakes-St. Lawrence River Basin Water Resources Compact (Compact) charges regulators to "protect, conserve, restore, improve and effectively manage" water resources by monitoring and restricting, where necessary, withdrawals to protect hydrologically based ecosystems (MCL 324.23401). The Compact caps cumulative withdrawals in designated water management areas (WMAs), where caps are based on water levels necessary to support characteristic fish populations (MCL 234.32701). Additionally, the state also allows large quantity water users (100,000 or more gallons per day) and local government officials to voluntarily collaborate to

govern resources to stay within the limits of caps (MCL 324.32725). Unlike the situation in Kansas, where water users' self-initiated efforts led to a self-imposed governance regime monitored and enforced by the state, Michigan water users have withdrawal restrictions imposed on them and can choose to collaborate or not. Perhaps because Michigan water users do not perceive immediate scarcity in the same way as Kansas producers, they are not motivated to voluntarily collaborate. It may be that the Michigan case goes against Ostrom's design principle that rules should match local needs and conditions because water users do not perceive water caps and voluntary collaboration as necessary.

Does the number of types of actors predict the mode of institutional genesis?

Continuing with Kansas and Michigan, these cases suggest that a lower diversity of actor types makes self-initiated collaboration more likely to occur than in situations of higher actor diversity. Agricultural producers in Kansas were able to form the LEMA through grassroots efforts partly because all participants are the same type of user – agricultural producers – and therefore share similar backgrounds, interests, and desired outcomes from collaboration (Feltman et al., under review). Producers were strongly motivated to extend the life of the High Plains aquifer because irrigation is key for crop yields and the long-term viability of farming in the region. They saw collaboration as a means of achieving this goal together, while simultaneously avoiding top-down rules imposed by the state.

The situation is different in Michigan. While agricultural producers comprise a large proportion of water users, the state's implementation of the Compact is more inclusive by explicitly including all large-quantity water users and government officials (who, ostensibly, represent the interests of the public who care about water but are not large-quantity water users – such as people who care about the health of hydrologically based ecosystems). While water users have been able to form WUCs since 2008, to date, none have formed. It is likely that other factors – such as relative water abundance – confound the simple statement that a higher diversity of actor types in Michigan has prevented collaboration, but it is also likely that this actor diversity represents an important obstacle to be overcome if collaboration is to occur.

Conclusion

The role of structural power has critical and wide-ranging impacts on how institutions are structured and function, who can participate and who is excluded, what types of policies and practices emerge from institutions, and how institutions impact the broader social-ecological

systems within which they are embedded. One key factor for determining the specific nature of structural power for any given institution is how the institution forms, a phenomenon identified by Emerson and Nabatchi, and which I have coined as institutional genesis.

Recognizing how structural power relates to institutional genesis, and integrating institutional genesis into the SESF enables researchers to ask new and valuable questions about the governance of social-ecological systems. Posing and exploring these questions can improve our understanding of how different conditions give rise to self-initiated, independently convened, or externally mandated collaborative institutions, and how each genesis mode may impact variables in the SESF. These new insights may ultimately increase researchers' and policymakers' ability to use the SES as a diagnostic tool for evaluating the conditions of a social-ecological system and the collaborative governance institution(s) in place to manage resources, identify potential problems to be addressed, and find solutions to issues parties desire to resolve.

Conclusion

Throughout this dissertation I have focused on local collaborative water governance as a structural fix for water quantity problems. However, this is only one way of thinking about how to address environmental issues. Cognitive and technological fixes also have important roles to play in sustainable resource governance. Researchers and policymakers will be able to gain a more holistic understanding of social-ecological systems and craft more effective policies if research agendas and policy discussions consider cognitive, technological, and structural fixes as interrelated lenses and tools that each offer unique points of leverage for engaging environmental problems.

Moreover, local collaborative institutions are often integrated into larger political structures – counties, states, nations, etc. While it is important to consider the conditions that foster the development of collaborative governance institutions and explore how this strategy can aid equitable and sustainable resource management, it is equally important to understand how these institutions can contribute to the success of higher-scale governance regimes. The future of natural resource sustainability will entail building thoughtful synergies between top-down and bottom-up governance efforts, as well as creating horizontal connections between actors/institutions to promote inter-agency cooperations.

Dissertation Key Takeaways

There are four main takeaways from this dissertation. First, it is essential to include more nuanced social factors for understanding resource users' motivations for collaborating, as well as for understanding how resource users evaluate the performance of collaborative efforts. Second, fairness and flexibility may be considered institutional design principles – the presence of which increases the likelihood that collaboration will occur and prove successful through time. Third, the perceived abundance or scarcity of a resource strongly predicts resource users' willingness to voluntarily collaborate. Finally, more strongly incorporating the construct of power into frameworks that depict the functioning of social-ecological systems offers researchers fruitful avenues of research – the pursuit of which may ultimately help resource users and policymakers better design and implement institutions to accomplish goals of environmental sustainability, social equity, and economic productivity.

Including social factors in efforts to understand resource users' motivations for collaborating, as well as how they measure the success of collaborations, brings to light the lived

experiences of individuals and communities involved in governance. While environmental factors are clearly important in situations centered on resource governance, the inclusion of social factors provides a richer picture by illuminating the role of resources in the lifestyles, traditions, and cultures of resource users.

Ostrom (1990) identified eight institutional design principles that were virtually always present in cases of successful local collaborative governance, and my research indicates that fairness and flexibility may be important design principles as well. This is especially true in cases of bottom-up collaborations where resource users voluntarily choose to comanage resources. If resource users are going to voluntarily collaborate, it is likely that perceptions that the rules are fair and provide enough flexibility for individuals to make decisions that make sense for their personal circumstances, will increase the likelihood that collaboration will occur and continue through time.

Previous research has found that the relative availability of a resource predicts resource users' willingness to collaborate. Resource users' willingness diminishes both when resources are perceived as too scarce (collaboration will not fix a problem that is too severe) or too abundant (there is no reason to collaborate because there is not a problem to be addressed). In the Kansas study I find that water users collaborated because they perceived water as being scarce enough to warrant changing how they govern resources, while in Michigan resources are perceived as abundant and so water users do not have the incentive to collaborate.

Finally, resource governance is a highly political matter where power strongly determines who has access to resources and the ends towards which governance regimes aim (e.g., sustainability, economic profitability, etc.). By thinking about power as related to the structure of institutions and recognizing that the process by which institutions come into being affects the structures of institutions, it is possible to better incorporate the construct of power into frameworks that depict social-ecological systems. The value of a framework rests on its ability to accurately portray a situation and its usefulness in guiding research and policy. One crucial way of increasing the value of frameworks – particularly the Social-Ecological Systems Framework – is by integrating the construct of power.

Actions taken to address environmental problems such as water scarcity, and efforts to intentionally adapt societies towards social, economic, and political processes that promote resource sustainability, are fraught with uncertainty and unintended consequences. Sustainability

is a wicked problem, and engaging with it promises only temporary and tentative solutions; ‘achieving’ sustainability is an ongoing process rather than an end that can be fully realized in any final or absolute sense. Finding ourselves in this precarious position, it is natural to seek out answers that can provide some surety. The goal of this dissertation was to examine the role of local collaborative governance as a theoretical foundation and pragmatic tool for addressing water scarcity issues. Understanding what motivates resource users to collaborate, how they measure the success of their collaborative efforts, and design elements of institutions that promote successful collaboration will help stakeholders, researchers, and policymakers better understand when local collaboration is appropriate, and how best to facilitate it.

REFERENCES

Adom, D., Hussein, E.K., Agyem, J.A. (2018). Theoretical and conceptual frameworks: mandatory ingredients of quality research. *International Journal of Scientific Research, 7*(1).

Alexander, I. (2021). Climate Justice. *Peace, Justice and Strong Institutions.* https://doi.org/10.1007/978-3-319-71066-2_2-1.

Alauddin, M., Quiggin, J. (2008). Agricultural intensification, irrigation and the environment in South Asia: Issues and policy options. *Ecological Economics, 65*, 111-124. http://doi.org/10.1016/j.ecolecon.2007.06.004.

Amin, N., Hossain, S., de Bruyn, L.L., Wilson, B. (2020). A systematic review of soil carbon management in Australia and the need for a social-ecological systems framework. *Science of the Total Environment, 719.* https://doi.org/10.1016/j.scitotenv.2019.135182.

An, B.Y. (2021). Bottom-up or top-down local service delivery? Assessing the impacts of special districts as community governance model. *The American Review of Public Administration, 51*(1). https://doi.org/10.1177/0275074020933968.

Anderies, J.M., Barreteau, O., Brady, U. (2019). Refining the robustness of social-ecological systems framework for comparative analysis of coastal system adaptation to global change. *Regional Environmental Change, 19.* https://doi.org/10.1007/s-10113-019-01529-0.

Annahar, N., Widianingish, I., Paskarina, C., Muhtar, E.A. (2023). A bibliometric review of inclusive governance concept. *Cogent Social Sciences, 9*(1). https://doi.org/10.1080/23311886.2023.2168839.

Ansell, C., Gash, A. (2008). Collaborative governance in theory and practice. *Journal of Public Administration Research and Theory, 18*(4). https://doi.org/10.1093/jopart/mum032.

Araral, E. (2009). What explains collective action in the commons? Theory and evidence from the Philippines. *World Development, 37*(3). https://doi.org/10.1016/j.worlddev.2008.08.002.

Arfaoui, N., le Bas, C., Vernier, M.F., Vo, L.C. (2022). How do governance arrangements matter in the circular economy? Lessons from five methanation projects based on the social ecological systems framework. *Ecological Economics, 197* https://doi.org/10.1016/ecolecon.2022.107414.

Ataei, P., Karimi, H., Eh'haghi, S.R. (2022). Socio-cognitive analysis of farmers' water conservation behavior: the case of Kavar Plain, Iran. *Science Progress, 105*(4). https://doi.org/10.1177/00368504221128777.

Bardhan, P. (1993). Analytics of the institutions of informal cooperation in rural development.

World Development, 21(4). https://doi.org/10.1016/0305-750X(93)90115-P.

Basurto, X., Gelcich, S., Ostrom, E. (2013). The social-ecological system framework as a knowledge classificatory system for benthic small-scale fisheries. *Global Environmental Change, 23*(6). https://doi.org/10.1016/j.gloenvcha.2013.08.001.

Baudoin, L., Arenas, D. (2020). From raindrops to a common stream: using the social-ecological systems framework for research on sustainable water management. *Organization & Environment, 33*(1). https://doi.org/10.1177/1086026618794376.

Bennett, D.E., Gosnell, H. (2015). Integrating multiple perspectives on payments for ecosystem services through a social-ecological systems framework. *Ecological Economics, 116* https://doi.org/10.1016/j.ecolecon.2015.04.019.

Bernacchi, L.A., Fernandez-Bou, A.S., Viers, J.H., Valero-Fandino, J., Medellin-Azuara, J. (2020). A glass half empty: limited voices, limited groundwater security for California. *Science of the Total Environment, 738*. https://doi.org/10.1016/j.scitotenv.2020.139529.

Bianchi, C., Nasi, G., Rivenbark, W.C. (2021). Implementing collaborative governance: models, experiences, and challenges. *Public Management Review, 23*(11) https://doi.org/10.1080/14719037.2021.1878777.

Blanco, E., Lopez, M.C., Villamayor-Tomas, S. (2015). Exogenous degradation in the commons: field experimental evidence. *Ecological Economics, 120* https://doi.org/10.1016/j.ecolecon.2015.03.028.

Blythe, J., Cohen, P., Eriksson, H., Cinner, J., Boso, D., Schwarz, A.M., Andrew, N. (2017). Strengthening post-hoc analysis of community-based fisheries management through the social-ecological systems framework. *Marine Policy, 82.* https://doi.org/10.1016/j.marpol.2017.05.008.

Bossert, W.A. (1993). Overview of Kansas Groundwater Management Districts: their duties, authorities and expectations. *Water Organizations in a Changing West (Summer Conference, June 14-16).* https://scholar.law.colorade.edu/water-organizations-in-changing-west/4.

Brauer, D., Devlin, D., Wagner, K., Ballou, M., Hawkins, D., Lascano, R. (2017). Ogallala Aquifer Program: A Catalyst for Research and Education to Sustain the Ogallala Aquifer on the Southern High Plains (2003-2017). *Journal of Contemporary Water Research & Education, 162,* 4-17. http://doi.org/10.1111/j.1936-704X.2017.03256.x.

Brisbois, M.C., de Loe, R.C. (2016). State roles and motivations in collaborative approaches to water governance: a power theory-based approach. *Geoforum, 74.* https://doi.org/10.1016/j.geoforum.2016.06.012.

Buchanan, R.C., Wilson, B.B., Butler, J.J. (2023). The High Plains Aquifer. *Kansas Geological*

Survey. https://kgs.ku.edu/high-plains-aquifer.

Butler, J.J., Johnson, C.K. (2024). Groundwater depletion: a global challenge for intergenerational equity. *Interpretation: A Journal of Bible and Theology, 78*(1). https://doi.org/10.1177/00209643231201998.

Butler, J.J., Whittenmore, D.O., Wilson, B.B., Bohling, G.C. (2023). Are we making a difference? Data-driven approaches for assessing the effectiveness of groundwater conservation activities in the High Plains aquifer. *American Geophysical Union (Fall Conference, December 11).*

Calderon-Contreras, R., White, C.S. (2020). Access as the means for understanding social ecological resilience: bridging analytic frameworks. *Society & Natural Resources, 33*(2). https://doi.org/10.1080/08941920.2019.1597233.

Carlisle, K., Gruby, R.L. (2019). Polycentric systems of governance: a theoretical model for the commons. *Policy Studies Journal, 47*(4). https://doi.org/10.1111/psj.12212.

Chaffin, B.C., Gosnell, H., Cosens, B.A. (2014). A decade of adaptive governance scholarship: synthesis and future directions. *Ecology and Society, 19*(3). https://www.jstor.org/stable/26269646.

Chappell, B. (2023). A source of carbon – a building block of life – in found on Jupiter's moon Europa. *National Public Radio.* https://www.npr.org/2023/09/22/1201071390/carbon-jupiter-moon-europa#:~:text=NASA%2FJPL%2DCaltech-,New%20analysis%20has%20found%20a%20source%20of%20carbon%20within%20Europa,spacecraft%20in%20the%20late%201990s.

Christensen, K. (2020). Fresh, local, dependable: nurturing UP food systems. *Michigan Tech News.* https://www.mtu.edu/news/2020/05/fresh-local-dependable-nurturing-up-food-systems.html.

Clement, F. (2010). Analyzing decentralized natural resource governance: proposition for a "politicized" institutional analysis and development framework. *Policy Sciences, 43.* https://doi.org/10.1007/s11077-009-9100-8.

Clement, F. (2013). For critical social-ecological systems studies: integrating power and discourses to move beyond the right institutional fit. *Environmental Conservation, 40*(1). https://doi.org/10.1017/S0376892912000276.

Cotterman, K.A., Kendall, A. D., Basso, B., Hyndman, D.W. (2018). Groundwater depletion and climate change: future prospects of crop production in the Central High Plains Aquifer. Climate Change, 146, 187-200. http://dx.doi.org/10.1007/s10584-017-1947-7.

Cox, M. (2014). Applying a social-ecological system framework to the study of the Taos Valley irrigation system. *Human Ecology, 42.* https://doi.org/10.1007/s10745-014-9651-y.

Coy, D., Malekpour, S., Saeri, A.K., Dargaville, R. (2021). Rethinking community empowerment in the energy transformation: a critical review of definitions, drivers, and outcomes. *Energy Research & Social Science, 72.* https://doi.org/10.1016/j.erss.2020.101871.

Cruse, R.M., Devlin, D.L., Parker, D., Waskom, R.M. (2016). Irrigation aquifer depletion: the Nexus linchpin. *Journal of Environmental Studies and Sciences, 6*(1). https://doi.org/10.1007/s13412-016-0369-6.

Dade, M.C., Bennett, E.M., Robinson, B.E. (2022). Property rights play a pivotal role in the distribution of ecosystem services among beneficiaries. *Ecosystems and People, 18*(1). https://doi.org/10.1080/26395916.2022.2037715.

Deines, J.M., Kendall, A.D., Crowley, M., Rapp, J., Cardille, J., Hyndman, D.W. (2019). Mapping three decades of annual irrigation across the US High Plains Aquifer using Landsat and Google Earth Engine. Remote Sensing and Environment.

Deines, J.,Kendall, A.D., Butler, J.J., Basso, B., Hyndman, D.W. (2021). Combining remote sensing and crop models to assess the sustainability of stakeholder-driven groundwater management in the High Plains Aquifer. *Water Resources Research, 57*(3). https://doi.org/10.1029/2020WR027756.

Delgado-Serrano, M.M., Ramos, P.A. (2015). Making Ostrom's framework applicable to characterize social ecological systems at the local level. *International Journal of the Commons, 9*(2). https://www.jstor.org/stable/26522849.

Dobbin, K.B., Lubell, M. (2021). Collaborative governance and environmental justice: disadvantaged community representation in California Sustainable Groundwater Management. *Policy Studies Journal, 49*(2). https://doi.org/10.1111/psj.12375.

Douglas, S., Ansell, C., Parker, C.F., Sorensen, E., Hart, P.T., Torfing, J. (2020). Understanding collaboration: introducing the collaborative governance data bank. *Society and Policy, 39*(4). https://doi.org/10.1080/14494035.2020.1794425.

Eaton, W.M., Brasier, K.J., Whitley, H., Bausch, J.C., Hinrichs, C.C., Quimby, B., Burbach, M.E., Wutich, A., Delozier, J., Whitmer, W., Kennedy, S., Weigle, J., Williams, C. (2022). Farmer perspectives on collaboration: evidence from agricultural landscapes in Arizona, Nebraska, and Pennsylvania. *Journal of Rural Studies, 94.* https://doi.org/10.1016/j.jrurstud.2022.05.008.

Eckerberg, K., Bjarstig, T., Zachrisson, A. (2015). Incentives for collaborative governance: top down and bottom-up initiatives in the Swedish mountain region. *Mountain Research and Development, 35*(3). https://doi.org/10.1659/MDR-JOURNAL-D-14-00068.1.

Elliott, J., Deryng, D., Muller, C., Frieler, K., Konzmann, M., Gerten, D., Glotter, M., Florke,

M., Wada, Y., Best, N., Eisner, S., Fekete, B.M., Folberth, C., Foster, I., Gosling, S.N., Haddeland, I., Khabarov, N., Ludwig, F., Masaki, Y., Olin, S., Rosenzweig, C., Ruane, A.C., Satoh, Y., Schmid, E., Stacke, T., Tang, Q., Wisser, D. (2014). *Proceedings of the National Academy of Sciences of the United States of America, 111*(9), 3239-3244.

Emerson, K., Nabatchi, T., Balogh, S. (2012). An integrative framework for collaborative governance. *Journal of Public Administration Research and Theory, 22*(1). https://doi.org/10.1093/jopart/mur011.

Emerson, K., Nabatchi, T. (2015). *Collaborative Governance Regimes.* Washington, D.C.: Georgetown University Press.

Epstein, G., Morrison, T.H., Lien, A., Gurney, G.G., Cole, D.H., Delaroche, M., Villamayor Tomas, S., Ban, N., Cox, M. (2020). Advances in understanding the evolution of institutions in complex social-ecological systems. *Current Opinions in Environmental Sustainability, 44.* https://doi.org/10.1016/j.cosust.2020.06.002.

Espinoza, V., Bernacchi, L.A., Eriksson, M., Schiller, A., Hayden, A., Viers, J.H. (2023). From fallow ground to common ground: perspectives on future land uses in the San Joaquin valley under sustainable groundwater management. *Journal of Environmental Management, 333.* https://doi.org/10.1016/j.jenvman.2023.117226.

Feltman, B., Zwickle, A., Kendall, A.D., Hyndman, D.W. Butler, J.J. Mapping motivations and measuring success: implementing the institutional analysis and development framework for the collaborative governance of groundwater. *Society & Natural Resources: submitted.*

Ferreria, A., Zimmerman, H., Santos, R., von Wehrdhen, H. (2019). A social-ecological systems framework as a tool for understanding the effectiveness of biosphere reserve management. *Sustainability, 10*(10). https://doi.org/10.3390/s10103608.

Fischer, A., Sanderson, M. (2022). Water, culture, and adaptation in the High Plains-Ogallala Aquifer region. *Journal of Rural Studies, 95.* https://doi.org/10.1016/j.rurstud.2022.08.004.

Flynn, C.D., Davidson, C.I. (2016). Adapting the social-ecological systems framework for urban stormwater management: the case of green infrastructure adoption. *Ecology and Society, 21*(4). https://www.jstor/org/stable/26270003.

Forsyth, T., Johnson, C. (2014). Elinor Ostrom's legacy: governing the commons and the rational choice controversy. *Development and Change, 45*(5). https://doi.org/10.1111/dech.12110.

Frischmann, B.M., Marciano, A., Ramello, G.B. (2019). Tragedy of the Commons after 50 years. *Journal of Economic Perspectives, 33*(4). https://doi.org/10.1257/jep.33.4.211.

Ghosh, A., Ghosh, A. (2023). Farmer Producer Organizations (FPOs): an emerging way of strengthening agricultural sector. *Indian Farmer, 10*(6).

Gilmore, S., Cosens, B., Griffith, D.L., Alessa, L., Kliskey, A. (2022). Adapting to socio environmental change: institutional analysis of the adaptive capacity of interacting formal and informal cooperative water governance. *Sustainability, 14*(16). https://doi.org/10.3390/su141610394.

Glose, T., Zipper, S., Hyndman, D.W., Kendall, A.D., Butler, J.J. (2022). Quantifying the impact of lagged hydrological responses on the effectiveness of groundwater Conservation. *Water Resources Research, 58*(7). https://doi.org/10.1029/2022WR032295.

Golden, B., Guerrero, B. (2017). The Economics of Local Enhanced Management Areas in Southwest Kansas. Journal of Contemporary Water Research & Education, 162, 100-111.

Griggs, B.W. (2021). Reaching consensus about conservation: High Plains lessons for California's Sustainable Groundwater Management Act. *University of the Pacific Law Review, 52*(3). https://scholarlycommons.pacific.edu/uoplawreview/vol52/iss3/7.

Guimaraes, M.H., Guiomar, N., Surova, D., Godinho, S., Correia, T.P., Sandberg, A., Ravera, F., Varanda, M. (2018). Structuring wicked problems in transdisciplinary research using the social-ecological systems framework: an application to the *montado* system, Alentejo, Portugal. *Journal of Cleaner Production, 191.* https://doi.org/10.1016/j.clepro.2018.04.200.

Gurney, G.G., Darling, E.S., Jupiter, S.D., Mangubhai, S., McClanahan, T.R., Lestari, P., Pardede, S., Campbell, S.J., Fox, M., Naisilisili, W., Muthiga, N.A., D'agata, S., Holmes, K.E., Rossi, N.A. (2019). Implementing a social-ecological systems framework for conservation monitoring: lessons from a multi-country coral reef program. *Biological Conservation, 240.* https://doi.org/10.1016/j.biocon.2019.109298.

Haacker, E.M.K., Kendall, A.D., Hyndman, D.W. (2015). Water Level Declines in the High Plains Aquifer: Predevelopment to Resource Senescence. Groundwater. http://dx.doi.org/10.1111/gwat.12350.

Hamm, J.A., Hoffman, L., Tomkins, A.J., Bornstein, B.H. (2016). On the influence of trust in predicting rural land owner cooperation with natural resource management institutions. *Journal of Trust Research, 6*(1). https://doi.org/10.1080/21515581.2015.1108202.

Hardin, G. (1968). The tragedy of the commons. *Science, 162*(3859), 1243-1248. http://dx.doi.org/10.1126/science.162.3859.1243.

Heberlein, T.A. (2012). *Navigating environmental attitudes.* Oxford University Press, USA.

Hertz, T., Schluter, M. (2015). The ses-framework as boundary object to address theory

orientation in social-ecological system research: the ses-theory approach. *Ecological Economics, 116.* https://doi.org/10.1016/j.ecolecon.2015.03.022.

Holstenkamp, L. (2019). What do we know about cooperative sustainable electrification in the global south? A synthesis of the literature and refined social-ecological systems framework. *Renewable and Sustainable Energy Reviews, 109.* https://doi.org/10.1016/j.rser.2019.04.047.

Hickey, G.M., Roozee, E., Voogd, R., de Vries, J.R., Sohns, A., Kim, D., Temby, O. (2023). On the architecture of collaboration in inter-organizational natural resource management networks. *Journal of Environmental Management, 328.* https://doi.org/10.1016/j.jenvman.2022.116994.

Huffman, J.L. (2009). Comprehensive river basin management: the limits of collaborative, stakeholder-based, water governance. *Natural Resources Journal, 49*(1) https://digitalrepository.unm.edu/nrj/vol49/iss1/4.

Ingalls, M.L., Stedman, R.C. (2016). The power problematic: exploring the uncertain terrains of political ecology and the resilience framework. *Ecology and Society, 21*(1). https://www.jstor.org/stable/26270347.

Jager, N.W., Newig, J., Challies, E., Kochskamper, E. (2020). Pathways to implementation: Evidence on how participation in environmental governance impacts on environmental outcomes. *Journal of Public Administration Research and Theory, 30*(3). https://doi.org/10.1093/jopart/muz034.

Jimenez, A., Saikia, P., Gine, R., Avello, P., Leten, J., Lymer, B.L., Schneider, K., Ward, R. (2020). Unpacking water governance: a framework for practitioners. *Water, 12*(3). https://doi.org/10.3390/w12030827.

Johnson, T.R., Beard, K., Brady, D.C., Byron, C.J., Cleaver, C., Duffy, K., Keeney, N., Kimble, M., Miller, M., Moeykens, S., Teisl, M., van Walsum, G.P., Yuan, J. (2019). A social-ecological system framework for marine aquaculture research. *Sustainability, 11*(9). https://doi.org/10.3390/su11092522.

Kansas Department of Agriculture. (2016). Sheridan 6 County LEMA. https://agricultre.ks.gov/divisions-programs/dwr/managing-kansas-water-resources/local-enhanced-management-areas/sheridan-county-6-lema.

Kansas Department of Agriculture. (2018a). Estimated Impact of Agriculture, Food, and Food Processing Sectors. https://agriculture.ks.gov/docs/default-source/ag-marketing/ag-contribution-2018-with-retail-ethanol-combined-update-final.pdf?sfvrsn=2ffa84c1_4.

Kansas Department of Agriculture. (2018b). Groundwater Management District Act. https://agriculture.ks.gov/docs/default-source/statues-water/gmd_act.pdf?sfvrsn=12.

Kansas Department of Agriculture. (2023). Sheridan 6 LEMA. https://agriculture.ks.gov/divisions-programs/dwr/managing-kansas-water-resources/local-enhanced-management-areas/sheridan-6-lema.

Kansas Department of Commerce. (2023). Agriculture. https://www.kansascommerce.gov/industry/agriculture/#:~:text=Kansas%20livestock%2producers%20are%20a,%2C%20bison%2C%20hogs%20and%20soybeans.

Kilic, Z. (2020). The importance of water and conscious use of water. *International Journal of Hydrology, 4*(5). https://doi.org/10.15406/ijh.2020.04.00250.

Koontz, T.M., Newig, J. (2014). From planning to implementation: top-down and bottom-up approaches for collaborative watershed management. *The Policy Studies Journal, 42*(3). https://doi.org/10.1111/psj.12067.

Kopainsky, B., Huber, R., Pedercini, M. (2015). Food provision and environmental goals in the Swiss agri-food system: system dynamics and the social-ecological systems framework. *Systems Research and Behavioral Science, 32*(4). https://doi.org/10.1002/sres.2334.

Langridge, R., Van Schmidt, N.D. (2020). Groundwater and drought resilience in the SGMA era. *Society & Natural Resources, 33*(12). https://doi.org/10.1080/08941920.2020.1801923.

Lautenberger, M.C., Norris, P.E. (2016). Private rights, public interest and water use conflicts: evolving water law and policy in Michigan. *Water Policy, 18.* https://doi.org/10.2166/wp.2016.037.

Leitheiser, S., Trell, E.M., Horlings, I., Franklin, A. (2022). Toward the commoning of governance. *Environment and Planning C: Politics and Space, 40*(3). https://doi.org/10.1177/23996544211033992. **CO**

Lu, H., Carter, A. (2023). Emergent regional collaborative governance in rural local food systems development. *Community Development,* 54(2). https://doi.org/10.1080/15575330.2022.2135550. **IO**

Lubell, M., Blomquist, W., Beutler, L. (2020). Sustainable groundwater management in California: a grand experiment in environmental governance. *Society & Natural Resources, 33*(12). https://doi.org/10.1080/08941920.2020.1833617.

McGinnis, M.D., Ostrom, E. (2014). Social-ecological system framework: initial changes and continuing challenges. *Ecology and Society, 19*(2). https://www.jstor.org/stable/26269580.

McKay, P.A., Olabisi, L.S., Vogt, C.A. (2020). Assessing improvements in socio-ecological

system governance using mixed methods and the quality governance framework and its diagnostic tool capacity. *Environment Systems and Decisions, 40.* https://doi.org/10.1007/s10669-019-09744-0.

Mekonnen, M.M., Gerbens-Leenes, W. (2020). The water footprint of global food production. *Water, 12*(10). https://doi.org/10.3390/w12102696.

Mendez, P.F., Amezaga, J.M., Santamaria, L. (2019). Explaining path-dependent rigidity traps: increasing returns, power, discourses, and entrepreneurship intertwined in social-ecological systems. *Ecology and Society, 24*(2). https://doi.org/10.5751/ES-10898-240230.

Michigan Department of Environment, Great Lakes, and Energy. (2018). Water law explanation. https://www.michigan.gov/-/media/Project/Websites/egle/Documents/Multi-Division/Water-Law-Explanation.pdf?rev=a79d8f67f04c48b69d002176f5489d65#:~:text=Underlying%20the%20reasonable%20use%20doctrine,to%20The%20Great%20Lakes%2DSt.

Michigan Department of Environment, Great Lakes, and Energy. (2024). Large quantity withdrawal registration. https://www.michigan.gov/egle/about/organization/water-resources/water-use/need-to-register-a-large-quantity-withdrawal#:~:text=Large%20quantity%20withdrawals%20are%20defined,gallons%20per%20day%20or%20more.

Miro, M.E., Famiglietti, J.S. (2018). A framework for quantifying sustainable yield under California's Sustainable Groundwater Management Act (SGMA). *Sustainable Water Resources Management, 5.* https://doi.org/10.1007/s40899-018-0283-z.

Mishra, B.K., Kumar, P., Saraswat, C., Chakraborty, S., Gautam, A. (2021). Water security in a changing environment: concepts, challenges and solutions. *Water, 13*(4). https://doi.org/10.3390/w13040490.

Muir, A.M., Bernhardt, J.R., Boucher, N.W., Cvitanovic, C., Dettmers, J.M., Gaden, M., Hinderer, J.L.M., Locke, B., Robinson, K.F., Siefkes, M.J., Young, N., Cooke, S.J. (2023). Confronting a post-pandemic new-normal – threats and opportunities to trust-based relationships in natural resource science and management. *Journal of Environmental Management, 330.* https://doi.org/10.1016/j.jenvman.2022.117140.

Muff, K., Liechti, A., Dyllick, T. (2020). How to apply responsible leadership theory in practice: a competency tool to collaborate on the sustainable development goals. *Corporate Social Responsibility and Environmental Management, 27*(5). https://doi.org/10.1002/csr.1962.

Nagel, B., Partelow, S. (2022). A methodological guide for applying the social-ecological system (SES) framework: a review of quantitative approaches. *Ecology and Society, 27*(4). https://doi.org/10.5751/ES-13493-270439.

Nagendra, H., Ostrom, E. (2014). Applying the social-ecological systems framework to the diagnosis of urban lake commons in Bangalore, India. *Ecology and Society, 19*(2). https://www.jstor.org/stable/26269569.

National Aeronautics and Space Administration. (2024). Why is water so important for life as we know it? https://astrobiology.nasa.gov/education/alp/water-so-important-for-life/.

Natural Resources and Environmental Protection Act. Mich. Comp. Laws § 324.32701.

Natural Resources and Environmental Protection Act. Mich. Comp. Laws § 324.32725.

Natural Resources and Environmental Protection Act. Mich. Comp. Laws § 324.34201.

Newig, J., Challies, E., Jager, N.W., Kochskaemper, E., Adzersen, A. (2018). The environmental performance of participatory and collaborative governance: a framework of causal mechanisms. *Policy Studies Journal, 46*(2). https://doi.org/10.1111/psj.12209.

Oakes, J. (2016). Garrett Hardin's tragic sense of life. *Endeavour, 40*(4). https://doi.org/10.1016/j.endeavour.2016.10.007.

O'Connor, C., Joffe, H. (2020). Intercoder reliability in qualitative research: debates and practical guidelines. *International Journal of Qualitative Methods, 19.* https://doi.org/10.1177/1609406919899220.

O'Neil, G. (2024). Map of C and D zones in Michigan generated from the Water Withdrawal Assessment Tool. *Personal communication.*

Oniki, S., Berhe, M., Negash, T. (2020). Role of social norms in natural resource management: the case of the Communal Land Distribution program in northern E000thiopia. *Land, 9*(2). https://doi.org/10.3390/land9020035.

Osborne, M., Sundstrom, E., Bodin, O. (2019). Ecological interdependencies and resource competition: the role of information and communication in promoting effective collaboration in complex management situations. *PloS ONE, 14*(12). https://doi.org/10.1371/journal.pone.0225903.

Ostrom, E. (1990). *Governing the Commons: The evolution of institutions for collective action.* Cambridge University Press: New York, NY.

Ostrom, E. (1998). A behavioral approach to the rational choice theory of collective action: presidential address, American Political Science Association, 1997. *American Political Science Review, 92*(1). https://doi.org/10.2307/2585925.

Ostrom, E. (1999). Polycentricity, Complexity, and the Commons. *The Good Society, 9*(2), 37-41. https://www.jstor.org/stable/20710947.

Ostrom, E. (2005). *Understanding Institutional Diversity*. Princeton, NJ: Princeton University Press.

Ostrom, E. (2007). A diagnostic approach for going beyond panaceas. *Proceedings of the National Academy of Sciences of the United States of America, 104*(39). https://doi.org/10.1073/pnas.0702288104.

Ostrom, E. (2009). A general framework for analyzing sustainability of social-ecological systems. *Science, 325*(5939). https://doi.org/10.1126/science.1172133.

Ostrom, E. (2010). Beyond Markets and States: Polycentric Governance of Complex Economic Systems. The American Economic Review, 100(3). https://www.jstor.org/stable/27871226.

Ostrom, E. (2010). Polycentric systems for coping with collective action and global environmental change. *Global Environmental Change, 20*(4), 550-557. http://dx.doi.org/10.1016/j.gloenvcha.2010.07.004.

Ostrom, E. (2011). Background on the Institutional Analysis and Development Framework. *Policy Studies Journal, 39*(1). https://doi.org/10.1111/j.1541-0072.2010.00394.x.

Ostrom, E., Cox, M. (2010). Moving beyond panaceas: a multi-tiered diagnostic approach for social-ecological analysis. *Environmental Conservation, 37*(4). https://doi.org/10.1017/S0376892910000834.

Paganelli, C.S. (2007). Creative judicial misunderstanding: misapplication of the public trust doctrine in Michigan. *Hastings Law Journal, 58*(5). https://repository.uchastings.edu/hastings_law_journal.

Partelow, S. (2018). A review of the social-ecological systems framework: applications, methods, modifications, and challenges. *Ecology and Society, 23*(4). https://doi.org/10.5751/ES-10594-230436.

Partelow, S., Manlosa, A.O. (2023). Commoning the governance: a review of literature and the integration of power. *Sustainability Science, 18.* https://doi.org/10.1007/s11625-022-01191-2.

Papadimitropoulos, V. (2017). The politics of the commons: reform or revolt? *Journal for a Global Sustainable Information Society, 15*(2).

Perez-Quesada, G., Hendricks, N.P. (2021). Lessons from local governance and collective action efforts to manage irrigation withdrawals in Kansas. *Agricultural Water Management, 247.* https://doi.org/10.1016/j.agwat.2021.106736.

Pfeiffer, L., Lin, C.Y.C. (2014). Does efficient irrigation technology lead to reduced

Groundwater extraction? Empirical evidence. Journal of Environmental Economics and Management, 67, 189-208. http://dx.doi.org/10.1016/j.jeem.2013.12.002.

Piazza, A. (2021). Collective responsibility in the cooperative governance of climate change. *Sustainability, 13*(8). https://doi.org/10.3390/su13084363.

Pohl-Wostl, C., (2019). The role of governance modes and meta-governance in the transition towards sustainable water governance. *Environmental Science & Policy, 91*. https://doi.org/10.1016/j.envsci.2018.10.008.

Rabiee, F. (2004). Focus-group interview and data analysis. *Proceedings of the Nutrition Society, 63*(4), 655-660.

Ran, B., Qi, H. (2019). The entangled twins: power and trust in collaborative governance. *Administration & Society, 51*(4). https://doi.org/10.1177/0095399718801000.

Reeves, H.W., Nicholas, J.R., Seelbach, P.W., Hamilton, D.A. (2010). Management of surface water and groundwater withdrawals to maintain environmental stream flows in Michigan. *American Society of Civil Engineers Watershed Management Conference 2010.* https://ascelibrary.org/doi/abs/10.1061/41143(394)37.

Rev (2023). Record & transcribe interviews with Rev's mobile app. https://www.rev.com/apps-and-tools/voice-recorder.

Richter, B.D., Brown, J.D., DiBenedetto, R., Gorsky, A., Keenan, E., Madray, C., Morris, M., Rowell, D., Ryu, S. (2017). Opportunities for saving and reallocating agricultural water to alleviate water scarcity. Water Policy, 19, 886-907. http://dx.doi.org/10.2166/wp.2017.143.

Roozee, E., Kim, D., Sohns, A., de Vries, J.R., Temby, O.F., Hickey, G.M. (2024). Managing inter-organizational trust and risk perceptions in transboundary fisheries governance networks. *Marine Policy, 159.* https://doi.org/10.1016/j.marpol.2023.105927.

Rosa, L., Chiarelli, D.D., Rulli, M.C., Dellangelo, J., D'Odorico, P. (2020). Global agricultural economic water scarcity. *Science Advances, 6*(18). https://doi.org/10.1126/sciadv.aaz6031.

Rutting, L., Vervoort, J., Mees, Driessen, P. (2022). Strengthening foresight for governance of social-ecological systems: an interdisciplinary perspective. *Futures, 141.* https://doi.org/10.1016/j.futures.2022.102988.

Salehi, M. (2022). Global water shortage and potable water safety; today's concern and tomorrow's crisis. *Environment International, 158.* https://doi.org/10.1016/j.envint.2021.106936.

United Nations. (2023). *The Sustainable Development Goals Report 2023: Special Edition.*

https://unstats.un.org/sdgs/report/2023/?_gl=1*5oqrez*_ga*Mzk4ODk3MjYzLjE3MDczMzY4ODc.*_ga_TK9BQL5X7Z*MTcwNzMzNjg4Ni4xLjEuMTcwNzMzODQ3Ny4wLjAuMA.

Sampson, G.S., Hendricks, N.P., Taylor, M.R. (2019). Land market valuation of groundwater. *Resources and Energy Economics, 58.* https://doi.org/10.1016/j.reseneeco.101120.

Sanderson, M.R., Frey, R.S. (2015). Structural impediments to sustainable groundwater Management in the High Plains Aquifer of western Kansas. Agriculture and Human Values, 32(3), 401-417. http://dx.doi.org/10.1007/s10460-014-9567-6.

Scanlon, B.R., Fakhreddine, S., Rateb, A., de Graaf, I., Famiglietti, J., Gleeson, T., Grafton, R.Q., Jobbagy, E., Kebede, S., Kolusu, R.S., Konikow, L.F., Long, D., Mekonnen, M., Schmied, H.M., Mukherjee, A., MacDonald, A., Reedy, R.C., Shamsudduha, M., Simmons, C.T., Sun, A., Taylor, R.G., Villholth, K.G., Vorosmarty, C.J., Zheng, C. (2023). Global water resources and the role of groundwater in a resilient future. *Nature Reviews Earth & Environment, 4.* https://doi.org/10.1038/s43017-022-00378-6.

Schluter, M., Haider, L.J., Lade, S.J., Lindkvist, E., Martin, R., Orach, K., Wijermans, N., Folke, C. (2019). Capturing emergent phenomena in social-ecological systems: an analytical framework. *Ecology and Society, 24*(3). https://www.jstor.org/stable/26796977.

Schmitt-Harsh, M., Mincey, S.K. (2020). Operationalizing the social-ecological systems framework to assess residential forest structure: a case study in Bloomington, Indiana. *Ecology and Society, 25*(2). https://doi.org/10.5751/ES-11564-250214.

Sikor, T., He, J., Lestrelin, G. (2017). Property rights regimes and natural resources: a conceptual analysis revisited. *World Development, 93.* https://doi.org/10.1016/j.worlddev.2016.12.032.

Smidt, S.J., Haacker, E.M.K., Kendall, A.D., Deines, J.M., Pei, L., Cotterman, K.A., Li, H., Xiao, L., Basso, B., Hyndman, D.W. (2016). Complex water management in modern agriculture: Trends in the water-energy-food nexus over the High Plains Aquifer. Science of the Total Environment, 5566-567, 98-1001. http://dx.doi.org/10.1016/j.scitotenv.2016.05.127.

Smidt, S.J., Kendall, A.D., Hyndman, D.W. (2019). Increased Dependence on Irrigated Crop Production across the CONUS, Water, 11, 1548. http://dx.doi.org/10.3390/w11071458.

Sohns, A., Hickey, G.M., de Vries, J.R., Temby, O. (2021). Methodological challenges in studying trust in natural resources management. *Land, 10*(12). https://doi.org/10.3390/land10121303.

Steiner, J.L., Devlin, D.L., Perkins, S., Aguilar, J.P., Golden, B., Santos, E.A., Unruh, M. (2021). Policy, technology, and management options for water conservation in the Ogallala Aquifer in Kansas, USA. *Water, 13*(23). https://doi.org/10.3390/w13233406.

Steinman, A.D., Nicholas, J.R., Seelbach, P.W., Allan, J.W., Ruswick, F. (2011). Science as a fundamental framework for shaping policy discussions regarding the use of groundwater in the state of Michigan: a case study. *Water Policy, 13*(1). https://doi.org/10.2166/wp.2010.047.

Swette, B., Huntsinger, L., Lambin, E.F. (2023). Collaboration in a polarized context: lessons from public forest governance in the American west. *Ecology and Society, 28*(1). https://doi.org/10.5751/ES-13958-280129.

Tauer, M.D. (2011). Evolution of the doctrine of equitable apportionment – Mississippi v. Memphis. *The University of Mississippi Law Review, 41*(4).

Tenzing, K., Millar, J., Black, R. (2021). How property rights influence equity, efficiency and sustainability of high-altitude rangeland management in Bhutan. *Pastoralism, 11*(7). https://doi.org/10.1186/s13570-021-00193-6.

Thiel, A., Adamseged, M.E., Baake, C. (2015). Evaluating an instrument for institutional crafting: how Ostrom's social-ecological systems framework is applied. *Environmental Science & Policy, 53.* https://doi.org/10.1016/j.envsci.2015.04.020.

Torfing, J. (2019). Collaborative innovation in the public sector: the argument. *Public Management Review, 21*(1). https://doi.org/10.1080/14719037.2018.1430248.

Ulibarri, N., Scott, T.A. (2017). Linking network structure to collaborative governance. *Journal of Public Administration Research and Theory, 27*(1). https://doi.org/10.1093/jopart/muw041.

Ulibarri, N., Imperial, M.T., Siddiki, S., Henderson, H. (2023). Drivers and dynamics of collaborative governance in environmental management. *Environmental Management, 71.* https://doi.org/10.1007/s00267-022-01769-7.

Uphoff, U., Wickramasinghe, M.L., Wijayaranta, C.M. (1990). Optimum participation in irrigation management: issues and evidence from Sri Lanka. *Human Organization, 49*(1). https://doi.org/10.17730/humo.49.1.123pg568k40l135l.

Valizadeh, N., Bijani, M., Karimi, H., Naeimi, A., Hayati, D., Azadi, H. (2020). The effects of farmers' place attachment and identity on water conservation more norms and intentions. *Water Research, 185*(15). https://doi.org/10.1016/j.watres.2020.116131.

Van der Waldt, G. (2020). Constructing conceptual frameworks in social science research. *The Journal for Transdisciplinary Research in South Africa, 16*(1). https://hdl.handle.net/10520/EJC-1d2c5c78d4.

Vasseghian, Y., Hosseinzadeh, S., Khataee, A., Dragoi, E.N. (2021). The concentration of

persistent organic pollutants in water resources: a global systematic review, meta-analysis and probabilistic risk assessment. *Science of The Total Environment, 796.* https://doi.org/10.1016/j.scitotenv.2021.149000.

Veeck, G., Veeck, A., Yu, H. (2020). Challenges of agriculture and food systems issues in China and the United States. *Geography and Sustainability, 1*(2). https://doi.org/10.1016/j.geosus.2020.05.002.

Vermeylen, S. (2010). Resource rights and the evolution of renewable energy technologies. *Renewable Energy, 35.* https://doi.org/10.1016/j.renene.2010.03.017.

Villamayor-Tomas, S., Garcia-Lopez, G. (2018). Social movements as key actors in *governing the commons*: evidence from community-based resource management cases across the world. *Global Environmental Change, 53.* https://doi.org/10.1016/j.gloenvcha.2018.09.005.

Watson, N. (2014). IWRM in England: bridging the gap between top-down and bottom-up implementation. *International Journal of Water Resources Development, 30*(3). https://doi.org/10.1080/07900627.2014.899892.

Western UP Food Systems Collaborative. (2022). 2022 Annual Report. https://wuppdr-my.sharepoint.com/personal/marielle_wuppdr_org/_layouts/15/onedrive.aspx?id=%2Fpersonal%2Fmarielle%5Fwuppdr%5Forg%2FDocuments%2FAttachments%2FWestern%20UP%20Food%20Systems%20Collaborative%202022%20Annual%20Report%20%281%29%201%201%2Epdf&parent=%2Fpersonal%2Fmarielle%5Fwuppdr%5Forg%2FDocuments%2FAttachments&ga=1.

Whitmore, D.O., Butler, J.J., Wilson, B.B. (2023). 2023 status of the High Plains Aquifer in Kansas. *Kansas Geological Survey.* https://kgs.ku.edu/2023-status-high-plains-aquifer-kansas.

Wiegleb, V., Bruns, A. (2018). What is driving the water-energy-food nexus? Discourses, knowledge, and politics of an emerging resource governance concept. *Frontiers in Environmental Science, 6*(128). https://doi.org/10.3389/fenvs.2018.00128.

Xie, Y., Wen, Y., Cirella, G.T. (2019). Application of Ostrom's social-ecological systems framework in nature reserves: hybrid psycho-economic model of collective forest management. *Sustainability, 11*(24). https://doi.org/10.3390/su11246929.

Yandle, T., Noonan, D.S., Gazley, B. (2016). Philanthropic support for national parks: analysis using social-ecological systems framework. *Nonprofit and Voluntary Sector Quarterly, 45*(4). https://doi.org/10.1177/0899764016643612.

York, A., Yazar, M. (2022). Leveraging shadow networks for procedural justice. *Current Opinions in Environmental Justice, 57.* https://doi.org/10.1016/j.cosust.2022.101190.

Zwickle, A., Feltman, B., 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.* https://doi.org/10.1016/j.envsci.2021.07.021.