UNDERSTANDING HOW MICHIGAN FARMERS PERCEIVE WATER AVAILABILITY INDICATORS

By

Brockton Feltman

A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

Community Sustainability-Master of Science

2017

ABSTRACT

UNDERSTANDING HOW MICHIGAN FARMERS PERCEIVE WATER AVAILABILITY INDICATORS

By

Brockton Feltman

In 2008 Michigan became a signatory of the Great Lakes-St. Lawrence River Basin Water Resources Compact. The Compact helps protect against diversions of water outside the Basin, and compels signatories to adopt measures for protecting water resources within state boundaries. As part of Michigan's implementation of this law, it gives large quantity water users the opportunity to collaboratively govern water resources within water management areas. The ability for resource users to successfully manage common pool resources depends on a number of factors that have been identified and described by researchers, one of which is the necessity for members of collaborative governance organizations to have a shared understanding of resource conditions in order to design effective management institutions. This research focuses on Michigan crop irrigators and aims to discover what indicators are important to them for evaluating water resource availability. Results of this research show a high degree of similarity in terms of how irrigators define water resource availability, which is a promising sign for the probability that this community of water users will be able to effectively govern shared resources.

ACKNOWLEDGEMENTS

Funding for this research was provided by the Michigan State University Abundant Resources Researcher Group, comprised of Adam Zwickle, Joe Hamm, Sara Fingal, and Bruno Takahashi, along with the Guyer-Seevers Endowment. I appreciate the opportunity to contribute to the work pursued by these groups. The ability for societies to thrive and flourish will always depend upon the natural resources that provide for our diverse array of activities, and finding ways of sustainably conserving and consuming water resources is a key factor for prosperity in Michigan.

I would like to thank my committee members – Patricia Norris, Joseph Hamm, and Maria Claudia-Lopez – for their guidance and feedback that was so essential for the successful completion of my master's thesis. The freedom for creative thought and independence that Professor Norris offered was especially appreciated. She allowed me to grow and mature both as a student and person under her tutelage, and I know that the positive direction in which my life is now pointed is thanks in large part to my time as a researcher and friend in the Guyer-Seevers Program in Natural Resources Conservation.

I also appreciate the trust that Professor Hamm placed in me, and his vision to combine my interests with the goals of the Abundant Resources Researcher Group that he is a member of. Additionally, his excellent writing skills were always a major help as he suggested comments on my developing thesis work. Professor Claudia-Lopez offered deep insight into the inter-workings of collaborative governance groups, helping me to visualize how my work fit into this complex body of research. Moreover, her skills as a qualitative methodologist were crucial as I thought about the design of my study. I thank you all very much, and it has been a privilege working with you.

I'd also like to thank Rachel Nanteza for her help conducting focus groups, testing the codebook, and all of the interesting conversations we had driving around Michigan. Her dedication to this project, strong communication skills, and insightful comments were much appreciated, and I'm confident that she will be successful in whatever career path she chooses to pursue after earning her bachelor's degree.

Finally, this research was conducted with institutional review board approval, log number x16-1201e.

TABLE OF CONTENTS

LIST OF TABLES

CHAPTER 1: INTRODUCTION TO THE PROBLEM

1.1 The Concept of Natural Resource Sustainability

Sustainably managing natural resources is of great importance for the quality of human life. Like all animals, we depend on ecosystems to provide the basic conditions and materials for survival, but more than other creatures, people manipulate the environment in the pursuit of sustenance, comfort and entertainment. These manipulations bring about ecological changes that range from inconsequential to severe. The inseparability of human and environmental wellbeing underlies the imperative to sustainably integrate human political and socioeconomic activities with ecosystem processes, because doing so increases the ability for societies to prosper over the long-term while maintaining the integrity of natural systems they depend on.

The concept of sustainability has become an important guide for political, economic and social action (e.g., Baumgärner & Quass, 2010; Gupta & Vegelin, 2016). Globally, sustainability issues include population growth and intensifying pressures on natural resources (e.g., Bretschger, 2013; Bell et al., 2013); the production of large quantities and varieties of waste (Seadon, 2010); intensive modes of resource extraction and consumption (e.g., Plieninger, 2006; Naimen et al., 2011); and increasingly complex, nonlinear and persistent environmental problems that demand innovations in natural resource governance (Lockwood et al., 2010). With these and other socio-ecological challenges, achieving sustainable societies at a global scale is a difficult task.

Moreover, sustainability issues are situation-specific on local scales, meaning that challenges to sustainable societies vary dramatically from location to location. This variability makes it virtually impossible to design one-size-fits-all policy solutions (Rittel & Webber, 1973) and compels nations, states, cities and local communities (the scale depends on the issue) to craft policies specific to the issue at hand.

1.2 Collaborative Governance and Sustainability

This research is grounded in the problem of sustainable water use in Michigan farming communities. Irrigation is an agricultural practice relevant to sustainability worldwide, potentially allowing results from this research to have broad application; yet keeping a narrow focus on Michigan helps isolate sustainability challenges specific to this region and promotes the development of solutions to local water use issues. Furthermore, since crop irrigation can be studied from a variety of perspectives – such as application technologies, planting schedules, commodity prices, and others – it is important to clearly identify the frame employed in this research. Here the problem of sustainable water use is approached through the lens of governance, because the way political decision making power regarding water use is distributed and exercised influences water management goals and strategies.

Bodin and Crona (2009, p. 366) define natural resource governance as “the management of natural resources, as well as the structures and processes that provide the social and institutional environment in which the management can take place”. Natural resource governance organizations can take a variety of forms that vary in the degree of stakeholder participation (Cornwall, 2008), with some researchers arguing that natural resource governance institutions should aim for an optimal mix of state and stakeholder involvement (Murphy, 2012). The United States, including Michigan, has historically relied on privatization and state-centered decision-making authority to govern resources, which dramatically limits the decision-making power of stakeholders (Sandler, 2010). These management methods have been criticized because they often suffer from “high costs, politicization, and unsuccessful or incomplete implementation” (Koebele, 2015, p. 63).

The shortcomings of centralization and privatization mechanisms have opened up space for institutional evolution in the form of collaborative governance. Unlike top-down, command-and-control styles of resource management where decisions are made by a small number of bureaucrats or private landowners, the decision-making processes of collaborative governance organizations span multiple scales and are “polycentric”, featuring decentralized networks of public and private actors (Pahl-Wostl et al., 2007). Collaborative governance organizations can be compared to heterarchies found in other highly social creatures organized in complex ways to create social systems more dynamic and adaptive than could be achieved through strict hierarchy (Cumming, 2016). In heterarchies there are “multiple organizing principles”, some of which may “involve hierarchy” – such as bureaucratic structures within state regulatory agencies – but also exhibit horizontal links within society – as in partnerships between the State and other public and private organizations (Davies, 2009, p. 28). Collaborative governance heterarchies “consist of different forms of coordinated relationships: inter-personal networking, inter-organizational relations, and/or inter-systemic steering levels” (Olmedo, 2014, p. 578).

Collaborative governance has grown increasingly popular as a means for achieving sustainable resource management (e.g., Andersson et al., 2004; Sharma et al. 2014; Lubell, 2004; Pahl-Wostl et al., 2007), both in terms of social and environmental measures (Ansell and

Gash, 2007). Collaborative governance organizations have been found to help realize efficient allocations of resources (Lemos & Agrawal, 2006), ecological sustainability (Folke et al., 2002), democratic decision-making and political accountability (Lockwood et al., 2010), and social equity (e.g., Erkuş-Öztürk et al., 2010; Cuthill, 2010; McCall et al., 2012). While it is inappropriate to assume that these outcomes are guaranteed in every situation where decisions are made collaboratively, empirical studies suggest that this mode of decision-making is a viable solution to many sustainability issues.

Researchers in natural resource governance have noted that institutional efficacy varies with the degree to which management strategies align with social-ecological circumstances. Elinor Ostrom, in her work *Governing the Commons,* investigated a number of traditional collective management cases, that is, those that have been generated out of local communities and not created by governmental authorities, to understand why some were successful while others were not (Ostrom, 1990). She hypothesized that effective institutions would exhibit common traits, while defective institutions lacked one or more of these characteristics. By identifying necessary conditions for successful collaborative governance, researchers would have an empirically valid set of principles that could be used to design natural resource governance organizations based on principles that have proven effective.

1.3 Governing Common Pool Resources

Ostrom's work initiated subsequent efforts to isolate factors that determine the formation and success of collaborative institutions (e.g., Agrawal, 2001; Araral, 2009; McGinnis & Ostrom, 2014). One such factor is resource users' perceptions about prevailing resource conditions. If resource users have similar notions about the current status of resources being managed, they are more likely to successfully design and implement rules for governing themselves. Numerous researchers have discussed the importance of this variable for collaborative governance (e.g., Araral, 2009; Murtinho et al.; 2013; Meinzen-Dick et al., 2002; Allouche, 2011; Bogardi et al., 2012). Indeed its role in resource management is rather intuitive: resource users will find it easier to craft management institutions if they perceive the resource similarly (i.e., the empirical conditions of the resource) than if their perceptions are dissimilar, because collective management rules must be adapted to the real situation of the world, but what is *real* depends on human interpretation which is not necessarily identical from individual to individual.

Bardhan (1993, p. 636) found that when water resources are perceived to be either exceedingly scarce or abundant “the urge to cooperate diminishes”. In such conditions, actors perceive the costs of cooperating as too high, either because resources are so scarce that conservation efforts are unlikely to succeed or because resources are so abundant that cooperation costs outweigh perceived benefits. Others have reported similar findings, for example: Araral and irrigation systems in the Philipines (2009); Blanco, Lopez and Villamayor-Tomas and water users in rural Columbia (2015); and Uphoff et al. and irrigators in Sri Lanka (1990). Between thresholds of abundance and scarcity, irrigators may recognize benefits from cooperatively managing shared water resources. If the benefits of long-term sustainability of water resources outweigh real and opportunity costs associated with participating in meetings, monitoring resource use, resolving conflicts and other processes inherent to collective governance, then resource users have incentive to cooperate. But what if individuals do not share similar perceptions about resource conditions in terms of the relative abundance or scarcity of water?

Differences in perceptions about water resource conditions between crop irrigators can arise in several ways. First, individuals may agree about how water availability should be measured but do not have access to the same information about the value of these agreed upon indicators, and therefore do not draw similar conclusions about empirical conditions. Secondly, individuals may disagree about how water availability should be measured in the first place, or they may draw different conclusions about resource conditions even if they had access to identical information because individuals weigh factors differently. This research addresses the second question, focusing on whether irrigators share similar perceptions about which social-ecological indicators signify water resource availability.

The question driving this research is: *What social-ecological variables do Michigan crop irrigators perceive as indicators of water resource scarcity?* Answering this question is important for understanding how irrigators evaluate water availability and provides insight into the degree to which farmers agree or disagree on how water resource conditions ought to be measured. This information, in turn, may help to reveal how probable it is that irrigators will be able to collaboratively design rules for managing shared water resources in a sustainable fashion.

1.4 Agricultural Water Use in Michigan

The choice to study Michigan farmers was made for two reasons. First, Michigan has historically had abundant water resources but is beginning to experience scarcity in certain locations. The emergence of scarcity is the result of changes in demand and supply. Water demand comes from municipal and industrial use, agricultural and golf course irrigation, and the production of thermoelectric power (Seedang & Norris, 2011). Supply is affected by Michigan's establishment of minimum flow standards in waterbodies across the state to preserve ecological integrity, which reduces the amount of water available for appropriation (Mich. Comp. Laws § 324.34201). Furthermore, climate change is expected to affect scarcity by increasing temperatures and decreasing precipitation during growing seasons (Kim et al., 2016).

Since Michigan farmers currently find themselves in a period of transition, in terms of long-held assumptions about water availability, it is an opportune time to investigate the perceptions this population holds regarding indicators of water scarcity. It may be that irrigators have been personally affected by the abovementioned changes in water conditions or know others in the community who have been compelled to adapt their farming practices to changing social and ecological circumstances. Then again, it is also possible that in certain locations irrigators have not altered their activities because the status of water availability has remained insulated from significant changes.

A second reason for studying Michigan farmers is that state law grants the opportunity for "all registrants, permit holders, and local government officials" within a watershed to meet and collectively decide upon operational rules for managing shared water resources (Mich. Comp. Laws §324.32725). The fact that crop irrigators in Michigan have the opportunity to establish collaborative governance organizations for managing shared water resources makes this research particularly significant, especially since it explores perceptions of water availability indictors by collecting data from individuals who actually have the state-recognized ability to engage in collective resource management.

Focus group methods were employed to address the research question. Focus groups were conducted in four Michigan counties – Branch, Gratiot, Montcalm, and St. Joseph. The primary goal of focus group meetings was to have participants identify and describe the social-ecological variables they think are most important for evaluating water resource conditions. This information is important because it helps researchers understand the degree to which Michigan irrigators have similar ideas about what aspects of the world indicate water availability, where greater similarity corresponds with a higher probability that irrigators will be able to reach consensus about resource conditions and design strategies to sustainably manage water resources.

Results from the focus group discussions can help guide dialogue among Michigan crop irrigators as they seek to develop a shared understanding of water resource conditions – a crucial prerequisite for the establishment of functional collaborative governance institutions. Cooperation is more readily fostered by understanding *why* and *how* perceptions of resource availability indicators differ, as opposed to knowing only *that* they vary. Facilitators, such as government regulators or extension professionals, can use the information produced from this research to understand potential barriers between resource users, in terms of their ideas regarding water availability indicators, and, through dialogue, help them to first understand each other's perspective and then create a shared vision of the resource they are to co-manage.

CHAPTER 2: COMMON POOL RESOURCE PROBLEMS

2.1 Riparian Doctrine in Michigan

Michigan water policy developed in conditions of abundance. The Great Lakes region is particularly rich in freshwater, representing “ninety-five percent of the fresh surface water in the United States and twenty percent of the world’s supply” (Hall, 2011, p. 305). As the state was being settled, water resources were so plentiful that the Riparian Doctrine, from English Common Law, was relied upon and remains foundational to Michigan’s water policy (Paganelli, 2007). Riparian Doctrine rests on the assumption that water resources are able to meet the majority of social-ecological demands without adversely altering the hydrological systems being tapped (Huffman, 2009). In water rich environments like Michigan, physical availability of water is rarely a limiting factor for human activities, and instead citizens face technological, political, social, economic or other environmental constraints before the availability of water becomes a restriction.

Riparian Doctrine applies to individuals who own land adjacent to water (riparian land), and use of water is tied to owning that land. The principle mechanisms that Riparian Doctrine uses to regulate water use are correlative rights and reasonable use. Correlative water rights state that riparian landowners have “limited but more or less equal rights to use the stream” (Vermeylen, 2010, p. 2403). These rights are qualified by reasonable use, where “the primary right of a riparian proprietor is to receive protection for his reasonable use of the stream or lake from an unreasonable use by another” (Tauer, 2011, p. 901). Water is a common pool resource (rival and non-excludable), and correlative rights give riparian landowners equal ability to access and use water, while reasonable use doctrine protects the use of one riparian against another whose use is deemed unreasonable; reasonable use doctrine recognizes that although riparian users have equal rights based on land ownership, not all uses of water are equally reasonable.

Evolution of water management policy in the State has extended the principles of reasonable use and correlative rights to groundwater as well. The court ruling in *Michigan Citizens for Water Conservation v. Nestle Waters North America, Inc.* established a "legal relation among all water users, whether surface water or groundwater, with all water users afforded a right to reasonable use of water and a correlated duty to avoid unreasonable interference with the rights of other users" (Lautenberger & Norris, 2016, p. 913). The legal recognition of connectedness between groundwater and surface water is important because it reflects the hydrological reality that these two sources of water are linked.

The tenets of Riparian Doctrine are highlighted by contrasting this method of water management with that of Prior Appropriation found in regions of the United States where the lack of water often constrains agriculture, municipal development and other socioeconomic processes. Prior Appropriation is based on the idea of "first in time, first in right" (Elbakidze et al., 2012). Available water resources are allocated by the states through permits until water is no longer available, and once this threshold is reached additional citizens seeking rights to water are denied while the rights of permit holders are protected. Riparian Doctrine, in contrast, compels riparian users to share resources so that even if all available supplies are tapped, a new user who sues for the enforcement of their rights gains access to water by having other permit holders reduce the amount they consume – assuming their proposed use is found to be reasonable (e.g., Craig, 2012; Wurbs & Walls, 1989).

Furthermore, in Prior Appropriation states, if a situation arises where the quantity of available water falls below the amount granted by permits (the summation of all permitted allocation amounts), those most recently permitted are first to lose partial or complete access to water. In Riparian Doctrine, water shortages are shared across permit holders by having each user reduce their use as opposed to having junior appropriators bear all reduction costs while senior users' allocations are preserved (e.g., Huffaker, Whittlesey, & Hamilton, 2000; Donohew, 2009). This is the principle of correlative rights as exhibited in Riparian Doctrine and absent in Prior Appropriation.

2.2 Emerging Scarcity and Evolving Water Law

While Michigan's water management strategy continues to be sufficient in many areas, intensifying pressures on water resources have resulted in the emergence of scarcity in certain locations. According to a 2015 report by the Great Lakes Regional Water Use Database, agricultural irrigation was the largest consumptive user of water in Michigan, using 204 million gallons per day (Great Lakes Commission, 2015). From the supply side, climate change (Angel & Kunkel, 2010) and state-established minimum flow standards on waterbodies (Mich. Comp. Laws § 324.34201) constrain water availability. These pressures have caused Michigan to adapt regulatory institutions in order to meet new social-ecological challenges – as revealed by the State's adoption of the Great Lakes-St. Lawrence River Basin Water Resources Compact.

Michigan's implementation of the Compact has effectuated two major alterations in the State's water law. First, this law establishes environmental standards for hydrological systems based on the conditions necessary to support thriving fish populations; second, it creates the opportunity for registered and permitted large quantity water users and local government officials to collaboratively manage resources within water management areas (Mich. Comp. Laws §324.32725). Environmental standards help guarantee ecological integrity by deterring transfers of water outside the Great Lakes basin and outlining clear rules for water use within the basin (Stack, 2010). These standards also reduce the amount of water available for appropriation by placing a lower limit on how far down waterbodies can be drawn.

Empowering water users to design operational rules for managing water resources can help foster greater congruence between institutions and watershed-specific conditions, while keeping collaborative groups situated within the larger body of state and federal water law (Ostrom, 1990, p.53). Collaborative governance combines centralized regulatory agencies – which provide the basis for common rules across large geographic areas – with the ability for local resource users to "develop a system that is well matched to the ecological system as well as to the practices, norms, and long-term economic welfare of the participants" (Ostrom, 2008, p. 27). But the question of how collaborative water management organizations should be structured to achieve social, economic, political and environmental goals is difficult to answer because solutions vary according to particular circumstances. As Ostrom (2007) said, it is not possible to prescribe simple panaceas to resolve complex social-ecological issues.

2.3 Designing Collaborative Governance Institutions

Natural resource governance refers to the organization of political decision making power around questions of resource use and management. Collaborative governance systems are considered to be more democratic than centralized and/or privatized forms of governance (e.g., Lockwood et al., 2010; Kates et al.; 2005, Memon & Weber, 2010) because they foster a greater degree of inclusivity across stakeholder groups. Institutions that emerge from collaborative governance groups have the potential to be more representative since a greater array of perspectives is involved (Groenfeldt & Schmidt, 2013). It is argued that more democratic forms of natural resource governance promote efficient allocation of resources (Lemos & Agrawal, 2006), ecological sustainability (e.g., Folke et al,. 2002; Lubell, 2004; Pahl-Wostl et al., 2007; Ostrom, 2007), and increased social equity (e.g., Erkuş-Öztürk et al., 2010; Cuthill, 2010; McCall et al., 2012; Vodden, 2015). Collaborative governance has also been found to increase stakeholder trust in policy outcomes (Scott, 2015).

Collaborative natural resource governance has been effective for numerous resource types – such as forests, irrigation canals, pest control and managing wildlife and fish populations (Pretty, 2003) – implying that there may be certain principles common to a variety of resource management contexts. Ostrom distilled eight design principles: "design clear boundaries, congruence with local conditions; opportunities for collective choice and local self-determination; approaches to monitoring, sanctions, and conflict resolution; and incorporation of multiple, nested layers of organization" (Dell'Angelo, 2016, p. 103). However, researchers have expanded upon this initial research and identified numerous other important characteristics of successful collaborative governance. This research contributes to collaborative governance literature by focusing on one of these variables – the role that similarity of perceptions about resource conditions plays in influencing resource users' ability and willingness to co-manage resources. This factor represents a fundamental challenge that has to be addressed whenever groups seek to organize appropriation behaviors related to common pool resources.

It is reasonable to argue that, holding all else equal, agents are more likely to cooperate in designing policies and practices if they share similar notions about (a) the social-ecological indicators that should be measured when evaluating resource availability, and (b) the current value of these indicators. Larson et al. (2009, p. 1013) argued that "divergent values and perspectives present a formidable barrier to collaborative efforts that engage diverse stakeholders in decision making". Not only do perceptions differ about what indicators should be measured to understand resource availability, but the amount that is available from the perspective of someone who places greater weight on, for example, economic utilization may differ from that of someone who measures availability from a strong stewardship perspective (Barry & Smith, 2008). In other words, even if individuals agree both on how resource availability should be measured and the value of these indicators, their beliefs about how water ought to be used in the world are not necessarily the same.

Michigan crop irrigators are likely to perceive their livelihoods as potentially constrained by the availability of water, since it is a vital input into their mode of economic production. Michigan farmers face increasing levels of water scarcity, making it logical to expect that conflict over water access and use will become more prevalent in the future. Irrigators in Michigan have the ability to collectively govern resources within state-defined water management areas, and this strategy may be leveraged to help satisfy the socioeconomic needs of farmers while also meeting environmental regulations set by the state. Olson (1965, p. 5) argues that all organizations share a common goal: “the furtherance of the interests of their members”. Since irrigators all depend on the sustainability of shared water resources, it makes sense that they have an incentive to form collaborative governance organizations to manage resources in ways suitable to their needs.

CHAPTER 3: WATER AVAILABILITY INDICATORS

3.1 Measuring Water Availability

Human beings cannot survive without consuming water, and numerous socioeconomic activities depend upon specific patterns of interaction with water resources (Chenoweth, 2008). Freshwater makes up an incredibly small proportion of the world's water resources, with less than 1% readily available for human use (Meerganz von Medeazza, 2004). Our dependence on freshwater, combined with its rarity in nature – which is compounded by the fact that resources are geographically heterogeneous – has caused researchers and governments to try defining what it means for a region to be in a state of water scarcity.

Across the planet, drivers of scarcity include population growth, institutional failure, and unequal power relations that determine how resources are allocated within society (Mildner, Lauster, & Wodni, 2011). Scarcity can also be said to exist where there is "pollution, poor sanitation, industrial waste, and salinization" because even if there are adequate quantities the quality of the water is poor (Padowski & Jawitz, 2009, p. 99). Perceptions of water availability are related to objective conditions, in the sense that the existence of water in certain locations at certain times is an empirical fact not subject to interpretation. However, relative scarcity or abundance is ultimately defined by individuals, organizations and governments (e.g., Hiedanpää, Jokinen, & Jokinen, 2012; Jaeger et al., 2013). In spite of these subjective elements, the practical necessity for finding a common way of speaking about water availability in research and government contexts has led to several definitions.

Chenoweth (2008, p. 8) describes a quantity-based definition of water scarcity created by Falkenmark (1986) which, according to the Food and Agriculture Organization (FAO), is "now almost universally adopted":

(a) countries experience water stress when the available quantity falls below 1667 m^3/capita;

(b) health and economic activities are adversely impacted when water is below 1000 m^3/capita;

(c) absolute scarcity occurs when water is less than 500 m^3/capita.

These definitions are useful for generalizing water conditions over large regions, but are rather course when considering that water is heterogeneous across landscapes and people have various expectations about the sorts of lifestyles and socioeconomic activities that water resources should support (Mehta, 2007). To help capture this variability, a number of rival descriptions regarding water availability have been put forth, one of which is called the affordability index of water. This index is "based upon an assessment of the cost of supplying all segments of a nation's population with an adequate supply of clean sustainable water and sanitation services, and comparing this cost with national income" (Chenoweth, 2008, p. 8).

This cost perspective is fairly specific, but scarcity can be described in more general economic terms as occurring whenever quantity demanded exceeds quantity supplied at an acceptable price (e.g., Noemdoe, 2006; Chenoweth, 2008; Murtinho et al., 2013; Theisen, 2008). In markets, price is an indicator of resource scarcity or abundance, with increasing prices corresponding to increasing scarcity and cheaper prices indicating abundance. Rijsberman

(2006, p. 6) adds that whether an area qualifies as water scarce depends upon a number of factors: “(a) how people’s needs are defined – and whether the needs of the environment, the water for nature, are taken into account in that definition; (b) what fraction of the resource is made available, or could be made available, to satisfy these.” Rijsberman’s qualification of the term scarcity is intuitive because it emphasizes the anthropocentric nature of the term *availability*. Highlighting the subjectivity inherent in the concept of water availability is important because not only does it concern economic interests, but also interests in ecosystem services, perceived moral responsibilities towards future generations, biodiversity, aesthetic enjoyment of water-based ecosystems, recreation opportunities, and other human values (Jaeger et al., 2013).

Another way of describing water availability is from policy and legal viewpoints. For example, the state of Michigan has established environmental standards for rivers, streams and lakes to ensure ecological integrity and deter large water transfers out of the basin– in the form of irrigation water to regions of the country where this resource is more scarce, for example (Stack, 2010). In *Sporhase v. Nebraska (1982)*, the U.S. Supreme Court ruled that diversion restrictions cannot be made for the “economic protection of in-state interests” and that states must “treat in-state and out-of-state interests evenhandedly” (Lautenberger & Norris, 2016, p. 914). For this reason, the Great Lakes Compact compels signatory states to adopt rules that provide the same degree of in-state protection that is afforded by preventing out of state diversions.

The standards for in-state protection of water resources in Michigan are based upon hydrological conditions necessary for maintaining characteristic fish populations as determined by scientists at the Michigan Department of Natural Resources (Reeves et al., 2010). The State has established a minimum flow for each waterbody according to ideal conditions for a given stream type and its representative fish populations. A body of water is considered to be in Zone A when levels are abundant in terms of what is essential for fish communities, whereas Zone D represents the legal minimum beneath which levels are not to drop because fish populations will be adversely impacted (Zorn, Seelbach, & Rutherford, 2012).

While each of these types of definitions for resource scarcity is applicable in certain respects, it is also the case that each person builds a personal definition through direct interaction with the resource. These personal definitions are far more difficult to distill in scientific terms. This conclusion can be reached by a simple proof: (1) 'knowing' is an emergent property of neural systems (Chalmers, p. 87, 2010), and (2) each individual possesses a neural network (brain) separate and distinct from other people. Marx argued a similar point about knowledge being a social construct, that is, consciousness as being a product of our interaction with the world, saying that *social practice* defines our understanding of reality (Post, 2010, p. 34).

Since water users develop subjective definitions of resource availability through personal interaction with the resource, and because water is unpriced in Michigan making price-based analyses of water scarcity difficult, it is important to understand how water users think about resource scarcity and abundance. Resource availability is determined by supply and demand factors, and investigating factors that water users think affect the supply of and demand for water may reveal water availability indicators other than price. Moreover, these indicators will likely show what factors are most important to water users – information that might not be immediately obvious to others who do not interact with resources in the same way as water users.

3.2 Water Availability Indicators

In this research, the traditional economic approach of evaluating resource abundance or scarcity in terms of price is not feasible, because water is not priced. Water users' bills reflect infrastructure and energy costs associated with obtaining water, but the water itself does not have an associated monetary value. Therefore, it was important to find indicators of water availability other than price. Researchers have described numerous indicators of water availability that could be important for farmers concerned with water abundance and scarcity (e.g., Tang et al., 2013; Zeng et al., 2013). Furthermore, similar to the way that changes in price reflect changes in resource supply and/or demand, non-monetary indicators of water availability can still be thought about in economic terms because changes in non-monetary indicators may correspond to shifts in water supply and/or demand curves.

Drawing upon the previous work of researchers, indicators that might be used by Michigan crop irrigators to assess water availability were identified and compiled into three categories: (1) environmental factors; (2) social-economic factors; and (3) policy-legal factors. These three indicator types correspond to different aspects of the world that may affect availability and, as a result, act as indicators of water availability. Approaching the concept of availability from these three angles may help create a more holistic understanding of farmers' perceptions about how resource conditions should be evaluated. Moreover, since the notion of resource availability is framed by supply and demand, it is also important to consider how indicators within the environmental, socioeconomic and policy-legal categories may represent the supply of and/or demand for water.

Table 1 shows environmental, socioeconomic and policy-legal variables that researchers have found to be important for indicating the relative availability of water resources. Table 1 also displays the expected relationships between the variables found in these three categories of water availability indicators and the supply of or demand for water.

Table 1. Environmental, Social-Economic and Policy-Legal Indicators of Water Availability, and Hypothesized Relationship with Water Supply and Demand.

Type	Name	Supply or Demand Factor
Environ-mental		
	Absolute Size of Resource	Supply
	Variability of resource over space and time	Supply
	Depth to groundwater	Supply
	% of use from surface v. groundwater	Supply
	Potentially irrigable land	Demand
	Degree of aquatic biodiversity	Supply
	Soil type	Demand
	User distance from surface water source	Supply

Table 1. (cont'd)

	Water quality	Supply
	Climate change scenarios	Both
	Presence of wetlands and other aquatic ecosystems	Supply
Social-Econo-mic		
	Number of Users	Demand
	Quantity-based Hydrological standard	Supply
	Access to information about resource conditions	Both
	Social Capital	Demand
	Market Conditions	Demand
	History of Conflict	Both
	Ability to collaborate at the operational level	Demand
	Projections of population growth	Demand
	Diversity of User types	Demand
	Equitability of Resource distribution	Supply
	Total Population in Watershed	Demand
	Water Storage Capabilities	Supply
	Clarity of Property Rights	Supply
	Relative Income Equality	Demand

Table 1. (cont'd)

	Ethnic Diversity	Demand
Policy-Legal		
	Applicable Water Regulations	Demand
	Clarity of Property Rights	Both
	Stringency of Environmental Regulations	Supply

3.3 Environmental Variables

Researchers have found numerous environmental indicators of water availability to be relevant for farmers when forming perceptions about resource conditions. These include: the size of the resource, variability of resources over time, the relative ease of accessing water, the potential for further agricultural development, biodiversity, soil type, type of water source available, and water quality.

One of the main environmental indicators of water availability is the size of the resource, because this directly corresponds to total physical supply. Gleditsch et al. (2006, p. 366) argue that smaller water supplies "play a very important role in the potential for conflict escalation" when water is an important socio-economic input. In terms of groundwater, the saturated thickness of the aquifer being tapped indicates the total volume available, where the thicker the aquifer is, the greater supply of water that is available (Collins & Bolin, 2007).

Along with the absolute size of water sources, variability of water over space-time has also been shown to be important indicator of water availability (e.g., Noemdoe, 2006; Jaeger, 2013). The greater the variability of water resources, the more likely it is be perceived as scarce because of greater difficulty predicting when resources will be available and in what quantity. Water availability depends in part upon climate and hydrology patterns over space-time, so it is likely regions facing unfavorable future climate scenarios may be considered more water scarce than areas with favorable climate projections (Jaeger et al., 2013).

The relative ease with which farmers are able to access groundwater may also be an important indicator of water availability. The deeper the well farmers have to drill to access water, the more costly it becomes to irrigate (Carrion et al., 2016), which may make them perceive water as more scarce. However, Forouzani et al. (2013) found that, in areas prone to drought, farmers perceive shallow wells as relatively unsafe compared to deeper wells that are more resilient to fluctuations in precipitation patterns. Deeper wells are also preferable in areas where well-to-well conflicts occur at shallow depth.

Another indicator of water availability is the prospect of further agricultural development in areas where farmers irrigate, because a large amount of potentially irrigable land may substantially increase demand on water resources as new irrigation systems are installed. For this reason, areas with a greater amount of land that might be converted to irrigation may be perceived as having a greater chance of experiencing scarcity compared to areas where the land that is currently not irrigated is unlikely to become so (Martin-Carrasco et al., 2013).

The type of soil present where farmers raise crops is also likely to be an indicator of water availability. Sandy soils tend to have higher rates of drainage, while clay soils have higher retention rates (Oberkircher & Hornidge, 2011). Therefore, farmers who farm on soils that retain moisture may be less likely to invest in irrigation than those on more rapidly drained soils. Moreover, the type of soil present in an area may influence the types of crops farmers choose to grow, since crops that require wetter soils might not be feasible on dryer ground without irrigation, or crops that require dryer soils might not be feasible on relatively wet ground without drainage.

Reliance on one type of water source, e.g., surface water or groundwater, results in greater likelihood that water resources will be perceived as scarce compared to the ability to access both types of sources (e.g., Urquijo & de Stefano, 2016; Mangrio et al., 2015). Surface water is cheaper to access than groundwater because it does not require well drilling and has smaller pumping costs, but wells – particularly those that are relatively deep – tend to be more insulated from drought and well-to-well conflicts than shallow wells. Access to both sources means that it is possible to use the cheaper surface water resources while they are plentiful and augment with groundwater if surface water availability is limited.

Many researchers report that even if an adequate volume of water is available to meet demand, low quality supplies might be unusable for desired purposes and effectively reduce availability (e.g., Uriquijo & Stefano, 2016; Mangrio et al., 2015; Malley et al., 2008). For instance, if water is too saline it may harm crops and cannot be used. Therefore, no matter how much saline water is available, there is effectively no water available for irrigation.

3.4 Social-Economic Variables

The socioeconomic context that Michigan farmers are embedded within is another key perspective from which to consider water availability indicators. While environmental factors may influence the empirical quantity available, socioeconomic factors are often associated with demands placed on water resources and norms about what water use behaviors are acceptable. Researchers have described a number of socioeconomic variables that act as indicators of water resource availability, including: the number of irrigators in a region, access to information about resource conditions, market conditions, social conflict, the presence of collaborative governance organizations, diversity of user types, equitability of resource distribution, and the presence of water storage infrastructure.

Given that water resources are finite, the number of water users in an area may influence farmers' perceptions of water availability. As the number of irrigators increase, the total demand from the community on the water supply increases as well, which may lead farmers to perceive water as more scarce due to higher demand (Perveen & James, 2011). Similarly, as the total population increases in an area, farmers may perceive water resources to be scarcer because household, municipal, industrial and other pressures on water supplies compound those attributable to other farmers (e.g., Padowski & Jawitz, 2012; Murtinho, 2013).

Additionally, access to information about resource conditions is important for making decisions about water availability. Researchers have found that the behaviors of farmers vary greatly "under conditions of risk or uncertainty" because they are unable to have much confidence in the consequences of their actions (Marchildon et al., 2016, p. 249). It is reasonable to expect that if farmers are able to access quality information more readily, they will have a clearer understanding about resource conditions than if they are only able to acquire either low quality or limited information.

Another socioeconomic indicator of water availability is the market for crops. As market prices for commodities increase, farmers are likely to use greater amounts of water to ensure high yields if higher prices are expected to cover irrigation costs. This will likely place greater demands on water supplies and push resources towards greater scarcity compared to times when investing in constructing and operating irrigations systems is less likely to result in larger profits.

The form of governance used to manage water resources also influences perceptions of water availability. Allouche (2011, p. s5) argues that “water related conflicts are caused more by the way in which water use is governed than by water scarcity”. While state-centered governance of water resources is likely to prioritize certain uses of the resource over others, leaving groups that feel underrepresented with little recourse for action, collaborative forms of governance are more likely to “address and resolve problems of public interest” in more equitable ways by giving voice to the competing demands placed on water from various stakeholder groups (Huh & Lall, 2013, p. 1143). Wheeler et al. (2017, p. 252) report similar findings, saying that “greater public participation in environmental decision-making” often leads to “greater trust in government and environmental bodies”.

Another source of conflict over water use arises from the different values that humans hold towards water, which influence their beliefs regarding how it ought to be managed. A greater diversity of value orientations makes in more difficult to synthesize the beliefs of stakeholders and devise a single management regime (Jaeger, 2013). Often different belief systems are associated with ethnic groups, and so ethnic diversity is often associated with value diversity; therefore “ethnically diverse countries” often face intense “inter-group competition” regarding resource management (Sirin, 2011, p. 124). Another issue that causes conflict is the unequal distribution of water resources, with those groups who enjoy privileged access and use experiencing relatively abundant conditions compared to those that are less able to utilize or preserve the resource as they would like (Chenoweth, 2008).

Another indicator of water availability is the presence of water storage infrastructure. Noemdoe et al. (2006, p. 775) have found that a “lack of storage infrastructure contributes to the notion of water being scarce”. This is especially true in locations where the seasonal availability of water varies greatly, because without the ability to store water in dry times, supplies of water can shrink dramatically. Infrastructure technologies can improve perceptions of water availability, such as dams for large quantity storage, as well as accurate water monitoring systems to understand and appropriately manage water use.

3.5 Policy-Legal Variables

In addition to environmental and social-economic factors, the policy-legal context in which irrigators are embedded may influence perceptions about water availability indicators. Regardless of the empirical condition of water resources, irrigators’ ability to access and use water depends, in part, on how their rights are defined by law. Relevant policy-legal factors that influence water availability include the degree to which irrigators understand applicable policies and laws, the clarity of property rights, and the stringency of environmental regulations.

Water rights are complex because water is an essential input in numerous and competing socioeconomic processes and the distribution and movement of the resource in nature is complicated. Individuals' rights to water are qualified by federal, state and local law, changing attitudes about stewardship responsibilities, and other legal and cultural considerations. The intricacies of rules surrounding water use by the farming community can make it a challenge for members of this group to understand clearly what their rights are, and a lack of clarity may produce a sense of uncertainty about their ability to access and use water.

Even if water users consider themselves knowledgeable about their legal rights, the policy structure itself may be open to interpretation for a variety of reasons, thereby creating uncertainty. For instance, Michigan common law relies in part on the notion of reasonable use, where reasonableness is a normative term whose current meaning can only be understood as an historical progress of court decisions and in the context of a specific conflict. Irrigators and/or other water users may need court adjudication to resolve disputes that have not been dealt with in previous court cases (Jarvis, 2013). A lack of clarity regarding water rights is likely to result in perceptions of scarcity when a user feels that his or her ability to access and use water rests upon legal assumptions that are less than certain.

Even if water policies are well defined and understood, the nature of these laws have definite consequences for water availability. Specifically, if laws are relatively loose and allow farmers greater freedoms of water use, it is likely that resources will be considered abundant compared to situations where laws are more stringent. Grantham et al. (2014, p. 316) argue that "increased environmental flow protections may have significant and inequitably distributed impacts among water users". This is unsurprising since even if there is adequate water from irrigators' point of view, if this water cannot be accessed due to legal restrictions it is virtually the same as if there was not enough water from an empirical perspective.

CHAPTER 4: STUDY AREA AND METHODOLOGY

4.1 Study Area

This research was conducted in four Michigan counties – Branch, Gratiot, Montcalm and St. Joseph. These areas were selected based on a number of criteria. First, these counties have relatively large areas designated by the State of Michigan's Water Withdrawal Assessment Tool as Zone D. This means that expansion of existing withdrawals and new withdrawals is not allowed, thereby increasing the potential for conflict over water use and raising questions about if/when collaborative governance organizations will develop. Secondly, these counties have relatively large populations of irrigators compared with other counties, which increased the probability that a sufficient number of individuals could be recruited to participate in the study. Thirdly, farmers in these counties have relatively large areas under irrigation compared to other parts of the state, indicating a heavy reliance on water use and the possibility that study participants may participate in collaboratively managing water in the future. Lastly, farmers in these counties irrigate a diversity of crop types, allowing for an exploration of whether the types of crops irrigators grow influences which water availability indicators they think are important.

It is common for studies focusing on collaborative governance organizations managing common pool resources to be limited to "situations where substantial scarcity exists, rather than abundance" (Ostrom, 1990, p. 26). This may be because collective governance is less common in regions of resource abundance because the costs of participating outweigh the benefits, or perhaps because researchers were more interested in situations where it appeared that successful governance was needed. In either case, this limitation is partially overcome in this research. While it is true that the counties selected are experiencing a certain degree of scarcity according to the State's Water Withdrawal Assessment Tool, it is also the case that (1) not all irrigators in these counties inhabit Zone D regions, and (2) regardless of how the State designates regions, irrigators may have opinions about water availability that differ from those of the State.

4.2 Participant Selection

Participants were selected using a contact list obtained from the Michigan Department of Agriculture and Rural Development. Registered water users provide this agency with their name, address and contact information, and these pieces of information were used to reach potential focus group participants for recruitment in the study. In one sense the sampling process was non-random, insofar as the population of participants was restricted to those irrigators who report water use with the State and therefore excludes those who (in violation of state law) do not report water use.

On the other hand, the list of candidates was randomized by giving each contact a code 1-3. The contact lists for each county were alphabetized, with the first person assigned the number 1, the second person the number 2, the third 3, then the fourth 1, and so on. Initially individuals with the number 1 were called and recruited, but since it was not possible to schedule all proposed meetings using individuals assigned the number 1, contacts with the number 2 were called next, followed by those assigned the number 3.

Phone conversations followed a recruitment script (appendix A.). Crop irrigators who agreed to participate received a reminder letter in the mail with the date, time and location of the meeting, as well as my contact information in case they had questions or concerns they wished to discuss. Furthermore, beginning December 7th, the procedure of calling farmers who agreed to participate several days before the meeting was added as an additional reminder. This step was included after two meetings where individuals who agreed to participate failed to show up, resulting in unexpectedly low participation rates.

4.3 Focus Group Methods

Focus group methods were used to investigate Michigan irrigators' perceptions of water availability indicators because they are an effective way of eliciting rich datasets through semi-structured dialogue. Focus groups are organized around the concept of Grounded Theory, a social science perspective that views scientific processes "co-constructed" by researchers and research subjects (Brown et al., 2016, p. 2) as crucial for identifying and exploring "a range of beliefs, attitudes, ideas, opinions and behaviors in the population of interest (O'Donnell et al., 2007, p. 972). To some degree focus group meetings are structured by the researcher, who decides what questions will be posed and in what order; on the other hand, there is an element of spontaneity that arises from conversations between participants that reveal information the researcher did not previously predict, as well as impromptu questions posed by the researcher when unlooked-for opportunities arise to discuss something relevant (Morgan, 1996).

Focus groups are especially effective in "exploring people's knowledge and experience" to elucidate "not only what people think but how they think and why they think that way"

(Kitzinger, 1995, p. 299). This is because focus group methods encourage participants to express their ideas, opinions, attitudes and other subjective mental states that researchers do not have to guess at, but learn directly from the participants themselves. This allows researchers to move past third-person descriptions of human behavior by allowing individuals themselves to provide first-person accounts of their experiences.

In deciding how many focus group sessions to conduct, Krueger and Casey (2009) suggest sampling to the point of saturation. This occurs when a researcher has “heard the range of ideas” and is no longer “getting new information”, which often occurs after three or four meetings (Krueger & Casey, 2009, p. 21). Based on this standard, the original intention was to conduct nine focus groups, with three held in each of three counties (Gratiot, Montcalm, and St Joseph).

In total, 6 focus group meetings were held, two in Gratiot County, two in Montcalm County, one in St. Joseph County and one in Branch County. The decision to include the additional study location of Branch County was based on the desire to reach saturation, which was difficult to achieve using only the original three counties because of lower than expected participation rates. Branch County met the criteria used to select the original three counties, as described in section 4.1.

There were six participants in the Gratiot County meetings, with four in the first session and two in the second. Nine irrigators participated in the Montcalm County meetings, with three in the first session and six in the second. Three irrigators participated in the St. Joseph County meeting, and two participants came to the Branch County meeting. In total, 20 irrigators participated in this study.

4.4 Focus Group Design

Focus group meetings began with attendees filling out and signing consent forms (appendix B.) and participant information forms (appendix C.). The purpose of the consent form was to ensure that participants understood that data collected during the focus groups was going to be used for this thesis and that certain measures would be taken to ensure the anonymity of participants in the reported results. The participant information form collected information about the participants, including their age, the length of time that they have been irrigating, the types of crops they grow, whether they irrigate with surface water, groundwater or both, and other pieces of data. Participant information enabled deeper analysis of data collected during focus groups, by showing how certain personal characteristics may be associated with particular ideas concerning water availability indicators.

Once all participants completed these forms, the meeting commenced according to the focus group script (appendix D.). During focus group meetings, researchers play the role of "group facilitator and moderator" responsible for "keeping people from interrupting or arguing with each other, dealing with overly talkative people who would monopolize the conversation, encouraging shy people to contribute, and so on" (Taylor & Bogdan, 1998, p. 113). The goal of focus groups is to "let people spark off one another, suggesting dimensions and nuances of the original problem that any one individual might not have thought of", and researchers should aim to facilitate an emergent understanding of the problem through participant dialogue (Ruben & Ruben, 1995, p. 140).

In each focus group meetings participants were asked to complete an exercise in which they were presented with hypothetical watersheds and asked to compare them in terms of relative water abundance (appendix E.). Comparisons among two pairs of watersheds were made based on descriptions of the watersheds that did not vary plus a set of water availability indicators unique to each watershed. The water availability indicators were chosen based on literature on indicators, along with conversations with Michigan State University professors and Extension professionals (Lusch, 2016; Miller, 2016; Kelley, 2016). The following three indicators were included in the watershed comparison exercise:

1. River conditions at the end of August: August is typically the driest time of the year in Michigan, when surface water levels are lowest. This variable is visibly obvious to farmers and does not require complicated measurements to evaluate. Presumably, river conditions indicate the supply of water available, with lower water levels equated with lower availability. Three values of this variable were used: (a) the river never runs dry; (b) the river runs dry only in the very driest years; (c) the river runs dry every year. The assumption underlying this variable was (a) indicated the most abundant supply, (b) an intermediate supply, and (c) the scarcest supply.
2. Depth of wells necessary to access satisfactory water supplies: This variable was used to indicate how easily farmers can access sufficient supplies of groundwater. Presumably, the cost of accessing the resource increases as the depth of the well increases, since deeper wells are more expensive to drill and require more energy to bring water to the surface. Two values of this variable were described: (a) 150 ft or deeper; (b) 50-80 ft, where (a) was assumed to indicate greater scarcity than (b).
3. Percentage of farmland irrigated: This variable was used to indicate the extent to which available water is being used by irrigators in the region. This variable is associated with

the demand being placed on water, i.e., how much of a finite supply is being used to irrigate cropland. Two values were described for this variable: (a) 60% of cropland is currently irrigated; (b) 30% of cropland is currently irrigated, where (a) was assumed to indicate greater scarcity than (b).

Participants were presented with two comparisons, one between watersheds A and B, and the other between watersheds C and D. For both of these comparisons, the watersheds had no values in common, that is, between A and B none of the indicators had the same value, and for C and D none of the indicators had the same value. Giving focus group participants comparisons between watersheds with the greatest degree of variability possible helped to determine which indicators had the most weight in their decision-making process, as well as understand what values of the indicators they thought were associated with greater abundance or scarcity. Additionally, based upon the assumption regarding the indicator values mentioned above – that a lower percentage of cropland irrigated, shallower wells, and running rivers throughout the summer signal greater abundance – it was hypothesized that farmers would select watershed A as more abundant than B based on well depth and river conditions, and select D as more abundant than C based cropland irrigated and depth to wells.

A final important aspect of the watershed comparison exercises was that it primed participants to brainstorm additional indicators following the watershed comparisons, as described in the focus group script. After naming and explaining environmental, socioeconomic and policy-legal indicators, participants were asked to vote (using three stickers each) on which indicators were most significant to them. They could vote for the same variable a number of times if it seemed particularly relevant for evaluating water availability or vote once for three different indicators. The purpose of voting was to rank indicators according to their degree of importance, which allowed both for comparison across focus groups and aggregating votes from the entire study to determine which indicators of water resource availability were most important to focus group participants.

4.5 Focus Group Data Analysis

Focus group discussions were audio recorded for later transcription, and participants were made aware of this fact in the signed consent forms. This method of capturing dialogue is relatively simple, in that it does not require specialized software or other tools. However, the evaluation of focus group data may be labor intensive due to the volume of information that is collected and mined, along with the critical thought necessary to organize data into a coherent narrative. Taylor and Bogdan (1998, p. 140) argue that qualitative data analysis is a "process of inductive reasoning, thinking, and theorizing" that does not have a definite end like mathematical calculation, leaving much discretion to the researcher for defining the story that emerges from data.

There is a general consensus in focus group literature that "an inductive approach to the data, based on content analysis" is appropriate (Sim, 1998, p. 348). Rothwell (2010) identifies commonalities across suggested methods, including the use of codes to organize material after thoroughly reading data, "recontextualizing" that data in terms of the coding scheme to identify emergent patterns, and interpreting the initial research question in terms of the patterns uncovered by the researcher. Rabiee (2004, p. 657) summarizes the process of focus group data analysis as a five-step process that includes “familiarization; identifying a thematic framework; indexing; charting; mapping and interpretation”.

The familiarization stage refers to the transcription process itself, where the purpose is to develop a “holistic acquaintance with the data and to identify recurring themes” that emerge within focus group dialogues (Bolla et al., 1996, p. 332). Next, identifying a thematic framework entails building a conceptual model for structuring information based on the research question using ideas that arise from the dialogues. Constructing this model should continue until the point of “thematic data saturation” which occurs “when there are no new emerging ideas in the data” (Hancock et al., 2016, p. 2125). Third, indexing involves highlighting, making notes in transcript margins, and compartmentalizing the undifferentiated data into the conceptual categories that comprise the thematic framework. Following this step is charting the information by reorganizing it to fit the thematic frame. The final phase is interpreting the thematic narrative to draw important conclusions, suggest avenues for further research, and identify policy suggestions. Interpretation represents the transformation of what the information gathered *is* to what it *means* for answering the research question.

Taylor and Bogdan (1998, p. 142-156) outline a comprehensive process for analyzing focus group data that encompasses and expands upon the process described above; this process was used to analyze the information collected from focus groups in this research:

1. <u>Read and reread data:</u> Read through the data several times to become well acquainted with it.

2. Look for emerging themes: Find patterns in the data, such as conversation topics, vocabulary, recurring activities, meanings, feelings, or folk sayings and proverbs.
3. Construct typologies: Make classification schemes to help identify themes, concepts and theories. These make conceptual linkages between seemingly different phenomena and help researchers build theory.
4. Develop concepts and theoretical propositions: First, look for words and phrases in informants' own vocabularies that capture the meaning of what they say or do. Second, compare statements and acts with one another to see whether there is a concept that unites them. Third, look for underlying similarities.
5. Develop charts, diagrams, and figures to highlight patterns in the data: Sketch out potential relationships between different groupings of data and see whether this helps lead to new understandings.
6. Develop a storyline: The storyline is the analytic thread that unites and integrates the major themes in a study. Coming up with a sentence, short paragraph or phrase that describes the study in general terms helps to determine what concepts and themes should be communicate in the study and how data should be organized and coded.
7. List all major themes, typologies, concepts, and propositions: List the major themes in the data. At this point in the analysis, a master list of coding categories will be developed.
8. Coding: Assign a symbol or number to each category, then go through the transcript and indicate which data fit under which coding categories.

9. Sort data into the coding categories: Assemble all the data coded according to each category.
10. Compare the data and refine the analysis: Coding and sorting data enables analysis of all data relevant to a theme, concept or proposition. By comparing different pieces of data, researchers are able to refine and tighten up ideas and gradually move to a higher level of conceptualization.
11. Discounting data: The final activity is interpreting data in the context in which it was collected.

After transcribing focus group dialogues from audio recordings (appendix F.), the transcriptions were read multiple times to understand the content that was collected. Once the material became familiar, then next step was to identify emerging themes within the data. Since the Environmental-Socioeconomic-Policy/Legal framework, along with the Supply-Demand framework, had been developed beforehand, the search for emergent themes were guided by these lenses, but it was also important to look for other themes that were not crafted a priori. From the themes found in the data – both those that were created before the focus groups and those that emerged within them – a storyline was developed (appendix G.) based on the study question which helped to guide interpretation of data and development of codes.

Next, the transcripts were coded based on the major themes and ideas found in the data relevant to the study question. The codebook can be found in appendix H. First, codes were applied within the transcript, and specific ideas and examples tagged with the appropriate code. Sometimes multiple codes could be applied to the same word or sentence. Next, the body of the transcript was rearranged from the original form according to the codes. In other words, the organizational principle of the transcript changed from the structure of the focus group as recorded to the coded ideas found in the data. Reorganizing the information according to the codes made it easier to sort data into the relevant codes, and begin to decipher how the information in each code category answers the research question. Once the information had been satisfactorily sorted into the code categories, the final step was interpreting the data in the context of the research question, and drawing conclusions about how the data answers the question.

CHAPTER 5: RESULTS

5.1 Characteristics of Focus Group Participants

A total of 20 Michigan irrigators participated in this study, two from Branch County, six from Gratiot County, nine from Montcalm County, and three from St. Joseph County. Characteristics of participating farmers are shown in table 2. The average length of time farmers across these counties have irrigated is 29.15 years, with the longest time irrigating at 50 years, and the shortest at 4 years. The average age of focus group participants was rather high, 57.9 years, reflecting the aging farming population of America (Reed, 2008). The oldest farmer to participate in this research was 74 years old, and the youngest was 32. Farmers in this study tended to be highly educated, with 20% possessing a master's degree, 50% with a bachelor's degree or some college, and the remaining 30% with a high school education.

Table 2. Information Collected from Focus Group Participants about Their Operations and Themselves

County	Time Irrigating (Years)	% Surface Water	% Ground Water	Crops Irrigated	Contract Crops	Age	Education	Farming Income (%)
Branch	40	0	100	SC, SB	SC	66	High School	100
Branch	17	0	100	SC, SB, H	SC	39	Bachelors	100
Gratiot	38	15	85	OC, OP, SugB, C	None	36	Masters	100

Table 2. (cont'd)

Gratiot	40	10	90	C, SB, A, W, O	None	70	High School	100
Gratiot	16	0	100	C, SB, SugB, Cuc	Cuc	45	Masters	100
Gratiot	15	10	90	C, SB	SB	54	High School	80
Gratiot	18	0	100	Cuc, W, SB	None	45	Bachelors	100
Gratiot	10	0	100	C, SB	None	57	High School	90
Montcalm	4	0	100	C, SB	None	66	Bachelors	50
Montcalm	50	40	60	Pot, C, DB, W	Pot, C, DB, W	70	Bachelors	99
Montcalm	40	0	100	C, SC, Pot, SB, W, B, GP, EB	SC, Pot, SB, GP	62	Masters	100
Montcalm	40	50	50	C, SC, SugB, DB, SB	SC	68	Bachelors	100
Montcalm	45	60	40	C, DB, SB, W, A	None	68	High School	100
Montcalm	40	0	100	C, A, W, DB, Pot	DB	58	Bachelors	50

Table 2. (cont'd)

Montcalm	40	10	90	C, SB, W, A	None	65	Bachelors	100
Montcalm	15	30	70	C, SB, FGS	FGS	32	Bachelors	100
Montcalm	22	0	100	SugB, C, SB	None	55	Some College	99
St. Joseph	25	50	50	SC, CC, SB, H	SC	56	GED	100
St. Joseph	38	0	100	SC, CC, SB, Pot	SC, Pot	72	Masters	100
St. Joseph	38	0	100	SC, CC, SB, Pot	SC	74	Bachelors	100

For Crops Irrigated and Contracts grown under Contract:

SC = Seed Corn	CS = Corn Silage	DB = Dry Beans
SB = Soy Beans	P = Peas	B = Barley
H = Hay	Cuc = Cucumbers	GP = Green Peas
OC = Organic Corn	W = Wheat	EB = Edible Beans
OP = Organic Peas	Pot = Potatoes	FGS = Food Grade Soybeans
SugB = Sugar Beets	A = Alfalfa	CC = Commercial Corn
C = Corn	O = Oats	

Regardless of age, length of time irrigating, level of education, or county of residence, irrigators relied predominantly on groundwater. Over half of participants, 55%, relied solely on groundwater to irrigate crops, and there were no farmers who exclusively used surface water. Of those who used a mix of surface water and groundwater, the average percentage of irrigation water that came from surface sources was 30.56%. There was only one focus group participant, from Montcalm County, with over half of their irrigation water coming from surface sources at 60%.

Another commonality across focus group participants that varied little was their reliance on farming for income. The average percentage of focus group participants' income that came from farming was 93.4%. For 70% of participants, farming was their only source of income. For the remaining 30% who had additional sources of revenue, farming still accounted for the majority of total income at 78%.

Participants grew a variety of crops, a number of which were common across study areas – such as corn and soybeans – while other crops were only found in one or two locations. Cucumbers and oats were grown only in Gratiot County, sugar beets and wheat in Gratiot and Montcalm Counties, alfalfa, dry beans and peas in Montcalm County, and seed corn in Brand and St. Joseph Counties. Regardless of the types of crops participants grew, a large percentage raised one or more crops under growing contracts. 100% of participants from Branch County, 50% of participants from Gratiot County, 55.6% of participants from Montcalm County, and 100% of participants from St. Joseph County grew at least one crop under contract.

5.2 Watershed Comparison Exercise Results

Results of the watershed comparison exercise were highly consistent across focus groups. The hypothesis that participants would consider A as more abundant than B was correct, with 19/20 choosing A. When asked to explain their reasoning, the most common answer was that in watershed A the river never ran dry, while in dry years the river in watershed B did go dry. Focus group participants said that the river conditions was the main indicator for them, with some even saying that they did not even consider the other factors after analyzing the river indicator. One Gratiot County participant said that most people will as "what are the conditions of the rivers that we can see, this is what the majority of people will base their decision on. That was the biggest one for me." A St. Joseph County participant echoed this idea, saying "looking at these I based in on stream flow conditions. You don't want something always running dry."

In addition to river conditions, some participants also explained that watershed A was more abundant because a *greater* percentage of cropland was irrigated. A participant from Gratiot County said that if "60% of the land is irrigated" compared to 30%, then "there's abundance." This was surprising because it was hypothesized that as the percentage of cropland irrigated increased, perceptions of scarcity would also increase. Participants justified their reasoning by saying that if an area is able to support higher levels of irrigation, it is more probable that farmers will be able to access and use water compared to a location were a smaller percentage of cropland is irrigated. The idea is that if water sources are relatively abundant, they will be tapped and used by farmers; therefore, places where more irrigation is occurring are likely to have greater water availability than places where there is less irrigation.

Well depth played a smaller role in participants' decision making compared to river conditions and the percentage of cropland irrigated. Watershed A had average well depth in the watershed of 50-80ft, while in B it was 150ft or deeper. Some participants noted that it is relatively rare for wells to exist in the shallow range of 50-8-ft described in the exercise. It may be that this value seemed unrealistic to focus group participants, and therefore did not weigh heavily in their deliberation, though it is also true that participants positively stated the importance of river conditions and percentage of cropland irrigated.

When comparing watersheds C and D, all 20/20 participants chose C as having a greater abundance of water resources contrary to the original hypothesis. Participants argued that watershed C had better river conditions, and also stated that since C had more cropland irrigated that it was more abundant than D where a smaller percentage was irrigated. Participants tended to interpret the percentage of cropland irrigated differently than expected, arguing that places where more cropland was irrigated indicated that water was more abundant since it could support higher levels of irrigation.

5.3 Environmental, Social-Economic, Policy-Legal and Knowledge Indicators

Data from focus group conversations reinforced the environmental, socio-economic, policy-legal framework that was developed based on prior research. While this is partially unsurprising considering that participants were asked to brainstorm indicators within each of these categories and vote on them in order to rank their importance, it is significant to note that before this exercise and framework were introduced there were numerous opportunities for farmers to describe indicators during the focus group meetings. In other words, since the majority of indicators farmers discussed before the environmental-socioeconomic-policy/legal framework was described fit neatly within this model, it emphasizes the fact that this framework does a good job of categorizing the indicators of water availability important to farmers.

However, there were also some indicators that were not easily subsumed within this categorization scheme, and this resulted in the addition of another category – knowledge indicators. Knowledge indicators are unique and were not easily captured by the original framework. Environmental indicators deal with non-human aspects of the external world, socioeconomic indicators with connections between individuals mediated by their interactions with water resources, and policy-legal indicators with rules and regulations regarding acceptable and forbidden interactions with water. Knowledge indicators, on the other hand, deal with individuals' personal knowledge about various aspects of the world that have bearing on how they understand water availability and use water in practice.

Table 3 shows the voting records from each of the meetings, featuring all of the indicators that were brainstormed during the respective sessions as well as the number of votes each variable received to indicate its relative importance compared to the others on the list. A number of indicators were mentioned during two or more focus groups, while some were mentioned only in one meeting. Table 4 shows a compilation of indicators identified at meetings in all the counties and the total number of votes that each received. Other indicators were discussed during the meetings but did not appear on the voting lists, making it impossible to know how these indicators rank in comparison to those that were voted upon. The indicators that were not voted upon are included in the discussion following.

Table 3. Voting Records from Indicator Brainstorming Segment of Focus Groups from Each County

County	Indicator	Number of Votes
Gratiot 1	Depth of wells	3
	Ease of accessing water (Successful well/# of test wells)	3
	Number of users (more users = more water abundance)	2
	Soil type	1
	Presence of surface water/Natural ecosystems	1
	Proximity of irrigation wells in relation to residential areas	1
	Regulators are harder to work with	1
	Crop type	0
	Regulations becoming more strict	0
	Burden of proof on farmers in irrigation-residential well conflicts	0
	Health department and environmental regulations	0
Gratiot 2	Water Withdrawal Assessment Tool	4
	Historical/professional (well driller) knowledge about water availability	2
	Information from neighbors about well depth and age	0
	Depth of wells to sufficient supplies	0
	3-phase power	0

Table 3. (cont'd)

Montcalm 1	Soil type (sandy = more drainage, clay = more storage)	3
	Presence of surface water/natural ecosystems	3
	GAMPs from Right to Farm Act	1
	Number of users (more users = more water abundance)	1
	Residential zoning rules	0
	Health Department regulations	0
	Access to 3-phase power	0
Montcalm 2	Presence of surface water/natural ecosystems	8
	Number of users (more users = more water abundance)	4
	Crop type	3
	Worry about quotas	1
	Contract farming	1
	Does my neighbor irrigate (perception that a neighbor's practice is useful)	1
	Water Withdrawal Assessment Tool	0
	Increased reporting requirements	0
	Crop prices	0
	Irrigation as insurance policy	0
	Soil type	0

Table 3. (cont'd)

St. Joseph 1	Density of irrigators	3
	Contract crops/ Crop type	2
	Intensity of water use	1
	Irrigating at night	1
	Temperature	1
	Soil Type	1
	Proximity of irrigation wells in relation to residential areas	0
Branch 1	Presence of surface water/natural ecosystems	3
	Soil type	2
	Size of farm	1
	Precipitation	0
	Crop type	0
	Health department	0

Table 4. Aggregate Voting List from Indicator Brainstorming Segment of Focus Group Sessions across all Counties

Variables	Variable Type	Votes
Presence of surface water/Natural ecosystems	Environmental	15
Number of users (more users = more water abundance)	Social-Economic	10

Table 4. (cont'd)

Soil type	Environmental	7
Crop type	Social-Economic	5
WWAT	Policy-Legal	4
Depth of wells	Environmental	3
Ease of accessing water (Successful well/# of test wells)	Environmental	3
Historical/professional knowledge	Knowledge	2
Proximity of irrigation to residents	Social-Economic	1
Regulators are harder to work with	Policy-Legal	1
Regulations becoming more strict	Policy-Legal	1
GAMPs from Farm Act	Policy-Legal	1
Contract farming	Social-Economic	1
Neighbor irrigates	Social-Economic	1
Intensity of water use	Social-Economic	1
Irrigating at night	Social-Economic	1
Temperature	Environmental	1
Size of farm	Social-Economic	1
Burden of proof on farmers in irrigation-residential well conflicts	Social-Economic	0
Harder to place a well (regulations)	Policy-Legal	0
Lack of consistent rules	Policy-Legal	0
Information from neighbors about well depth and age	Social-Economic	0

Table 4. (cont'd)

Residential zoning rules	Policy-Legal	0
Health Department regulations	Policy-Legal	0
Access to 3-phase power (to run irrigation)	Social-Economic	0
Increased reporting requirements	Policy-Legal	0
Crop prices	Social-Economic	0
Irrigation as insurance policy	Social-Economic	0

A total of five environmental indicators, thirteen social-economic indicators, nine policy legal indicators, and one knowledge indicator were identified. In addition to the quantitative voting data, an extensive amount of information was collected about why irrigators consider it important to measure these indicators in order to understand relative water availability. More specifically, while they did not actually refer to supply or demand, participants often described how changes in the value of an indicator would shift supply and/or demand, thereby affecting resource availability. Some of these indicators referred to direct indicators of scarcity – such as the relative abundance of surface water as a factor of supply – while others *moderate* scarcity. Such moderators include temperature and farming under contract, because these things lead to more or less scarcity – both higher temperatures and farming under contract lead to higher levels of water use – but these indicators do not directly signal the relative availability of water resources.

5.4 Environmental Indicators of Water Availability

One of the most important environmental indicators was the presence and availability of surface water, which corroborates the findings from the watershed comparison exercise, where river condition was deemed by many participants to be the most important indicator of water availability included in the exercise. Most irrigators indicated that natural water-based ecosystems on the landscape – rivers and streams, lakes, and wetlands – are a sign of water abundance. Across the six focus group sessions, surface water conditions was explicitly mentioned on fifteen occasions. Indeed, many focus group participants thought that the presence of visible surface water that remained wet throughout the years was the most important indicator of water availability for irrigation (see Tables 3 and 4). Participants described the presence of lakes, wetlands, rivers and streams that remain wet during the year as an indicator that the likelihood of getting approval for a surface water withdrawal is more probable compared to places where surface waterbodies are absent or go dry, as well as an indicator of productive groundwater.

Another indicator of water availability that farmers considered important is the relative ease of finding groundwater, as measured by the ratio of successful wells to test wells. The process of accessing groundwater typically involves drilling one or more test wells before finding a well that can successfully yield quantities of water sufficient for meeting irrigators' demands. Drilling wells is expensive, so as the ratio of successful wells to test wells becomes very small, an area could be considered relatively water scarce compared to places where a small number of test wells are needed before a successful well is found. Places where a large number of test wells are needed before a successful well is located are likely to be considered water scarce to everyone except the wealthy, because digging a large number of wells is cost-prohibitive.

It is important to note that even if some water can be accessed, a well is not considered successful if it does not produce a sufficient volume. If wells are unable to provide volumes necessary for growing crops, it does not make sense to call such wells successful; the notion of successful wells should be qualified by the ability to supply enough water to meet irrigators' demands. Focus group participants often stated that the simple truth of the matter is that they think of water availability in terms of whether they are able to access and use enough to grow healthy crops to support their economic enterprise. If they are able to get enough water to satisfy demands, then it is abundant, if not, then it is scarce. Wells might be considered scarce, then, even if they are not completely dry, because there is a certain minimum threshold necessary for growing crops – depending on the amount of cropland a farmer is irrigating, as well as the types of crops that they are growing. Irrigators also mentioned the fact that sometimes wells go dry over time. Some focus group participants said that information about the age of wells is an important indicator of water availability, because if there are old wells that remain viable it indicates that new irrigation systems have a good probability of getting water compared to areas where older wells have either dried up completely or seen a significant reduction in the volume they are able to produce such that they cannot be used for irrigation any longer. If there have been numerous wells that have gone dry in a given region, it is likely that irrigators in that area might fear that their own wells will not remain productive indefinitely. When participants were asked to comment on the three indicators included in the watershed comparison exercise, a farmer in Gratiot County said that another important thing to consider is “how many wells have went dry”, that is, have been depleted.

The relative availability of groundwater can be evaluated not only in terms of the ratio of successful/test wells and the quantity produced, but also the depth irrigators must drill in order to access water. There were two perspectives from which farmers spoke about well depth, some arguing that shallower wells are preferable to deep wells, while others held the opposing view. Shallower wells were considered better from a cost perspective, because they are cheaper to dig than deep wells and less costly to operate in terms of energy. On the other hand, deeper wells are thought to be better because they are less likely to impact residential wells – which are typically shallower – and because deeper wells are less likely to have negative impacts on fish populations. Moreover, deeper wells are more insulated from drought than shallow wells.

Furthermore, water quality is an important consideration because even if sufficient quantities can be withdrawn, water for irrigation would still be considered scarce if it is overly saline or otherwise unusable for irrigation. Participants expressed this idea during discussions about how water availability varies across Michigan when they described regions in the “thumb” of the State known to have salty water unsuitable for irrigation without costly.

Irrigators were aware of the relationship between surface water and groundwater availability and underlying geology. Participants discussed the fact that water availability varies substantially across Michigan and on local scales within their respective counties and even on individual fields. A participant in Montcalm County said that water “definitely varies due to the ecology of the state. We have aquifers close to the surface, especially in southwest Michigan, and then there are deeper aquifers beneath limestone and clay layers. So the availability of water varies dramatically across the state." Another participant in Gratiot County said that "the glacier that covered Michigan" influenced "how the ground structure around here developed." Irrigators often reasoned that geological formations were responsible for the variability of surface water presence, the depth of wells necessary to access sufficient water quantities, the volume of water produced in a given location, and the number of test wells needed to find successful wells.

Another geological idea discussed in focus groups was the connection, or lack thereof, between groundwater and surface water. Opposing views were expressed in this regard. Those who thought that surface water and groundwater are connected talked about how the use of irrigation wells might negatively impact surface water and fish populations. For instance, some participants talked about how it is harder to dig shallow wells because of likely impacts that this will have on surface waterbodies. Those who doubted the connectivity between surface water and groundwater expressed this idea by saying that they doubted whether Michigan's Water Withdrawal Assessment Tool accurately reflects the impacts that irrigation has on fish populations. Irrigators in St. Joseph County, for example, described how members of the community have invested in data collection independent of the State to prove that their water use was not having adverse impacts on fish populations.

Water availability indicators are not limited to observations about surface water and groundwater. Soil type was cited by focus group participants as another indicator of availability because it influences how accessible water resources are. As one farmer stated "soil that takes water will give water." In other words, sandy soils allow water to drain more quickly through the profile, and therefore likely require more irrigation that heavier soils, but an irrigator is also more likely to be able to extract water from sandy soils due to the relative ease with which water moves through the low porosity sand than clay and other heavy soils with higher porosity. Several focus group participants talked about temperature and humidity, in terms of how they have the potential to increase demand for water, and therefore push resources towards increasing scarcity. Warmer temperatures result in higher evapotranspiration rates, which in turn cause farmers to irrigate more frequently and/or more heavily per application. Similarly, low humidity increases rates of evapotranspiration, resulting in more frequent and/or heavier water application. In these ways warmer temperature and lower humidity tend to increase demand for irrigation water and over time diminish resource availability. These are examples of variables that moderate scarcity, rather than indicators of scarcity per se.

5.5 Social-Economic Indicators of Water Availability

Focus group participants provided a rich set of data regarding social-economic indicators of water availability. Contrary to expectations, irrigators often reasoned that if an area has a greater number of irrigators it implies there is greater water availability compared to regions with fewer irrigators. Consequently, it seems that irrigators expect their own probability of successfully installing irrigation systems to be greater in locations where many other farmers have already established irrigation. One Gratiot County participant said that “if people see lots of irrigation in a certain area, they can be pretty sure that water is relatively abundant. That is the quickest first-pass through. If you’re coming into a new area, and you see lots of irrigation, you’re going to think that you can pull it off too.” This notion appears to be based on the assumption either that water is not finite – where the addition of one more user is not going to negatively affect availability and the water use of others – or else that resources are finite but so abundant that increases in demand will have negligible impacts on the resource.

As was seen in the results of the watershed comparison exercise, the percentage of cropland irrigated was expected to be perceived by focus group participants as indicating strength of demand, such that a larger percentage of cropland irrigated corresponded with greater demand, and therefore reduced availability. Participants did not think about this indicator as originally expected, however, and claimed that if a particular landscape is able to support higher levels of irrigation, then it means that there is more water available than a place where less cropland is irrigated. Irrigators also said that it is important to consider what types of crops are being grown since, different crops have different water requirements. For instance, some crops need water from early spring until late fall while others only need water for a couple of months during the summer. Moreover, certain crop types require a greater total volume of water than others.

There were other irrigators who reasoned differently about the impact that a large number of irrigators have on the supply of resources compared to fewer irrigators, assuming that increased demand will reduce availability and push an area towards scarcity as the number of users increase. This idea was expressed through conversation about instances of conflict between wells, both irrigator-irrigator interferences and those between irrigation and residential wells, which are considered more likely to occur in an area where there are more irrigators compared to fewer. Indeed, well-to-well conflicts were a common theme in focus groups, suggesting concerns about a major source of emerging social conflict.

Most, although not all, participants acknowledged the connectivity of groundwater, as well as surface water with groundwater, and understood that the cones of depression which form around irrigation wells have the potential to cause interference with other irrigation or municipal wells, as well as surface waterbodies. Several irrigators described incidents that they have personally experienced, or had heard about from other farmers in their communities, of residential well owners who blamed wells going dry on irrigators. A participant in Gratiot County said that he "had a woman call me because she expected me to pay for a well of hers that went dry" and therefore "the more houses around I consider to be negative. We tend to drill wells in the middle of the field to avoid complaints." Focus group participants argued that a situation is developing where it is incumbent upon farmers to prove that their irrigation practices are not causing other wells to go dry, as opposed to having individuals whose wells are drying up prove that it is indeed due to farmers; some irrigators feel that they are considered guilty until proven innocent. For this reason the number of household wells in an area can be considered an indicator of water availability, because the more household wells there are in an area where irrigators operate, the greater the chance that irrigation wells will negatively impact residential wells.

Another indicator discussed during focus groups is whether an irrigator farms under contract or not. Contract farming increases the demand for irrigation water in two ways. First, if farmers do not have irrigation systems they are less likely to receive a contract, and so if a farmer wants to obtain a production contract it is likely that they will invest in irrigation, and thereby place greater demand on water resources. Second, companies that offer contracts expect particular yields, and so farmers are likely to apply water to ensure that those standards are met and increase the probability of securing a contract the following year, erring on the side of over-watering rather than under-watering. Both of these potential increases in water demand from contract farming may push the water resource towards increasing scarcity.

5.6 Policy-Legal Indicators of Water Availability

Focus group participants discussed a number of policy-legal indicators of water availability. Irrigators tended to think that water in Michigan is abundant, but fear that increased regulations will increase scarcity, in the sense that under a strict regulatory scheme maintaining current levels of irrigation or even increasing levels would still be feasible from an empirical perspective but would be illegal. A farmer from Montcalm County put it this way: “we are doing fine with water around here, but I bet someday there’ll be outsiders who try to regulate. They’ll say we have a problem with water when in fact we don’t.” The Water Withdrawal Assessment Tool was the most notable example of increased regulation, and many participants had applied for water withdrawals after its implementation and so had personal experience with it. Some irrigators had even been denied withdrawals either because they reside in a Zone D area or because their requested withdrawal would cause an area to enter Zone D.

Irrigators spoke often of the Water Withdrawal Assessment Tool as the final arbiter of whether an irrigation system would be possible in an area or not because the law places definite limits on what can be appropriated. Some participants took issue with these denials because of the view that water is present and could be used for irrigation, but that State regulations impose scarcity when there remains an abundance of water. As mentioned above, irrigators' perceptions of discrepancies between real-world conditions and those portrayed by the Water Withdrawal Assessment Tool upon which Michigan makes management decisions has caused some irrigators in St. Joseph County to invest in data collection independent of the State to evaluate the impacts of current practices on water resources. The reason for doing this is to build a body of information that can be cited, perhaps in court if necessary, to challenge the Water Withdrawal Assessment Tool if farmers think that the conditions predicted by the Tool, and subsequent regulatory decisions, are based on inaccurate information.

One consequence of irrigators fearing greater restrictions is that well-drillers have advised farmers to register water use as if they were using it 24 hours a day, 7 days a week, 365 days a year; this way if tighter regulations are indeed imposed and irrigators find themselves forced to reduce use they will still have plenty of water to run their operation. A Montcalm County participant said that his approach was to "get me as much water as I can get. I say shoot for 1500gpm even though I might only use 1000gpm." Moreover, the threat of increased restrictions has prompted numerous irrigators to invest in irrigation now, even if they would have preferred to wait for financial or other reasons, because it will likely be harder to register withdrawals in the future.

Participants also talked about how, in addition to state-level restrictions, county health departments are making it increasingly difficult to get approvals for irrigation. Participants commented that, although all county health departments in Michigan enforce the same state laws, their interactions with county-level regulators vary widely and, generally, it is getting harder to achieve irrigation goals. Not only is it possible for health departments to deny a well-construction permit even if the withdrawal has been approved through the Water Withdrawal

Assessment Tool, but irrigators described how there are enough health codes to make the process of navigating them confusing and cumbersome. Participants thought that it would be useful for health departments to organize a comprehensive set of rules that irrigators could access in a centralized location that is easy to find and understand.

Furthermore, while the State makes rules that are applicable to all irrigators in Michigan, county health departments have some degree of freedom to interpret and apply rules, and are also able to formulate additional regulations that impact irrigation. Additionally, some local units of government have crafted zoning ordinances around municipalities that have made it more difficult to place wells in certain areas, with the intent of protecting residential wells from interference from irrigation wells. The heterogeneity of these rules makes it easier for some farmers to install irrigation and more difficult for others; this may cause irrigators in more restrictive areas to feel that their situation is unfair.

A final policy-legal variable discussed by focus group participants involves the application of correlative rights and reasonable use doctrines to groundwater. While participants felt confident that rules surrounding surface water are well-defined and protected, there was less certainty about groundwater, particularly concerning issues of well-to-well conflicts between irrigation and residential wells where the burden of proof is felt to rest on irrigators who must prove that their use of water is not interfering with residential wells as opposed to homeowners proving their well issues are the result of irrigators. This situation, according to those focus group participants who discussed this issue, seems to indicate that residential use of water takes legal precedence over that of irrigation.

5.7 Knowledge Indicators of Water Availability

Two ideas emerged from the focus groups that could not easily be captured using the environmental, socio-economic, policy-legal framework, which gave rise to the addition of the knowledge indicators category as described in 5.3. The first knowledge indicator described by several participants was an understanding of crop biology, in terms of water requirements for healthy crop growth. Irrigators' knowledge of crop biology can influence their water use, because if they know the optimal quantity to apply to specific species, they will be less likely to either over- or under-water. One participant described how a neighbor mistakenly thought that his crops required more water than necessary, which not only led to over-watering but made it difficult to drive machinery across his field and perform essential operations. In other words, insufficient knowledge about water requirements may result in excess demand on water resources, which moves resources towards increasing scarcity.

A more common and important knowledge indicator of water availability described by participants was the knowledge of water resource conditions held by elder farmers and well-drillers. Focus group participants tended to have greater trust in information about resource conditions obtained from older farmers who have come to have extensive local knowledge of groundwater availability through the process of trial and error (surface water is more obvious). A Gratiot County farmer said that "if you talk to most farmers, generational knowledge is important – about where water is in the county, where it is in Michigan. The information that's been around and handed down, by well drillers and farmers, nothing new has opened up except the horizontal wells and that's been extraordinary. This knowledge was developed through trial and error, since there's nothing else to go on." This trial and error process is important because it provides empirical data about where groundwater can be found, and, unlike the Water Withdrawal Assessment Tool, does not depend on computer estimation. Knowledge about groundwater availability gathered in this way can be shared with younger generations of irrigators and helps the community to build a sophisticated understanding of water distribution in the local area.

Another source of trusted knowledge about water availability comes from well-drillers whose occupation it is to understand where water is likely to be found based on hydrogeological information and provide services to farmers that depend on reliably locating water supplies sufficient for irrigation. A St. Joseph participant said that "most of what I know of the water tables I've learned from the well drillers" – this was a common theme during the focus group meetings. Well-driller knowledge regarding water resources differs from that of irrigators, because the latter focuses on water as an input into farming operations while the former uses hydrogeology knowledge to access groundwater.

5.8 Supply and Demand Indicators

Thus far, water availability indicators have been discussed in terms of the environmental, social-economic, policy-legal, and knowledge schema, but it is also important to think about these indicators in terms of the supply-demand framework. Since water is a key input for agriculture (Hardelin & Lankoski, 2015), it is natural to analyze water availability indicators in terms of supply and demand to understand what indicators are associated with each concept. Combining the supply-demand framework with the environmental, social-economic, policy-legal, and knowledge framework provides a detailed conceptualization of irrigators' perceptions of water availability indicators.

The idea of water supply was discussed in numerous contexts. Focus group participants said that they thought water is relatively abundant but even so expected that regulations would become more stringent in the future; in other words water availability for irrigation is not limited by the resource itself but by what the State allows irrigators to withdraw through the Water Withdraw Assessment Tool. This regulation was not the only one described by irrigators to influence supply, because they also discussed the impact of health department restrictions and zoning ordinances on the ability to access water. In summary, regulations discussed during focus groups were seen by participants as constraining their ability to access water, and therefore increase perceptions of water being scarce even though they do not actually change the empirical quantity available.

The supply of water was also thought to be influenced by social conflict, with irrigators arguing that it is becoming increasingly important to consider how their farming practices are perceived by the general public. The visibility of irrigation processes – both in terms of the structures in the fields and the water being applied – makes it easy for residents to blame farmers for streams running dry and negative impacts on household wells, because agricultural water use is obvious to the naked eye. Some participants said that if irrigators did not begin to make relationships with society a priority, it is likely that restrictions will become tighter since non-farming members of society will pressure policy makers to bring perceived overuse of water by the farming community under control.

Aside from regulations and social conflict, a number of other indicators mentioned by irrigators were associated with the supply of water. It was often remarked that the most relevant and readily observable indicator of water availability is the presence of rivers, streams, lakes, wetlands and other sources of surface water. If these sources are considered plentiful, then participants are confident that they will be able to access water for irrigation purposes. Not only does an abundance of surface water increase the probability that irrigators can register a surface water withdrawal, but those who thought that surface water and groundwater are connected feel confident that that there will be plentiful groundwater as well.

The ease of finding a successful well also influences perceptions about water availability. It is costly to dig test wells, therefore the more test wells necessary to locate a successful well, the more likely irrigators will perceive water to be scarce. In addition to the ratio of successful wells/test wells, the depth that an irrigator has to drill to reach sufficient quantities of water affects perceptions of availability. Typically an irrigator would prefer a shallower well because it is less costly to drill and cheaper to operate from an energy input perspective. However, if there is a distinct risk that shallower wells will negatively impact neighboring wells – whether irrigation or residential – an irrigator may prefer deeper wells to avoid social conflicts.

A final variable discussed by focus group participants associated with water supplies is the number of irrigators in a region that have successful irrigation systems installed and operating. Irrigators tended to perceive areas where numerous farmers are able to irrigate as having greater water availability than areas where there are fewer irrigators present. This is contrary to the notion of number of irrigators as an indicator related to water demand. It was also acknowledged, however, that given two places with equivalent water supplies, those with a greater number of irrigators will have less water available for newcomers – recognition of the impact of demand. These differing perspectives hinge on perceptions about how readily water supplies can accommodate increased demand.

In terms of demand for water resources, a number of variables were introduced and discussed by participants. People living in residential areas increasingly think that irrigation has negative impacts on municipal and house wells, along with natural bodies of water, fostering societal perceptions that irrigators are overburdening water resources. When residential wells are negatively impacted, the burden of proof is often on irrigators to prove that their use is not the cause, as opposed to residents proving that it is indeed the result of farmers (guilty until proven innocent). This growing scrutiny on farming practices has caused numerous focus group participants to become more conscientious of the demands they place on water resources, especially in more densely populated residential areas.

Irrigators who consider themselves stewards are more likely to be concerned about the demands they place on water resources, knowing that it has impacts on the environment and society. Several efficiency measures allow irrigators to reduce their demand on water resources while maintaining productive farming operations. In other words, irrigators are able to produce equivalent volumes of crops using less water when certain measures are introduced. These include low-pressure technologies that allow irrigators to supply crops with sufficient amounts of water while using lower volume wells; the use of drop tubes that reduce the loss of water through evaporation; irrigating at night to lower evapotranspiration rates; the use of soil moisture sensing technologies that give irrigators frequent and accurate reports about soil conditions so that they are able to apply water more precisely as needed; using cover crops to build organic matter in the soil to reduce the rate at which water runs through the profile; and using crop rotations that reduce the total volume of water being consumed at a given time.

The types of crops farmers irrigate influence demands placed on water resources because some crops require irrigation for longer periods of the year and/or larger volumes per application. For instance, irrigating a smaller acreage of potatoes could use more water than irrigating a much larger acreage of beans. Moreover, irrigators farming under contract are more likely to place greater demands on water for two reasons. First, the majority of contracts prefer that farmers have irrigation systems as a form of insurance to increase the probability that crop yields guaranteed in the contract will be met and not hindered by drought. Second, the types of crops grown under contract often require greater volumes of water than crop types not grown under contract. One St. Joseph County participant said that “growing contract crops has put greater pressure on water resources. Economically, it is wise to go with contract crops, and the only way to get a contract is to have irrigation systems. And contract crops often require more water than others.” Prevailing crop prices also influence the demand for water, because price affects the time it takes irrigators to pay off investment costs associated with installing irrigation systems. The lower commodity prices are, the longer it will take for farmers to begin making profits from the investment, which dissuades investment and makes it less likely that demands on water for irrigation will increase.

Focus group participants commented on the fact that farmers pay attention to the activities of their neighbors and learn from one another. If a farmer sees that a neighbor has installed irrigation resulting in increased crop yields and/or crop quality, the non-irrigator may be more likely to invest in irrigation than if they had not witnessed the benefits enjoyed by their neighbor. Some irrigators who think that increased water use restrictions are likely to occur in the near future are inclined to invest in irrigation before a more restrictive regime develops, because if they have any inclination to purchase irrigation it is logical to do so before restrictions become more limiting. This means that even if an irrigator would like to wait to invest in irrigation – perhaps because they do not yet have the capital or their operation does not yet necessitate it – it is now rational to overlook these drawbacks because they are less detrimental than attempting to gain access to water under tighter restrictions.

Those irrigators whose income is primarily from farming are more likely to make decisions based on what will generate increased revenue. Participants stated that one of the biggest returns on investment is irrigation because it virtually guarantees increases in yield. This means that irrigators who depend on farming income are more likely to place greater demands on water resources than those who farm as a hobby. Hobby farmers are less likely to invest in expensive irrigation equipment because yields are less important for their economic situation than professional farmers, and therefore hobby farmers will probably place less demand on water resources.

Finally, temperature and humidity also influence the demand for water resources. Warmer and drier conditions require greater volumes of water application due to losses from evapotranspiration compared to cooler and more humid regions. This means that demand on water in warm and dry conditions is likely to be greater compared to demand in cooler and more humid areas.

5.9 Farmer Characteristics

Along with identifying indicators of water availability, focus group participants were asked to describe personal characteristics of farmers that might make them tend to think that certain indicators are more important than others. While it may be the case that irrigators would understand the rationale behind most of the indicators discussed in focus groups, individuals may have different perceptions about which indicators are most relevant for evaluating water resource availability. However, participants did not directly answer this question, and instead discussed what attributes of farmers would make them more likely to invest in irrigation.

One of the main characteristics that influences whether farmers invest in irrigation is their relative dependence of farming income. An individual who depends predominantly on agricultural income is more likely to invest in irrigation because of the benefits it confers in terms of crop yield. Focus group participants discussed the fact that farming is an increasingly competitive industry, and so if professionals want to remain in the business they must be knowledgeable about important technologies – such as irrigation – and willing to invest in them.

A final personal characteristic of farmers likely to influence decisions to invest in irrigation is age. Older farmers are less likely to invest in new irrigation systems because the length of time it takes for the investment to pay off and produce profits is longer than the expected retirement age of elder farmers. This is especially true for older farmers who have never purchased irrigation equipment before and/or who do not intend to pass their farming operations on to younger generations.

CHAPTER 6: DISCUSSION AND CONCLUSIONS

The primary goal of this research was to answer the question: *What social-ecological variables do Michigan crop irrigators perceive as indicators of water resource scarcity?* Answering this question has the potential to increase the likelihood that collaborative governance institutions, as outlined in Michigan's implementation of the Great Lakes Compact, will be successful. Developing a shared understanding about resource conditions – in terms of what variables should be measured to evaluate water availability – is a condition that must be satisfied before water users can agree upon how resources should be managed. By investigating the water availability indicators important to Michigan crop irrigators, this research can promote productive dialogue between irrigators, as well as other stakeholders, and help foster effective water management policies.

Results show a high degree of similarity among users in terms of the water availability indicators they think are important. This is perhaps unsurprising given the idea found in social theory that labor specialization goes hand-in-hand with "specialization at the cognitive level, meaning the acquisition of specialized or idiosyncratic knowledge" (Hecker, 2011, p. 21). Michigan irrigators comprise a distinct sector of the State's economy, defined by the growing of crops for sale using, amongst a variety of other inputs, irrigation water. Therefore, members of this community have special insight into this particular mode of economic production that non-practitioners do not have simply because the latter do not perform the specific labor activities associated with irrigating crops.

As discussed in the Results section, focus group participants built the case for a division of knowledge regarding water resources based upon where they get their knowledge about resource availability. Numerous irrigators said that their main source of information about water availability – particularly groundwater since surface water is readily apparent to the naked eye – comes from elder farmers who have gained an understanding of water availability in the local community through trial and error or from well-drillers whose *occupation* it is to know where water is located based on hydrogeological information. In the first place, older irrigators have come to their understanding of water availability through trial and error, a process that does not require specialized hydrogeological knowledge, but produces an effective empirical understanding of water availability by systematically identifying areas where wells fail to produce water or are successful. It is important to recognize that irrigators can come to a detailed knowledge about groundwater distribution without having a sophisticated understanding of hydrogeological processes because the act of drilling, whether it results in failure or success, produces empirical data about water availability that can be shared within the farming community. Secondly, reliance on well-drillers to know where drilling a well is most likely to result in success reveals that irrigators expect drillers to have a more detailed understanding of groundwater distribution because this is the *economic specialty* of well-drillers.

The idea that irrigators have specialized knowledge was emphasized not only by discussing the sources of information about groundwater distribution just described, but also because they have highly similar views about which social-ecological indicators of water availability are most important. The fact that irrigators displayed great similarity in perceptions about how water resource conditions ought to be evaluated implies a greater likelihood that collaborative governance organizations comprised of irrigators will be successful, compared to a scenario where perceptions about water availability indicators differed significantly. 20 individuals participated in focus group meetings. The fact that, during the process of voting on the relative importance of indicators, only 18 variables received votes (out of 29), that the top 5 variables received over two-thirds of the votes (41/60), and that the variable with the most votes (presence of surface water/natural systems) received a quarter of all votes (15/60) shows tremendous commonalities among participants.

While it cannot be said that each individual will weigh variables identically, and in fact the voting record shows that this was not the case during focus group meetings, it is nevertheless reasonable to assume that, in a situation where members of a collaborative governance organization were considering how to satisfactorily establish the condition of water resources, there will be considerable agreement on what indicators are important to measure. The top five water availability indicators were: (1) presence of surface water/natural ecosystems, (2) number of users, (3) soil type, (4) crop type, and (5) the Water Withdrawal Assessment Tool.

The presence of surface water/natural ecosystems and the number of users are both indicators of water supply, with the former considered an environmental indicator and the latter a social-economic indicator that was expected to be related to demand but was perceived differently by participants than anticipated. That these two were the most important indicators is telling. The presence of surface water/natural ecosystems is the strongest indicator of water availability – both surface and groundwater for those who think that these two sources are connected. It is not surprising that an indicator of water supply is the main concern to irrigators, because if water is not available for farming purposes then all other considerations regarding water for irrigation are irrelevant.

The second most important indicator – the number of users – was considered by participants as an indicator of availability, instead of demand as initially expected. Participants reasoned that a greater number of users in an area signals that water resources are relatively abundant compared to places with fewer irrigators, making it more likely that new users can access irrigation water where there is already a large irrigating population. This may be because locations where irrigators are not present signifies a lack of water for supporting irrigation in the first place, rather than a potentially untapped source of water.

The third and fourth variables – soil type (environmental) and crop type (social-economic) – deal with availability and demand respectively, and are closely related to one another. Soil type influences not only the probability that water, particularly groundwater, can be accessed if it is present (i.e., heavy clay soils make it more difficult to drill for water than sandy soils), but also partially determines which crop types are feasible in a given region. Since different crops require different water conditions to thrive, such as soil moisture content and particular volumes of water application, the soil type of an area is likely to influence irrigators' choices about what crops to grow. For example, focus group participants commented on the fact that potatoes need sandier soils because heavier soils can restrict the growth of the crop; that is, the potato is unable to expand in heavier soils because the soil resists the outward pressure of the plant as it increases in size. However, potatoes also require large volumes of water. Since sandy soils are poor at retaining water, potato growers are virtually guaranteed to need irrigation systems because it is unlikely that natural rain will provide adequate supplies. Although potatoes were used as an example to elucidate both how soil and crop types are interrelated concepts for irrigators, it is likely that similar thought processes accompany decisions about growing other crop types – though some species might be more accommodating of a variety of soil conditions compared to potatoes.

The fifth variable, the Water Withdrawal Assessment Tool, is a policy-legal indicator associated with both the supply of and demand for water. Although the Tool does not influence the empirical condition of resources, it determines whether irrigators are able to access and consume water. Those irrigators who voted for this indicator sometimes said it was the most important, because it was the final arbiter determining whether irrigators could use water irrespective of what other indicators might say about water availability. There was also a fair amount of skepticism shown for the Water Withdrawal Assessment Tool, because irrigators said that a modeling program based on a few data points and extrapolated to cover the entire State was not very reliable. Skepticism about the reliability of the tool, as well as the efforts of irrigators in some areas to collect data to challenge the tool, suggest that legal challenges to the Tool may arise as irrigators are increasingly denied approval for withdrawals.

Michigan irrigators who participate in collaborative governance of water resources will likely consider the five indicators discussed here as highly important for evaluating resource conditions. It is also likely that they will draw similar normative conclusions about water availability based on measurements of these indicators, though there is the possibility of some variability. All focus group participants agreed that the greater amount of surface water and natural ecosystems signified a greater abundance of water, and also that the Water Withdrawal Assessment Tool's designation of availability was not open to interpretation.

On the other hand, there were different ways of thinking about what the number of irrigators, soil type and crop type meant for water availability. Lack of consensus about what a large amount of existing irrigation indicates means that irrigators who might be members of a water governance organization would probably not rely on the number of irrigators present to determine the relative availability of water – though it could be effective to measure, for example, static water levels in wells and average surface water levels to determine if water is remaining constant, decreasing or increasing over time.

The probability that Michigan irrigators will be successful at collaboratively governing water resources is promising given that the majority of focus group participants had similar perceptions about what water availability indicators are most important. This information was not the only source of confidence that irrigators can collectively govern water, however, because interestingly a *lack* of trust in the State – particularly the Water Withdrawal Assessment Tool used to make permitting decisions – has already mobilized irrigators (in St. Joseph County) to work together and collect independent data about resource conditions. Moreover, these irrigators have undertaken the very task that motivates this research, namely, identifying and measuring indicators of water availability to construct an idea about resource conditions.

A lack of trust in institutions – such as governments or corporations – has been shown to increase public engagement, because individuals "skeptical of vested interests" and who are "concerned about outcomes" associated with policies or management actions are often “sufficiently motivated to assume the costs of time and resources to get engaged” (Parkins et al., 2017, p. 3). The irrigators of St. Joseph County have shown that it is possible to mobilize the farming community to create a detailed understanding of water resource conditions, but a challenge for the State of Michigan will be to discover ways of encouraging such efforts in an atmosphere of trust between resource users and regulators.

The fact that irrigators have begun to mobilize as a community seems to indicate two things. First, it is possible for irrigators in other regions to collectively organize in efforts to build an understanding of resource conditions, which is necessary to construct a shared vision for how resources ought to be managed, along with taking intentional steps to forward their political economy. While it is unlikely that irrigators in all water management areas across Michigan have identical capacity to mobilize, since social and financial capital important for organizing data collection may not exist to the same degree as in St. Joseph County, it is possible that (a) equivalent or higher levels of social capital do exist in other areas of Michigan, or (b) in places where social capital is lower than in St. Joseph County, it can be built up to a sufficient level to foster collective action.

In addition to discussing relationships between irrigators and regulatory agencies in terms of trust, focus group participants frequently spoke about interactions with residents in the context of potential social conflict. Irrigators tend to think that their operations are coming under closer scrutiny, predominantly due to residential wells going dry and people blaming these incidents on irrigation wells. Conflicts between irrigation and residential wells has not only created a situation where irrigators feel that they are guilty until proven innocent, but has made it more difficult to place wells due to health department regulations and local zoning ordinances. Social conflict may provide incentive for irrigators to participate in collaborative governance organizations because this is a source of political power, especially considering that Michigan's implementation of the Great Lakes Compact does not provide for involvement of stakeholders other than permitted water users, registered water users and local government officials in the collaborative management process. That is to say, irrigators have the opportunity to make rules regarding water use while other stakeholders – such as owners of residential wells – do not. Though the inclusion of local government officials in local water governance discussions means that other residents' interests are likely to be represented.

Irrigators participating in collaborative governance organizations to manage water resources gain more discursive power, that is, the ability to "shape social norms" around water use than if they choose not to participate in these organizations (Brisbois & de Loe, 2016, p. 204). In terms of social conflict, irrigators may have incentive to form collective management organizations because doing so will likely convey greater ability to normalize certain actions – such as placement of irrigation wells and technology standards – if they are able to justify their farming practices (a) as a community of irrigators as opposed to individuals, and (b) as legally sanctioned by the State of Michigan. Points (a) and (b) may increase the legitimacy of irrigators' practices, where legitimacy is understood as "a public belief that the decision makers have the right to make those decisions, and that the public should accept them" (Licht, 2011, p. 185).

First, if non-irrigators desire to bring complaints against a particular irrigator, they will essentially be lodging a complaint with the irrigation community itself. By forming a collective body, it is easier for irrigators to justify and defend their actions by identifying themselves with the community as a whole as opposed to remaining isolated and vulnerable to criticism as an individual. Secondly, the fact that irrigators are empowered by the State to form collaborative governance organizations and develop rules for managing water resources, as granted in Michigan's application of the Great Lakes Compact, means the State implicitly supports the rules these groups devise – assuming that they follow Federal, State and Local laws. Similar to the way that Generally Accepted Agricultural Management Practices, as outlined in the Michigan Right to Farm Act, protect farmers who follow these practices from nuisance suits (Laurent, 2002), irrigators whose activities are included in the rules created by collaborative organizations may enjoy greater protection from disputes brought forward by non-irrigating members of society.

However, even if membership in collaborative governance organizations lends irrigators a degree of political legitimacy and protection from interference from non-irrigation segments of society, the importance of irrigators' image as stewards promoting sustainability remains crucial. Sustainability was discussed by focus group participants as a way of building social capital with non-irrigating sectors, as well as a strategic business model enabling irrigators to remain prosperous into the future. Comito et al. (2013) contend that there is a tension between two roles farmers play, that of stewards and businessmen, because on one hand they are aware of the fact that "how they treat the land while they work it affects the worth and quality of that land in the future", but at the same time "implementing more environmentally sound conservation practices could limit yields; not farming marginal, highly erodible land reduces production" (p. 287). It may be the case that without Michigan's implementation of minimum water level standards irrigators would continue to intensify water use, but this law, combined with growing threats of social conflict, incentivizes greater synthesis between farmer as steward and businessman.

If irrigators in a collaborative water management organization are able to adopt practices that promote sustainability, it may improve social perceptions of irrigators and reduce the sense that irrigators' operations are closely scrutinized. McGuire et al. (2013) note that "non-farmers in the United States see farmers as disproportionately high users and polluters of water", so it is reasonable to think that if irrigators, as a water management community, are able to adopt sustainable practices and advertise this fact, it will help placate members of the public who are critical of irrigators (p. 67). Researchers note that sustainability practices most likely to be implemented by agriculturalists are those that "fit local environmental conditions, provide clear relative advantage, are easily discussed and learned about through existing social networks, and provide farmers with a continued sense of both independence and contribution to greater societal good" (White & Selfa, 2013, p. 390).

Additionally, researchers claim that local resource users have knowledge that technocrats do not (Weber et al., 2014), based on interaction with resources through direct economic practice, and are able to design effective management plans using this knowledge. This is perhaps unsurprising given the discussion of knowledge specialization associated with labor specialization. By collectively governing local water resources, irrigators may better understand how resources should be managed to promote sustainability and economic prosperity in their locality by leveraging the first-hand knowledge that has been gained through personal interaction with water resources over time.

In addition to sustainable irrigation practices improving relationships between farmers and the public, focus group participants described the pursuit of sustainability as an avenue for greater economic prosperity over time. Some researchers cite an impending decline in agricultural productivity (e.g., Liu et al., 2015; Loos et al., 2014; Singh, 2015). It may not be the case that Michigan irrigators are facing declining productivity, and perhaps farming operations could even be intensified; even so, some focus group participants spoke about farming communities in California and other western states that are suffering from drought and overuse of groundwater and argued that Michigan irrigators should take heed of these examples and conserve the abundant water found in this State. A participant in Montcalm County said "we are fortunate to be surrounded by freshwater, and anyone who doesn't understand this is blind to what we've got." Irrigators in collaborative governance organizations may be better equipped to institute sustainable water use practices within the community as a whole, as opposed to an individual-by individual basis, and thereby promote longevity of farming operations.

Although the social-ecological circumstances that Michigan farmers face are different than those faced by irrigators in other locations of the country or globe, it is possible that results of this research could inform efforts to collaboratively govern irrigation water resources generally. For instance, focus group participants were overwhelmingly concerned with variables indicating whether irrigation water was available in the form of surface water presence because this was taken to indicate the availability of both surface and groundwater. It may be that this indicator is of great relevance to irrigators in other locations as well, because the ability to access water is key for agricultural success worldwide.

Moreover, issues related to soil and crop type are likely to be instrumental for assessing water resource availability from the perspective of agriculturalists generally, because soil type influences how long water stays in the profile and how easily it can be accessed with wells. Crop type, no matter what sort or where they are being grown, depends, in part, on soil type and the ability to irrigate; if a certain soil type is unfavorable to certain crops and/or irrigation is unavailable, then it is likely that irrigators desiring to grow a particular crop will consider an area where it cannot be grown due to water limitations as relatively water scarce.

Along with findings of this research being generalizable to irrigators as an economic sector, the research question pursued here can be applied to investigations involving the collaborative governance of other kinds of common pool resources, such as forests, fisheries, grazing lands and others. The need for members of collective resource management groups to assess resource conditions is crucial for success in all contexts, because without an understanding of the state resource are in, it is not possible to manage them effectively. Therefore, understanding relevant resource availability indicators from the viewpoint of individuals who will be involved with resource management is an important research question that can be replicated in a variety of scenarios to shed light onto this feature of collaborative common pool resource governance organizations.

This research also sheds light on other avenues for further study. For instance, one limitation of this research is the fact that it focuses solely on crop irrigators, even though Michigan water law recognizes other registered and permitted water users and local government officials as having the opportunity to participate in collaborative resource governance. To better gauge the degree of similarity in perceptions about water availability indicators amongst all potential members of collective water management groups in Michigan, it would be useful to expand the current study to include other groups of people who may be involved. An idea that emerged in this research was that well drillers and irrigators had different perspectives on water availability due to the different roles water plays in their respective economic processes. Carrying this idea further, it may be that other large quantity water users, such as energy producers and water-bottling companies, and local government officials have perceptions of water availability indicators corresponding to their distinct economic practices.

Studying the entire population of potential water governance members would also present an opportunity to test the watershed comparison exercise in a more heterogeneous context. There was very little variability in how participants in this research responded to the watershed comparisons in the focus groups, and this may be because, as irrigators, they interacted with water in highly similar ways and so share perceptions about what things affect availability. With a more diverse group of participants, it may be that water availability is perceived to be affected by a wider array of variables, depending upon how each user type interacts with water.

APPENDICES

APPENDIX A.

Recruitment Script

Name of person ___________________
Phone number ____________________

Time called ______________________

Better time to call _________________

Hello, (Mr./Mrs.) ________. My name is Brockton Feltman and I'm a graduate student at Michigan State University. I am working on research looking at how farmers think about water availability. Am I correct that you farm and irrigate? I am contacting you to ask if you are willing to participate in a focus group meeting.

The meeting will include a small group of approximately seven farmers from your area, and the purpose is to understand indicators of water availability and, especially, the kinds of things that water users themselves look to as indicators of water availability.

In other words, I am interested in learning about the kinds of things that farmers think about when they think about how much or how little water there is in the region where they live and farm. Your input is critical for my research, and I hope my research will help other researchers, policy makers and other water users understand the lived experiences of people who rely upon irrigation water as an important production input.

Would you be interested in joining the discussion? There are going to be three meetings, so I have three possible dates you can choose from. The dates are [date 1], [date 2] and [date 3].

We will meet at [location] at [time] p.m., and I expect the meeting to last two hours. We will have refreshments and a small gift for you to show our appreciation for your time and help.

Would you be able to join us for one of those meetings?

NO ------- Okay. Thanks for your time. Good evening.

YES --- Great. Which of the dates would you prefer?

I'd like to send you a letter just to confirm everything. I have [address] as your mailing address. Is that correct?

Great. I'll send you the letter with the details, and we look forward to seeing you at [time] on [date].

APPENDIX B.

Focus Group Participant Consent Form

Study Title: Understanding How Michigan Irrigators Perceive Water Scarcity

Researcher and Title: Brockton Feltman, Masters Student

Department and Institution: Department of Community Sustainability, Michigan State University

Address and Contact Information: 206 Natural Resources Building, MSU, East Lansing, MI 48824; phone 517-353-2235; e-mail feltmanb@msu.edu

Purpose of research and what you will do:

The purpose of this research is to understand what kinds of variables irrigators in Michigan consider when thinking about water availability. You have been invited to join in this study because you use irrigation in farming and have valuable knowledge to share.

The focus group meetings will last around two hours and will be structured around a series of questions about irrigation, water availability and indicators of availability. You are encouraged to offer opinions and beliefs while answering these questions, and you should feel comfortable engaging in constructive dialogue with others in the room. There are no right or wrong answers; *your* experiences are what counts. We will also ask you to complete a very short written questionnaire to provide us with additional information that will help us analyze the information collected during the focus group conversation.

Information collected in these discussions and through the questionnaire will be used to create policy briefs and research articles. If specific quotes are used for explanation of points made during discussions, neither names nor any other identifiers will be linked to them. Additionally, information will be used as the basis for a survey, which will be sent to a larger population of Michigan irrigators during the winter of 2016/2017.

Your participation in this research is completely voluntary, and you do not have to provide any information you do not wish to share. Additionally, you may stop participating and leave at any time if you choose to do so.

You will receive a small gift as a token of our appreciation for your time and contributions.

(Over)

Contact information for questions and concerns:

If you have concerns or questions about this study, please contact the researcher, Brockton Feltman, by phone at 517-353-2235, or email at feltmanb@msu.edu.

If you have questions or concerns about your role and rights as a research participant, would like to obtain information or offer input, or would like to register a complaint about this study, you may contact, anonymously if you wish, the Michigan State University's Human Research Protection Program at 517-335-2180, Fax 517-432-4503, or e-mail irb@msu.edu or regular mail at 207 Olds Hall, East Lansing, MI 48824.

Documentation of informed consent:

Your signature below means that you voluntarily agree to participate in this research study.

____ ____________________

Signature Date

APPENDIX C.

Focus Group Participant Information Form

Participant # _________

1. How long have you used irrigation in your farm operation? ________ years.

2. Do you irrigate using groundwater, surface water, or both? ____________. If both, please estimate the percentage used from each source: _______% groundwater, _______% surface water.

3. Please list the types of crops that you irrigate.
____
____.

4. Do you grow any crops under contract, such as seed corn, potatoes or green beans? If so, what crops?
____
____.

5. How old are you? ________ years old.

6. What is your highest level of education? _____________.

7. What percentage of your income is from farming? ________%.

APPENDIX D.

Focus Group Script

Agricultural Irrigator Focus Groups: _____________ (name of county)

Introduction: Hello, my name is Brock Feltman, and I am a student at Michigan State University. This is Pat Norris, a professor at Michigan State University.

Thank you all for being here this evening and taking the time to contribute your ideas to help me with my research. I hope that this experience will be as valuable for you as it is for us.

Let me start by making it clear that we are here to learn from you. You know about farming and irrigation in ways that people who do not practice agriculture do not. I am looking forward to hearing your thoughts and learning from your experiences. This focus group is one of several I will conduct, all of which have the same two main goals. First, I want to learn about how you think about the availability of water resources. Second, I hope that my conversations with you and other farmers will help me refine my ideas about my research questions and the hypotheses I will test in a larger survey of farmers across Michigan for my Master's thesis. And, I expect that my conversations with you and other farmers will help me with the language I use in the survey to ensure I communicate clearly.

As you might recall from the telephone conversation we had when I recruited you for this meeting, our discussion tonight will center on perceptions about water availability in Michigan. In this and other states, water policy takes the abundance or scarcity of the resource into consideration but how determinations of water availability are made differs across different states. My research focuses on learning about indicators of water availability and, especially, the kinds of things that water users themselves look to as indicators of water availability.

The overarching theme for these focus groups is to try to understand whether you perceive water to be relatively scarce or relatively abundant and how you make that determination. As it turns out, even though we all pretty much know what the terms "scarce" and "abundant" mean, people often disagree about whether the same resource is relatively abundant or scarce and this is why these conversations are important. So, more precisely, I am trying to understand what you see or know that tells you about the availability of water where you live and farm. Throughout these sessions, I will be asking you questions about indicators you use to determine scarcity or abundance, and I will be asking you to participate in an exercise that will also help me explore how you perceive scarcity or abundance.

Before getting into specific questions, I want to emphasize that there are no right or wrong answers and that differing points of view are not only expected, but are welcome. Please feel free to share your point of view even if it differs from others, because this may spark some interesting conversation. More importantly though, as I alluded to previously, people often focus on different factors to determine water availability so the only way to understand all of this is to collect a rich set of opinions and beliefs.

We're interested in hearing from each of you. So if someone is talking a lot, I may purposely direct the conversations towards others who are not speaking as much. If you don't have an answer, or don't feel like answering, that is fine, but I want to make sure everyone has the chance to share their ideas.

Two other quick housekeeping things I want to note. As mentioned in the informed consent you completed, you do not have to answer any questions you don't wish to, and you are free to leave at any time. Also, note that we will record this discussion to free myself and Dr. Norris up to stay involved in the conversations. We will produce a typed copy of the recording, and we will use code numbers instead of names to maintain anonymity. At no point in will we ever share any information that could be connected to a specific individual during any of our analysis or in any of our reports, and we will delete the recordings as soon as we have transcribed them.

We will finish at ________ but feel free to get up and get more refreshments at any time if you would like. If you have a cell phone, please set it to vibrate. If you need to answer it, though, please feel free to step outside.

Let's get started.

<u>Opening Question</u>

- First, to help us get to know one another, will each of you please tell us your name, where you farm, and how long you have been farming?

Thanks for sharing. Now I want to get into some more specific questions about water abundance and scarcity. I'll turn on the audio recorder now to make sure I capture the discussion.

<u>Introduction Question</u>

- Do you think that water availability varies across the state of Michigan?

- What about the water availability where you irrigate?
    - Why do you think so? What signs or signals are you using to gauge water availability?

Thank you for your thoughts. To help us step further into this question of the indicators of scarcity and abundance, I'd like you to complete a short exercise. The exercise describes hypothetical watersheds and asks whether you think water is more abundant in one or the other based on those descriptions. I ask that each of you do the exercise individually, then we will reconvene and I'll ask some questions about it.

<u>Resource Ranking Experiment Questions</u>

This is an exercise I want to include in a survey I plan to send to farmers like you early next year. To help me make that survey work successful, I want to ask you a few specific questions to make sure the exercise makes sense.

- How clear was the paragraph describing the two watersheds and explaining what is in the tables?
    - Was it clear what I was asking you to do?

- As you saw, I made the watersheds differ in three ways: percentage of cropland that is irrigated, depth of useable wells, and streamflow conditions. Did these seem like realistic differences that could describe two watersheds in Michigan?

- I asked you to indicate in which watershed water is more abundant, but I could have framed the question in terms of scarcity. In other words, I could have asked: Do you think water is more scarce in Watershed A or Watershed B. Do you think it makes any difference whether I use the term abundant or scarce? Do you think it would change the way you think about the exercise in any way?

- I asked you to decide about relative water abundance between two watersheds in two different scenarios. How did you feel about doing the same exercise twice? Was it immediately clear that the situations were different in the two scenarios? Would it have been asking too much if I gave you more scenarios? Say – asking you to also compare watershed E and watershed F, or even more comparisons.
    - Since I am planning to include this kind of exercise in a survey of farmers, do you think it would be reasonable to ask them to consider two scenarios? What if I asked them to do three or four?

- Do you have any other comments or questions regarding the design and presentation of the resource ranking scenarios?

<u>Water Availability Indicators</u>

Thank you for the feedback! Now I want to go back to our discussion of the indicators of abundance or scarcity of water. The watershed comparisons we just went through highlighted the attributes I identified to describe watersheds in terms of water availability. Now I want to hear your beliefs about what indicators of water availability are especially relevant for you. And for these questions, I am going to record your answers on this chart so we can revisit them in the next part of the discussion.

- What environmental variables do you think are indicators of water availability? (if needed: By environmental variables, I am talking about natural conditions such as presence of wetlands or other water features or even precipitation or drought patterns. Streamflow conditions in the hypothetical watersheds is also an example).

- What social or economic variables do you think are indicators of water availability? (if needed: Social or economic variables are generally those that involve people, for example, number of large water users in a watershed or agreements among irrigators about best practices. In the exercise, the percentage of irrigated cropland is an example).

- What policy or legal variables do you think are indicators of water availability? (if needed: One example of a policy or legal variable is the restriction in Michigan law that sets caps on the total amount of water that can be withdrawn in any given watershed).

- Now I want you to think about whether you more likely to focus on some of the indicators we have brainstormed than on others? Then, I want you to vote on the three that you think are most important. I am giving each of you three stickers so you can use the stickers to indicate your top three.

Farmer Characteristics

Thank you again for taking part in the exercise. We have spent time talking about factors that you believe are indicators of water availability, and even within this small group there were some differences in ideas, as we can see by looking at our voting results. I suspect that whether irrigators pay more or less attention to any specific indicators of water scarcity may be affected by things like how long they've lived or farmed in an area, how long they've used irrigation, and other personal characteristics.

- What characteristics of farmers or their operations do **you** think might influence which indicators they look to in order to determine water availability?

Survey Questions

- For the survey I am going to do, I could send a questionnaire through the mail or I could send a letter asking people to do the survey online. Would you be more likely to respond to a mail survey or a request to do an electronic version of a survey, or does it matter?

Ending Question

- Is there anything else about water availability that you would like to talk about that did not yet come up in the conversation?

Thank you again for your time and help with this research. I greatly appreciate it. On your copy of your consent form you will find my contact information, and please feel free to call or email me if you have any further questions or comments.

APPENDIX E.

Watershed Comparison Exercise

Water is not distributed equally across the state of Michigan and, as a result, is more abundant in some watersheds than in others. For this activity, consider two watersheds that are almost identical.

Comparing Watershed A and Watershed B

Both watershed A and watershed B are roughly 60 square miles in size, and they are both largely rural with approximately one half of the land area in agricultural uses. Each watershed has one principle stream flowing through it. There is one small town within the boundaries of each watershed, and the size of the population living within each watershed is approximately the same. In fact, the two watersheds differ only in the three ways which are outlined in the table below.

Watershed A	Watershed B
60% of cropland is currently irrigated	**30%** of cropland is currently irrigated
Most irrigation wells reach a sufficient water supply at a depth of **50-80 feet**.	Most irrigation wells reach a sufficient water supply at a depth of **150 feet or deeper**.
At the end of August, the major stream in the watershed **never runs dry**.	At the end of August, the major stream in the watershed **runs dry only in the very driest years.**

Based on this information, do you believe water is MORE ABUNDANT in Watershed A or Watershed B? (check one) □A □B

Comparing Watershed C and Watershed D

As in the previous example, both watershed C and watershed D are roughly 60 square miles in size, and they are both largely rural with approximately one half of the land area in agricultural uses. Each watershed has one principle stream flowing through it. There is one small town within the boundaries of each watershed, and the size of the population living within each watershed is approximately the same. In fact, the two watersheds differ only in the three ways which are outlined in the table below.

Watershed C	Watershed D
60% of cropland is currently irrigated	**30%** of cropland is currently irrigated
Most irrigation wells reach a sufficient water supply at a depth of **150 feet or deeper**.	Most irrigation wells reach a sufficient water supply at a depth of **50-80 feet**.
At the end of August, the major stream in the watershed **runs dry only in the very driest years.**	At the end of August, the major stream in the watershed **runs dry every year**.

Based on this information, do you believe water is MORE ABUNDANT in Watershed C or Watershed D? (check one) □C □D

APPENDIX F.

Focus Group Transcript

Brockton: Do you think water availability varies across the state of Michigan, and if so, why is this the case?

G1-2: It depends on what's underneath, on the subsoil way below.

G1-5: Yeah, of course it varies. Both groundwater, surface water, rivers, lakes.

G1-7: I was always told groundwater flows north to south in our area. Where I live our wells are about 127 feet, but once you cross Beaver creek some people have to dig wells down to 400ft.

G1-5: I've got a well that's 250ft deep where my neighbors is down to 400ft.

M1-1: It all depends on the land you got. If there's no surface water available then you've got to rely on groundwater. It all depends on what's down there what you're going to get.

M1-9: If you go 15 miles east of the fields where we can't get well water you can get lots of water. Or even if you go just a half mile north there's a 1000gpm well.

M1-1: It all varies. We are lucky, we only have to go 100ft or so. Plus we have 10% surface water that we pump out of.

M1-8: We've got one pond that we pump out of that's got a 5 and 2in wells feeding it. We haven't even tried digging a well, but according to the previous farmer there's not enough water to justify it. On some other fields 150 to 250ft you get as much water as you want. Neighbors worry about their house wells running dry when I mention that I want to put in an irrigation well.

G2-1: Yeah, it depends on the way underground geology formed. There are places where you have to go deep, and places where it is shallow.

G2-6: The depth of the aquifer makes a big difference. And in some places, like the thumb area of Michigan, there is no option to drill a well because when they do they get brine water.

M2-6: Yes it does, I've got about 5 wells all around 100ft and get water no problem. Over in the thumb some guys have serious trouble getting water. Like a well driller explained, groundwater is just like surface water – its dry here, there's a river or lake over there and so on.

M2-5: Jeff's right, it varies dramatically over the state. In the middle of the first 40acre plot I owned there wasn't any water in the middle of it, but in the corner we could put a well down and got plenty of water. Within a quarter of a mile one well is dry and the other supplies plenty.

M2-7: An irrigation well on my farm is between 150-250ft, we want around 1200gpm. Irrigation drillers look at the milling from the test well and can tell what sort of formation is down there. Most house wells have great water maybe 50-60ft.

M2-1: We've got several wells that range from 90ft to 135ft. We've always had to do some test wells, but we've never given up on a spot just because we couldn't find water right away – we've always been able to get water after a few test wells. All about 600-1200gpm.

S1-1: It definitely varies due to the geology of the state. We have aquifers close to the surface, especially in SW Michigan, and then there are deeper aquifers beneath limestone and clay layers. So the availability of water varies dramatically across the state.

B1-1: Yes it varies.

B1-2: Of course it varies. Some places have good water, others you can barely get any.

B1-1: Luckily I get good water where I'm at, but I've known people it different parts of the state that have a real hard time finding enough. It can be a real problem.

Brockton: That gets into the second question: do you think water availability varies in the location where you irrigate?

G1-4: It varies farm to farm.

G1-5: We had to do a horizontal well in one of fields because a well driller went down 500ft and couldn't find anything. This was next to a field where it was easy to find well water.

G1-7: I've never understood how Montcalm County has so much more water than Gratiot.

G1-2: It's the sand, there' less clay. Here in Gratiot there's a clay layer down only 2 to 10ft. There are even artisanal wells in Shepherd.

G1-7: Down near Merrill there wells only 25 to 40ft deep. But down the road a man had to go down 500ft.

G1-2: It had to be a different water table.

M1-1: There's a lot of change in irrigation. Potato guys are putting down low-pressure technology that can water crops with less volume. People who once needed around 550gpm can grow the same crops with 350gpm.

M1-9: All the new pivots we put in use that new technology, then we put the drops in so the water falls from a lower height. You can go from 1000gpm to 750gpm with only 50psi instead of 100psi.

G2-6: Ours doesn't vary a whole lot. Where I farm we can go down to 90-120ft and find ample amounts of water. But not too far to the east, you have to go down 450-600ft to find adequate water.

G2-1: Ours is shallow, we run 20ft horizontal wells.

M2-4: I know where we're at its more surface water, and I don't think the availability differs but the formation differs. We've got some wells at 60ft giving good water then some at 60ft where you don't stand a chance but if you go deeper you're able to get it. One pond we have we can pump 500gpm out of it continuously and nothing changes, while the other runs dry most summers – even though they are in eyesight from each other.

M2-7: My thought is get me as much water as you can get. I say shoot for 1500gpm even though I might only use 1000gpm, because if I tell a driller to get 1000gpm I might only get 600gpm. We've definitely had it that you fail to find water at the first location but can get what you want someplace close by.

M2-5: It's got to be underground rivers. Sometimes you strike outside them, sometimes on the edge, and sometimes in the middle. The glacier that covered Michigan had something to do with it I'm sure. That's how the ground structure around here developed.

M2-7: I know sometimes drying up of house wells are blamed on irrigation wells, and that might be partially true, I don't know. But it seems to me like groundwater has got to be all connected.

M2-4: A lot of people will complain that irrigation wells are drying up house wells. We had a neighbor complain to us, but when we started renting his land 5 years ago we never heard anything from him about water issues again.

M2-7: It is very difficult to prove one way or another whether irrigation wells impact house wells or not.

M2-5: The problem is every time we irrigate we advertise that we are using water.

S1-2: In Sherman township we have to go about 140ft where it's more hills and stones, then in Florence township, about five miles away, it's more flatland and we can get a good well at about 60 or 70ft.

S1-3: Most of what I know of the water tables I've learned from the well drillers, and I never knew it but the groundwater flows through aquifers. I tried to drill a well near my pivot, but couldn't get water because of a clay shelf. We moved it 300ft and I got more water than I'd ever need. I was surprised there could be such a big difference in a short distance. I learned something about the terrain or contour of aquifers could be that much different.

S1-2: I had a similar experience. I wanted to put a well near a pivot point but couldn't get water because there was a lot of sand in it, so we moved it about 1000ft to the west and were about to get 1500gpm and I've never had any trouble with it.

S1-3: Yeah and my case the original attempt was at the lowest point of the slope in the field, and in my mind I expected a lower area is where you'd get water quicker and easier, but actually the well I ended up with was on top of the slope.

B1-2: Yeah it varies here in Branch County. Some guys can get groundwater anywhere they put a well on their land it seems like, but others have to try different places before they can find enough.

B1-1: And some guys have a tough time trying to get any on their fields. I know someone who has to pump water from a productive well in one field to add to another that doesn't get enough. Luckily I've been able to get water where I farm.

Brockton: Now we will move onto a short exercise that will be included in the survey. The first question is, how clear were the instructions?

G1-4: It’s an interpretation question. I would think that if the river never runs dry and 60% of the land is irrigated there’s abundance. There’s always somebody else in the picture.

M1-1: They were pretty straightforward, I could interpret them at least.

G2-6: They were clear.

G2-1: Yeah.

M2-5: You could say in the explanatory paragraph that farmers are using the same crops

M2-7: I think the timeframe over which you irrigate makes a big difference as well.

S1-3: First thing I thought was is it a trick question. I wasn’t sure what you’re going for. Is there a right or wrong, or is it a trick question. It is a little confusing to the average person.

S1-2: Looking at these I based it on stream flow conditions. You don’t want something always running dry.

B2-1: I think they seemed clear. Maybe I did it wrong, but it seemed easy enough.

B1-1: Yeah I thought it was fine.

Brockton: Did the three variables I selected seem like realistic measures for water abundance or scarcity?

G1-2: You’d look at how easy it is to dig a well, how easy it is to get water. That’s the main thing for me.

G1-4: I’ve got to use a motor to get water from an 8in hole 500ft down. That’s the economics of getting water. There are certain crops that make accessing water more or less economical depending on how much it costs to access water.

G1-5: A stream is different than a well. Where did the water come from that is in the stream, what effected it upstream before it gets to where you use it? That’s what makes your question difficult, there are so many other variables that it’s hard to tell. It’s a guess, an opinion. In my opinion the stream doesn't make any difference for a well, I want to know where the stream is coming from, if there are people pulling from it before me, if water from the watershed is flowing into it above me.

G1-2: How many well have went dry.

G1-7: Each well, I was told, made a quarter mile radius cone of depression. Irrigators tend to get blamed when municipal wells run dry.

G1-5: Yeah I had a woman call me because she expected me to pay for a well of hers that went dry.

M1-9: I'd say yeah.

M1-1: There's very few wells less than 100ft that I know of.

M1-8: I thought the same thing. Our shallowest well for irrigation is 120ft.

M1-9: House wells are around 50-80ft but not irrigation.

M1-8: With water quality problems, people are first going to blame farmers – where did you spread manure near your well.

G2-6: Yes

M2-5: One of the biggest issues here is what types of crops are being used and when they're being used.

M2-6: 30% of cropland using potatoes uses more water than 60% using beans. If you find the same amount of water at 50ft as at 150ft, then you have the same amount of water in your watershed. It's cheaper the more shallow it is, but that doesn't mean that there is more water.

S1-2: From what I understand we in St. Joe have been blessed with a very rich watershed. We are not limited like people in the Saginaw area.

S1-2: I think that the variables that you have are good, the depth of wells speaks to the geology issue talked about earlier. I think these are the variables that impact irrigation.

S1-3: I've talked to people in others states that have to go 600-800ft to get water, and I couldn't imagine having to do that here because it would be so expensive.

S1-1: Another variable might be the intensity; you have the area irrigated but not the rate.

B1-1: They seemed good. I don't think there are that many wells that shallow anymore. People have been drilling deeper. But other than that I thought they were fine.

B1-2: Yeah even with ground water, an important thing to look out for is the rivers. If the river is running dry, you know some people are going to be having problems.

Brockton: I posed the watershed comparisons in terms of abundance but could have framed in terms of scarcity. Do you think that if I had talked about scarcity it would have changed how you answered?

G1-7: I think if someone who got it and was in a place with bad PR would read it one way, while someone in the city would be swayed by the papers.

G1-5: I don't think it matters.

G1-4: Scarcity is a more negative term, while abundance implies that that there is enough for everybody. I think abundance is a better way to put it.

M1-9: I think abundance is alright.

M1-1: Abundance works good for me. The main variable is if the river runs dry, that's what most farmers are going to look at. Usually pumps don't effect the river if you're down there more than 100ft, but if you're at 40ft you're going to impact the river – but you aren't going to find that many wells that shallow anymore.

G2-1: It wasn't a buzzword for me when I read the question.

G2-6: Either way it seems like the same question.

M2-8: I would say when it dries up, if you don't see it then it's scarce. It's a straightforward answer, if there is nothing there it's scarce.

M2-7: I don’t think it makes a difference.

M2-8: The most important one to me was how deep you have to go down to get the water.

M2-4: I did just the opposite, and thought the river conditions were most important.

S1-1: In my view the use of the word ‘abundance’ in these scenarios makes it difficult to make a choice. Which might be more accessible or available is a decision easier to make. In our experience is that we have water readily available and abundant at both locations even though there are different well depths. I don’t know that, given these variables and these situations, we can say where water is more abundant. Water is probably more accessible to an irrigator if you can get water from a shallower well, but this doesn’t mean it is more abundant. However, if there is a neighbor with an irrigation system nearby there is a risk of them running each other dry, and in this case a deeper well may be more protected from this possibility.

S1-3: Did you say sustainable as one of your words? Could you have farmers compare watersheds in terms of sustainability? It seems like that’s what we are all trying to achieve here, because this is our livelihood. How you measure sustainability is very difficult, there are a great many possibilities. Watching what happened in California last summer makes you think yeah that could happen here too.

S1-1: Here in St. Joe we’ve employed a firm that has been taking well depth, stream flow, static water levels and other measurements to show that current irrigation practices in St. Joe is not impacting sustainability. Doing this independently from the State helps us to have a body of information that we can cite when the WWAT shows conditions that we don’t think are correct. The sustainability of water is important to us, because it is our lifeblood, and so it’s not a PR stunt but something that we are very concerned about for the sake of our way of life.

B1-2: It seems good. I can’t think of something better.

B1-1: Seems okay to me.

Brockton: Do you think that asking farmers to do two is too much, or would farmers be willing to do more?

G1-5: I would rewrite the explanatory paragraph. Mention that they are all operating under the same scenario

G1-4: There is very little of Michigan that will have up to 60% of cropland irrigated. Some places are around 40%. That much is rare.

G1-7: Gratiot is maybe 5% or so.

M1-8: How much more is with it, is it just those questions or will there be other questions as well? If it's just those it's fine, but it depends on how long of a questionnaire you're given them.

M1-9: If it's going to take them more than 10-15 minutes they're probably just going to toss it in the trash.

M1-1: Most surveys go in the trash, but looking at irrigation water everybody's going to be interested in water issues. People want to know the rules related to water because it is so important to a farming business.

G2-1: Keep it shorter. You could probably put a couple on, but don't make it many pages.

G2-6: I don't think you need to repeat the paragraph, you could just say 'under the same scenario as above.'

G2-1: Make it easy and you'll get a lot quicker response back.

M2-7: I think what you've got here is enough.

S1-1: In terms of receiving this in the mail, I wouldn't go more than a couple of pages. You might get 4 comparisons.

S1-3: I think maybe 5 questions is enough. As long as you can keep the attribute values far apart it will make it easier to tell the difference between the watersheds.

B1-2: It depends on the farmer. I think I could handle one or two more than this, but then I bet some people wouldn't do it at all. I'd keep it short if you want people to answer.

B1-1: I agree. Shorter is better to my mind.

Brockton: Are there any other questions or comments you have regarding the watershed comparison scenarios?

M1-1: The river water is the most important factor. It is very hard to get a surface water permit now.

M1-8: Yeah we've never requested a new permit, all the ones we use are preexisting ones.

G2-6: I think if I had more time to digest and really think about the scenarios … the answers would vary greatly based on who is reading it. What are the conditions of the rivers – that we can see – is what the majority of people will base their decision on. That was the biggest one for me.

G2-1: And the one about 60% of land in irrigation, people are going to be blaming farmers if the river runs dry.

G2-6: That's the biggest problem with irrigation right now, the general public. If you've got a stream running dry, and they can see the irrigation system running across the ditch, they're going to point the finger at you. And that's not right because the aquifer that's 80ft down has no connection with the surface water. But to the general public this is a contentious issue.

B1-1: I don't think so.

B1-2: No.

Brockton: What are your ideas about the important indicators of water abundance? What environmental variables do you think are indicators of water abundance?

G1-2: You might look at wetlands as a negative and try to tile it. If you're looking at pump water (groundwater) it's different than what is visible at the surface.

G1-5: Number of household wells in your area. Depth to wells.

G1-4: The ease of finding wells – number of test wells before a viable one is found.

G1-4: The main thing on environmental is the type of soil on top. If you've got soil that will retain water you're not going to have to irrigate, but if you've got little water retention you're more likely to irrigate.

G1-2: If there is surface water that you can pump out of that is really easy.

G1-4: If you've got heavy soils it holds water, if you've got sand it runs right through.

G1-5: And the crops you're using.

G1-7: We tend not to look at places where irrigation is necessary. I don't even look at sandy property.

G1-4: With pickles, carrots and potatoes you want sand. With corn you need soil that holds water better.

G1-5: I'd rather farm sand and irrigate it than heavy clay. This way it's controllable and yield potential is higher.

G1-4: You can control your water on sand, but if you get a heavy clay any rainwater is going to remain there.

G1-5: If I see a lot of irrigators in an area, I'm more confident about being able to get water from the same land. Another important factor is the location of pivots in relation to houses and town.

G1-2: The more houses around I consider a negative. We tend to drill wells in the middle of the field to avoid complaints. Gratiot

G1-7: If citizens can see the irrigation equipment, it is easier for them to complain and blame farmers when water is short.

M1-8: Soil type is an important factor. Sandy loam without clay, the availability will be tighter, while clay prevents water from just flowing through.

M1-1: Soil that will take water will give water. Also farming activities: if there are a lot of farmers getting water in an area, you're more likely to be able to access water as well. Talk to other farmers about how much water they are getting. If you have surface water that you can pump out of, that would be number one.

M1-9: Surface water is the cheapest option if you can get a permit. Those are getting harder to come by.

M1-1: A lot of zoning around towns about water is making it difficult for users to access more water. As long as the right to farm don't guarantee water, people are going to want these rights protected by law.

G2-1: If there are gravel pits around and they have water in them, that's a good sign of available water.

G2-6: How far down you have to dig a well to get sustainable water. I don't take into account surface water when I think about how much water there is.

G2-1: If others are irrigating around there, information about the depth they have to go, the yield of the wells. And talk to well drillers – they know what's down there. Another important thing is the water withdrawal assessment tool that we have to go through to see if we can even put in a well someplace.

G2-6: On the social side, I'd talk with neighbors to see how deep their wells are, how old their wells are. If theirs are down 50-60ft, you might want to go even deeper, down under where they are getting water so you don't interfere – the aquifers hopefully aren't connected.

G2-1: If there are interferences between municipal and irrigation uses of water, farmers use is cut back first, even if the farmer was using the water before municipal uses came it.

G2-6: If you talk to most farmers, generational knowledge is important – about where water is in the county, where it is in Michigan. The information that's been around and handed down, by well drillers and farmers, nothing new has opened up except the horizontal wells and that's been extraordinary. This knowledge was developed through trial and error, since there's nothing else to go on.

G2-1: Yeah, somebody who's been in the business can tell you what's down there.

M2-8: The presence of lakes or swamps, rivers and creeks. To me that means there's an abundance of water.

M2-1: More trees and grass with heavier soils. Not sandy.

M2-8: The soil type.

M2-1: If you've got heavier soils it'll hold moisture better.

M2-4: If people irrigate, it tells me that the ground is lighter, and if they are irrigating successfully I'll likely be able to irrigate there as well.

M2-5: It also depends on what industries are around, because I farm under certain contracts where if I don't irrigate then I lose the contract.

M2-6: There is a social side to irrigation. If Chris puts up a pivot and I see his crops are doing better than mine, then I'm probably going to think about putting up a pivot.

M2-7: We use irrigation on our farm as insurance.

M2-6: The price of commodities influences how likely a person is to use irrigation, because it impacts how quickly the investment pays for itself.

M2-5: The Water Withdrawal Assessment Tool tells you whether you can get any water in an area or not.

M2-6: We are up against that in one area where we can't dig anymore wells.

M2-1: I think that someday we are going to have a quota system on our water.

M2-8: They already have quota systems out in western states, so they'll probably start here even though we are setting good with water compared to drier states.

M2-6: When that first rule came out that we were supposed to start reporting water, there was a lot of gnashing of teeth. Contractors told us to put down that we are using a large volume 24 hours a day, 7 days a week, year round so that when the state starts cutting us back we will still have plenty to do what we need to do with it. So far it's just reporting, but someday it'll be more than that.

M2-5: The percentage of people who use water and report is definitely less than 100%. I bet around half of people who use water don't.

S1-1: Intensity of water use as opposed to just area irrigated. Also crop types bring with the different amount and timing of water demands. Density of users to one another in a given area.

S1-3: Presence of wetlands and surface water. Temperature.

S1-1: Slope of the land. If you are truly a good steward you don't want to produce so much runoff. The type of tillage and best management practices.

S1-3: Another one becoming more prevalent it irrigating at night instead of during the day to reduce evaporation rates.

S1-1: Soil type.

S1-3: The amount of organic matter in the soil. I have sandy ground that doesn't hold water so more organic matter would help retain water. I plan on starting to use cover crops to plow under and build a base of organic matter.

S1-1: Growing contract crops has put greater pressure on water resources. Economically, it is wise to go with contract crops, and the only way to get a contract is to have irrigation systems. And contract crops often require more water than others.

B1-2: Like we were saying earlier, I think that river conditions are important. If the river is drying up then people using river water are going to be in trouble, and it might mean that people even groundwater will be affected.

B1-1: Yes, river conditions are important. I think that the size of the farm matters to, because if you have a bigger farm you're going to be using more water than small farms. If you've got a big farm with lots of crops, it will be harder to tolerate drought. You'll have to decide what to save and what you might have to let go.

B1-2: Another thing is the kind of soil you've got. If you have really heavy soils it can be easy to get too much water and flood. You'll probably have to tile some of your land. Sandy soils though mean that it is tougher to keep water there, and means you'll probably have to apply it more often. And with that is the kinds of crops you go, because some do better in different soils.

B1-1: Rainfall matters. If you aren't getting enough rain you're going to have to irrigate more, but if its raining good maybe you can water less.

Brockton: Now what about policy indicators of water availability?

G1-2: They are the reason we drill a lot of wells in certain years because we expect it to get worse.

G1-2: I can't remember the name, but we knew there was more reporting going on.

G1-4: Look at the Nestle Company in north east Michigan. They were brining water from Canada in brand new trucks, brand new trailers. This was in the 80s when no one was drinking bottled water and you'd never guess how it's changed to today. There is nothing wrong with house water, it's a matter of convenience.

G1-5: Of course you worry about the law. As a farmer, it seems like there is a lot of room for interpretation. As a riparian it seems that if you can drill down to water and use it that it's yours, but now that's really not the case. If you get complaints from a neighbor it's up to the person using the most water to prove that you're not sucking the others dry. It's incumbent on the farmer to prove that they aren't injuring municipal/home wells.

G1-2: The regulation is going to get harder. They are harder now than 5 years ago, and with the tool, whenever anyone draws from a watershed there is less for others.

G1-5: It’s also harder to place a well. There are certain stipulations for the motor, where you can place the gas tank – 800ft from the well, 300ft from a natural gas pipeline. There are a lot of health department rules. And nobody tells you about the rules until you try, and each step you go you find out there’s more rules you didn’t know about. If there was some centralized information resource that outlined all the rules we had to follow that would be great.

G1-2: The people we are working with are getting harder. It’s harder to work with them that it used to be, or that you expect it to be.

G1-5: The local health department here seems to be much more on the ball. Even though each department is supposed to follow them same rules, they differ based on interpretation. Some just want to prove that they have power.

S1-1: Townships and municipalities are considering proximity to residential areas when they are determining whether a well can be placed in a certain location. A good neighbor policy, so you don’t place a well within so many feet of a neighbors well – whether it is residential or not.

B1-2: I don’t really know about that.

B1-1: I think that local rules are getting harder. It’s definitely harder to get a permit for surface water, even if the state says you can. The health department has extra rules for what you can and can’t do.

Brockton: We are now going to vote, based on this list, what are the most important indicators for determining water is abundant or scarce?

G1:
Gratiot 1: Depth of wells – 3 votes
Ease of accessing water (Successful well/# of test wells) – 3 votes
Number of users (more users = more water abundance) – 2 votes
Soil type – 1 vote
Presence of surface water/Natural ecosystems – 1 vote
Proximity of irrigation wells in relation to residential areas – 1 vote
Regulators are harder to work with – 1 vote
Crop type – 0 votes
Regulations becoming more strict – 0 votes
Burden of proof on farmers in irrigation-residential well conflicts – 0 votes
Harder to place a well (health department and environmental regulations) – 0 votes
Lack of consistent rules (municipalities implement rules differently) – 0 votes

---

M1:

Montcalm 1: Soil type (sandy = more drainage, clay = more storage) – 3 votes
Presence of surface water/natural ecosystems – 3 votes
State cap on withdrawals – 1 vote
GAMPs from Farm Act – 1 vote
Number of users (more users = more water abundance) – 1 vote
Residential zoning rules – 0 votes
Health Department regulations – 0 votes
Access to 3-phase power (to run irrigation) – 0 votes

G2:

Gratiot 2: Water Withdrawal Assessment Tool – 4 votes
Historical/professional (well driller) knowledge about water availability – 2 votes
Information from neighbors about well depth and age – 0 votes
Depth of wells to sufficient supplies – 0 votes

M2:

Montcalm 2: Presence of surface water/natural ecosystems – 8 votes
Number of users (more users = more water abundance) – 4 votes
Crop type – 3 votes
Worry about quotas – 1 vote
Contract farming – 1 vote
Does my neighbor irrigate (perception that a neighbors practice is useful) – 1 vote
Water Withdrawal Assessment Tool – 0 votes
Increased reporting requirements – 0 votes
Crop prices – 0 votes
Irrigation as insurance policy – 0 votes
Soil type – 0 votes

S1:

St. Joe 1: Density of irrigators – 3 votes
Contract crops/ Crop type – 2 votes
Intensity of water use – 1 vote
Irrigating at night – 1 vote
Temperature – 1 vote
Soil Type – 1 vote
Slope of the land – 0 votes

Proximity of irrigation wells in relation to residential areas – 0 votes

---

B1:
Branch 1: Presence of surface water/natural ecosystems – 3 votes
Soil Type – 2 votes
Size of farm – 1 vote
Precipitation – 0 votes
Crop type – 0 votes
Health Department rules – 0 votes

Brockton: So we've spend some time talking about indicators of water availability, and as we can see from the votes, even within this group there are some differences in opinion about what indicators are important. Are there certain characteristics of farmers and/or their operations that will make them more likely to believe some indicators are more relevant for predicting water availability?

G1-2: If you're very risk averse and worried about interfering with a neighbor's well, you might never drill. And for certain crops, such as potatoes, you have to irrigate, there's no other option.

G1-5: You have to have enough capital to put in irrigation systems, and to hire people to manage them. A hobby farmer is less likely to put in wells because he isn't doing it for the money as much as a person who's income is predominately from farming. And then there's the aspect of, if my neighbor is doing something that appears successful, I'll think about doing it too.

G1-4: If you've got land that doesn't absolutely need the water and can still produce, you're not going to irrigate because you can invest that money elsewhere. A well and a pivot is not something you want to take on late in life.

G1-5: It's a person's personality.

M1-8: I'm going to say if you are a larger farmer moving into a new area, or expanding, you're going to be worried about political issues related to putting down a well. They don't want to have to fight to access water, and that might determine whether they are going to try to move into the new area at all.

G2-1: If people see lots of irrigation in a certain area, they can be pretty sure that water is relatively abundant. That is the quickest first-pass through. If you're coming into a new area, and you see lots of irrigation, you're going to think that you can pull it off too.

G2-6: The type of soil farmers grow crops on will determine whether people will use irrigation. I hate irrigating, when I'm doing it there's always something breaking down and needing to be fixed. I don't look at ground and think about it in terms of abundance, I bet that people who've been irrigating their whole lives are more likely to think in those terms. I don't think climate change is something on people's mind because of crop technologies – with hybrids we can have excellent and good yields even with drier times.

M2-8: The bigger, more progressive farmers are thinking about irrigation than the hobby farmer. Pretty cut and dry. If you're making your money farming you're thinking about irrigation to increase yields, while a guy with a job who farms for fun is less likely to invest the money in irrigation.

M2-5: Yeah if 100% of your income comes from farming you're going to make decisions that increase your income.

M2-4: Older people who haven't used irrigation since they were young tend not to make the transition in their later years. And one of the first things I think people are going to look at is the Water Withdrawal Assessment Tool because if you can't get a permit it doesn't matter how much water is actually there.

M2-8: For professional farmers, its economics. If there is a way to make a buck, they're in for it. One of the best returns is putting water on crops. Farming is increasingly competitive, you've got to be smart and willing to be informed on the newest emerging practices and implement them wisely.

S1-1: I think that's to my point about the contract crops, because in that business water is so essential for those crops. If you're not looking at a contract crop you might not be as intensely interested in water availability. I think also it depends on your personal sense of stewardship and the role of farmers in sustainability. We do have irrigators who are not concerned about that at all, who say to themselves I'm going to take my money are run now.

S1-3: Yeah it again brings up sustainability. I'm looking at farming long term and I hope my son or daughters can continue our farming practices. If they chose not to that's fine, but I at least want that to be an option.

S1-3: You've got to have a return on investment. People are going to put in water irrigation if doing so allows them to make more money over time

S1-3: Another thing is knowledge about how much water is adequate for crops. I have a friend who oversaturates his field, and I think it's because he doesn't know what is enough.

S1-2: We put in technology to detect the soil moisture, and have been able to save ourselves a lot of money and water by being more precise with application. We can check our soil moisture frequently and accurately and then can only irrigate when it's necessary. It's an investment up front but it's worth it over time.

B1-2: I'd say it depends on how important farming is to you financially. The people who make their living farming are probably going to irrigate, because it is the biggest return on investment you can make.

Brockton: It terms of sending out the survey, do you think it would be best to have farmers fill out a paper copy or do it online?

G1-7: You send me an email, you're not going to get it back.

G1-5: Paper surveys are better. Give us a reason to do it, say it's for your thesis.

G1-2: I'd do paper.

G1-4: I get too many emails a day, it's not going to get done with email.

M1-8: Many of the older farmers don't like computers and going online, so you're better doing the paper option. But I'd rather use the internet option.

M1-1: You've got the generation gap, I'd rather do it with paper.

M1-8: If it's a shorter survey, I think paper is easier.

G2-1: Paper definitely.

G2-6: I never use the computer for surveys. Younger generation might use the computer but the people likely to respond are the older generation.

M2-7: I'd rather do it on paper. Maybe younger people would use a computer but I bet most will prefer paper.

M2-1: I would probably fill out a piece of paper first.

M2-5: Most of the guys are older and I bet most people will do it on paper.

S1-1: I think that paper will get more responses, because the farmer population is older and less likely to be comfortable with using the internet.

B1-1: Paper surveys are going to be better.

B1-2: Maybe some of the younger farmers would prefer to use the computer, but us older guys want something to hold in our hands.

Brockton: Is there anything else about water availability that you want to talk about, that you think is important but didn't get addressed yet?

G1-2: I think we are running into a problem with the state about what they are saying is available and what they can permit. We can't put in a 25ft ditch because it might drain the streams, but then we've got to put in a well that's super deep on the same plane as houses that might cause a well to well conflict. But if I'm at 25ft I'm pretty sure I'm not going to drain your house well. These are getting to be a tougher option though I think its best in the right soil.

G1-5: They are the hardest ones to permit right now because they are shallow and effect surface water and fish. You can permit a bedrock well because they don't consider that groundwater as connected to the surface water.

G1-4: It costs a lot of money to pump water.

G1-2: Once you've passed the screening tool, the health department can't deny you.

G1-5: I think the state needs to do a study to quantify water availability in the state. Michigan has more water than almost any place in the nation and we are afraid to develop these resources. Why are Michigan's economic capabilities poor when we have the ability to make use of them? If water isn't scarce, why aren't we going out and pursuing economic development?

G1-7: If we have rules that are reasonable and constant, the farmers can play by them. But if certain counties can change the rules when they want to, then farmers will be less apt to accept them.

M1-9: If there is 3-phase available, power availability is important.

G2-6: I think that as a farming community we're going to have to become very careful with how much we are trying to irrigate. Some land that's not productive but we are trying to irrigate it anyways. The right to farm act is strong, but there are a lot of people willing to pay more for food and so cheap food goes out the window – with cheap food is more land and a greater quantity of food to keep prices down. The reputation of farmers is under closer scrutiny and as more and more pivots go up, people will be more apt to blame farmers for dried up wells.

G2-1: Yeah, it's the visibility of the pivots. We have to be careful about what we do because if we get certain people in government we might have to start paying for water itself.

M2-4: I think the biggest thing is regulations. The water is there and I think it's safe to say that my kids will have water to pump out of the ground, but the question is if they will be allowed.

M2-8: We are very fortunate to be surrounded by freshwater, and anyone who doesn't understand that is blind to what we've got.

M2-5: We have a humid climate. That means we can use more water and have it returned to the system as opposed to evaporate away.

M2-1: An important question is who owns the water under your property.

M2-7: We all will probably agree that there is a fair amount of water in the state of Michigan, especially where we are in Montcalm County, and I haven't heard of anyone worried about scarcity from lack of water but from the threat of increased regulation.

M2-8: We are doing fine with water around here, but I bet someday there'll be outsiders who try to regulate. They'll say we have a problem with water when in fact no we don't.

APPENDIX G.

Transcript Analysis Storyline

This research is based in collaborative governance theory, focusing on the role that perceptions of resource conditions play in fostering cooperation amongst users of common pool resources. The idea is that the more similar perceptions are regarding resource conditions within a group, the more likely members are to collaboratively govern resources. In order to understand whether Michigan crop irrigators identified similar aspects of the world as water availability indicators, this research seeks to understand what indicators farmers use to evaluate water availability. Two water availability indicator classification schemes were developed prior to the research, based on previous investigations. The first framework organizes indicators according to whether they are on an environmental, socioeconomic, or policy-legal character. This categorization creates a nuanced understanding of how irrigators perceive the world around them in terms of water availability indicators, as well as what values of indicators signal relative scarcity or abundance. The second classification strategy designates whether a particular environmental, socioeconomic or policy-legal indicator shifts water supply or demand.

APPENDIX H.

Codebook

Farmer Characteristics
Use this code when participants discuss the idea that irrigators' perceptions of which water availability indicators are most important depend on personal characteristics, or characteristics of the farming operation.

Age of farmer
Use this code when participants discuss the role that farmers' age plays in influencing perceptions about which water availability indicators are most important.

Personal idiosyncrasies
Use this code when participates discuss the idea that irrigators' perceptions about which water availability indicators are most important depend on personal idiosyncrasies.

Risk averse individuals are less willing to invest in irrigation systems
Use this code when participants discuss the idea that irrigators' perceptions about which water availability indicators are most important depends on how risk averse individuals are.

Wealth
Use this code when participants discuss the idea that irrigators' perceptions about which water availability indicators are most important depend on degree of wealth, or the idea that ability to invest in irrigation systems and other technologies depends on wealth.

Environmental
Use this code when participants discuss water availability indicators that are of an environmental nature.

Availability ≠ abundance
Use this code when participants discuss the idea that water availability is not the same as water abundance.

Available surface water
Use this code when participants discuss the influence that available surface water has on perceptions about the abundance/scarcity of water resources.

Ease of accessing groundwater (success/attempts)

Use this code when participants discuss the influence that the ease of accessing groundwater has on perceptions about water availability.

Geology
Use this code when participants talk about the variability of surface water and groundwater across the landscape being a function of geological processes.

Groundwater-surface water connectivity
Use this code when participants talk about the interconnectivity of surface water and groundwater, or lack thereof.

Natural ecosystems (negative - drainage)
Use this code when participants discuss the presence of natural water-based ecosystems as having a negative impact on farming.

Natural ecosystems (positive – more water)
Use this code when participates discuss the presence of natural water-based ecosystems as having a positive impact on farming.

Soil type
Use this code when participants discuss the influence that soil type has on perceptions about water availability.

Temperature
Use this code when participants discuss the influence of temperature on perceptions about water resource availability.

Water quality
Use this code when participants discuss the influence of water quality on perceptions about water resource availability.

Well depth
Use this code when participants discuss the influence that the depth of wells irrigators have to drill in order to access sufficient quantities of water has on perceptions about water resource availability.

Well volume
Use this code when participants discuss the influence that the volume of water wells are able to produce has on perceptions about water resource availability.

<u>Social-Economic</u>
Use this code when participants discuss water availability indicators that are of a social-economic nature.

Above-stream users
Use this code when participants discuss the fact that personal water use is influenced by that of other water users' above-stream from them.

Age of wells
Use this code when participants discuss the influence that well age has on perceptions about water availability in a region.

Commodity prices
Use this code when participants discuss the influence that commodity prices has on investment in irrigation systems or perceptions about water availability.

Competition
Use this code when participants discuss the influence that competition has on investment in irrigation systems or perceptions about water availability.

Contract farming
Use this code when participants discuss the role of contract farming on investment in irrigation systems or perceptions about water availability.

Crop type
Use this code when participants discuss the role of crop type on investment in irrigation or perceptions about water availability.

Data collection independent of the State
Use this code when participants talk about collecting water resource measurements independent of the State's Water Withdrawal Assessment Tool.

Dry wells
Use this code when participants discuss the influence that dry wells have on perceptions about water availability in a region.

Efficiency
Use this code when participants discuss the importance of water efficiency or technologies that increase water use efficiency.

Farmer reputation in society
Use this code when participants discuss the importance that farmers' reputation in society has for the ability of this community to continue irrigating.

Incomplete reporting (free riders)
Use this code when participants discuss the fact that not all water users report use as they are supposed to.

Increased number household wells = increased social conflict
Use this code when participants discuss the role that a greater number of household wells has on the probability of well to well conflicts.

More irrigators = more abundance
Use this code when participants talk about the idea that a greater number of irrigators in an area indicates greater water availability.

More irrigators = more scarcity
Use this code when participants talk about the idea that a greater number of irrigators in an area indicates less water availability.

Power availability
Use this code when participants discuss their ability to irrigate as being influenced by the availability of electrical power.

Relative dependence of farming income
Use this code when participants discuss the idea that irrigators' perceptions about which water availability indicators are most important depend on their relative dependence on income from farming.

Social conflict
Use this code when participants discuss the influence that risks of social conflict have on perceptions about water availability, or farming practices.

Stewardship
Use this code when participants discuss the importance of irrigators considering themselves stewards with some responsibility for practicing sustainable agriculture.

Sustainability
Use this code when participants discuss ways that irrigators can practice sustainable water use.

Technology
Use this code when participants discuss technologies that can be used to increase the efficiency of water use.

Trust
Use this code when participants discuss trust in the State's Water Withdrawal Assessment Tool or regulators.

Water bottling companies
Use this code when participants discuss water bottling companies in the context of water use sectors in competition with agricultural irrigation.

Policy-Legal
Use this code when participants discuss water availability indicators that are of a policy-legal nature.

Access to information about rules
Use this code when participants discuss the benefits that easier access to relevant permitting information would have for successfully completing permit applications.

Consistent rules from county to county
Use this code when participants discuss the importance of consistent permitting rules across counties.

Farmer-regulator relations
Use this code when participants discuss the role that relationships between farmers and regulators has on perceptions about water availability.

Fear of greater restrictions
Use this code when participants discuss fear of increased water use restrictions.

Health department restrictions
Use this code when participants discuss the influence of health department restrictions on perceptions about water availability.

Rules about groundwater ownership
Use this code when participants discuss the influence that rules regarding groundwater ownership has on perceptions about water availability.

Water Withdrawal Assessment Tool
Use this code when participants discuss the influence of the Water Withdrawal Assessment Tool on perceptions about water resource availability, fear of restrictions, or trust in the State.

Zoning ordinances
Use this code when participants discuss the role of zoning ordinances on perceptions about water resource availability.

Knowledge
Use this code when participants talk about knowledge of various aspects of the world as influencing how they interpret resource availability.

Generational/well-driller knowledge

Use this code when participants discuss the idea that their personal knowledge of water availability is informed by older farmers and well drillers.

Knowledge of crop biology
Use this code when participants talk about how a lack of knowledge about crop biology results in inefficient watering practices.

<u>Supply</u>
Use this code when participants talk about water availability indicators associated with the supply of water resources.

Above-stream users
Use this code when participants discuss the fact that personal water use is influenced by that of other water users' above-stream from them.

Age of wells
Use this code when participants discuss the influence that well age has on perceptions about water availability in a region.

Availability ≠ abundance
Use this code when participants discuss the idea that water availability is not the same as water abundance.

Available surface water
Use this code when participants discuss the influence that available surface water has on perceptions about the abundance/scarcity of water resources.

Consistent rules from county to county
Use this code when participants discuss the importance of consistent permitting rules across counties.

Data collection independent of the State
Use this code when participants talk about collecting water resource measurements independent of the State's Water Withdrawal Assessment Tool.

Dry wells
Use this code when participants discuss the influence that dry wells have on perceptions about water availability in a region.

Ease of accessing groundwater (success/attempts)
Use this code when participants discuss the influence that the ease of accessing groundwater has on perceptions about water availability.

Farmer-regulator relations
Use this code when participants discuss the role that relationships between farmers and regulators has on perceptions about water availability.

Generational/well-driller knowledge
Use this code when participants discuss the idea that their personal knowledge of water availability is informed by older farmers and well drillers.

Geology
Use this code when participants talk about the variability of surface water and groundwater across the landscape being a function of geological processes.

Groundwater-surface water connectivity
Use this code when participants talk about the interconnectivity of surface water and groundwater, or lack thereof.

Health department restrictions
Use this code when participants discuss the influence of health department restrictions on perceptions about water availability.

Incomplete reporting (free riders)
Use this code when participants discuss the fact that not all water users report use as they are supposed to.

More irrigators = more abundance
Use this code when participants talk about the idea that a greater number of irrigators in an area indicates greater water availability.

More irrigators = more scarcity
Use this code when participants talk about the idea that a greater number of irrigators in an area indicates less water availability.

Natural ecosystems (negative - drainage)
Use this code when participants discuss the presence of natural water-based ecosystems as having a negative impact on farming.

Natural ecosystems (positive – more water)
Use this code when participates discuss the presence of natural water-based ecosystems as having a positive impact on farming.

Power availability
Use this code when participants discuss their ability to irrigate as being influenced by the availability of electrical power.

Rules about groundwater ownership
Use this code when participants discuss the influence that rules regarding groundwater ownership has on perceptions about water availability.

Social conflict
Use this code when participants discuss the influence that risks of social conflict have on perceptions about water availability, or farming practices.

Soil type
Use this code when participants discuss the influence that soil type has on perceptions about water availability.

Temperature
Use this code when participants discuss the influence of temperature on perceptions about water resource availability.
Trust
Use this code when participants discuss trust in the State's Water Withdrawal Assessment Tool or regulators.

Water quality
Use this code when participants discuss the influence of water quality on perceptions about water resource availability.

Water Withdrawal Assessment Tool
Use this code when participants discuss the influence of the Water Withdrawal Assessment Tool on perceptions about water resource availability, fear of restrictions, or trust in the State.

Well depth
Use this code when participants discuss the influence that the depth of wells irrigators have to drill in order to access sufficient quantities of water has on perceptions about water resource availability.

Well volume
Use this code when participants discuss the influence that the volume of water wells are able to produce has on perceptions about water resource availability.

Zoning ordinances
Use this code when participants discuss the role of zoning ordinances on perceptions about water resource availability.

<u>Demand</u>
Use this code when participants talk about water availability indicators associated with the demand for water resources.

Access to information about rules
Use this code when participants discuss the benefits that easier access to relevant permitting information would have for successfully completing permit applications.

Commodity prices
Use this code when participants discuss the influence that commodity prices has on investment in irrigation systems or perceptions about water availability.

Competition
Use this code when participants discuss the influence that competition has on investment in irrigation systems or perceptions about water availability.

Contract farming
Use this code when participants discuss the role of contract farming on investment in irrigation systems or perceptions about water availability.

Crop type
Use this code when participants discuss the role of crop type on investment in irrigation or perception of water availability.

Efficiency
Use this code when participants discuss the importance of water efficiency or technologies that increase water use efficiency.

Farmer reputation in society
Use this code when participants discuss the importance that farmers' reputation in society has for the ability of this community to continue irrigating.

Fear of greater restrictions
Use this code when participants discuss fear of increased water use restrictions.

Increased number household wells = increased social conflict
Use this code when participants discuss the role that a greater number of household wells has on the probability of well to well conflicts.

Knowledge of crop biology
Use this code when participants talk about how a lack of knowledge about crop biology results in inefficient watering practices.

Relative dependence of farming income
Use this code when participants discuss the idea that irrigators' perceptions about which water availability indicators are most important depend on their relative dependence on income from farming.

Stewardship
Use this code when participants discuss the importance of irrigators considering themselves stewards with some responsibility for practicing sustainable agriculture.

Sustainability
Use this code when participants discuss ways that irrigators can practice sustainable water use.

Technology
Use this code when participants discuss technologies that can be used to increase the efficiency of water use.

Water bottling companies
Use this code when participants discuss water bottling companies in the context of water use sectors in competition with agricultural irrigation.

BIBLIOGRAPHY

BIBLIOGRAPHY

Abedin, A., Habiba, U., Shaw, R. (2014). Community perception and adaptation to safe drinking water scarcity: Salinity, arsenic, and drought risks in central coastal Bangladesh. *International Journal of Disaster Risk Science, 5,* 110-124. http://dx.doi.org/10.1007/s13753-014-0021-6.

Agrawal, A. (2001). Common property institutions and sustainable governance of resources. *World Development, 29*(10), 1649-1672.

Allouche, J. (2011). The sustainability and resilience of global water and food systems: Political analysis of the interplay between security, resource scarcity, political systems and global trade. *Food Policy, 36,* s3-s8. http://dx.doi.org/10.1016/j.foodpol.2010.11.013.

Andersson, K.P., Gibson, C.C., Lehoucq, F. (2004). The politics of decentralized natural resource governance. *PS: Political Science and Politics, 37*(3), 421-426.

Angel, J.R., Kunkel, K.E. (2010). The response of Great Lakes water levels to future climate scenarios with an emphasis on Lake Michigan-Huron. *The Journal of Great Lakes Research, 36,* 51-58. http://dx.doi.org/10.1016/j.jglr.2009.09.006.

Ansell, C., and Gash, A. (2007). Collaborative governance in theory and practice. *Journal of Public Administration Research and Theory, 18*, 543-571.

Araral, E. (2009). What explains collective action in the Commons? Theory and evidence from the Philippines. *World Development, 37*(3), 687-697. http://dx.doi.org/10.1016/j.worlddev.2008.08.002.

Baker, T.J., Miller, S.N. (2013). Using the Soil and Water Assessment Tool (SWAT) to assess land use impact on water resources in an East African watershed. *Journal of Hydrology, 486,* 100-111. http://dx.doi.org/10.1016/j.jhydrol.2013.01.041.

Bardhan, P. (1993). Analytics of the institutions of informal cooperation in rural development. *World Development, 21*(4), 633-639.

Barry, J., Smith, K. (2008). Landscape, politics, labor and identity: Stewardship and the contribution of green political theory. *Landscape Research, 33*(5), 565-585. http://dx.doi.org/10.1080/01426390802323781.

Baumgärner, S., Quass, M. (2010). What is sustainability economics? *Journal of Ecological Economics, 69,* 445-450. http://dx.doi.org/10.1016/j.ecolecon.2009.11.019.

Bell, J.E., Autry, C.W., Mollenkopf, D.A., Thorton, L.M. (2012). Natural resource scarcity typology: Theoretical foundations and strategic implications for supply chain management. *Journal of Business Logistics, 33*(2), 158-166.

Berdej, S.M., Armitage, D.R. (2016). Bridging organizations drive effective governance outcomes for conservation of Indonesia's marine systems. *PloS One, 11*(1). http://dx.doi.org/10.1371/journal.pone.0147142.

Blanco, E., Lopez, M.C., Villamayor-Tomas, S. (2015). Exogenous degradation in the commons: Field experimental evidence. *Ecological Economics, 120*, 430-439. http://dx.doi.org/10.1016/j.ecolecon.2015.03.028.

Bodin, O., Crona, B.I. (2009). The role of social networks in natural resource governance: What relational patterns make a difference? *Global Environmental Change, 19, 366-374.* http://dx.doi.org/10.1016/j.gloenvcha.2009.05.002.

Bogardi, J.J., Dudgeon, D., Lawford, R., Flinkerbusch, E., Meyn, A., Pahl-Wostl, C., Vielhauer, K., Vörösmarty, C. (2012). Water security for a planet under pressure: Interconnected challenges of a changing world call for sustainable solutions. *Current Opinion in Environmental Sustainability, 4,* 35-43. http://dx.doi.org/10.1016/j.cosust.2011.12.002.

Bolla, C.M., Joseph, J., Norbeck, J., Smith, R. (1996). Social support as road map and vehicle: An analysis of data from focus group interviews with a group of African women. *Public Health Nursing, 13*(5), 331-336.

Booher, D.E. (2004). Collaborative governance practices and democracy. *National Civic Review, 93*(4), 32-46.

Bretschger, L. (2013). Population growth and natural-resource scarcity: Long-run development under seemingly unfavorable conditions. *Scandinavian Journal of Economics, 115*(3), 722-755. http://dx.doi.org/10.1111/sjoe.12017.

Brisbois, M.C., de Loe, R.C. (2016). State roles and motivations in collaborative approaches to water governance: A power theory-based analysis. *Geoforum, 74*, 202-212. http://dx.doi.org/10.1016/j.geoforum.2016.06.012.

Brown, J.F., Hamilton-Mason, J., Maramaldi, P., Barnhill, L.J. (2016). Exploring perspectives of individuals with intellectual disabilities and histories of challenging behaviors about family relationships: An emergent topic in a grounded theory focus group study. *Journal of Mental Health Research in Intellectual Disabilities,* 1-24. http://dx.doi.org/10.1080/19315864.2016.1181813.

Carrion, F., Sanchez-Vizcaino, J., Corcoles, J.I., Tarjuelo, J.M., Moreno, M.A. (2016). Optimization of groundwater abstraction system and distribution pipe in pressurized irrigation systems for minimum cost. *Irrigation Science, 34*(2), 145-159. http://dx.doi.org/10.1007/s00271-016-0489-5.

Chalmers, D.J. (2010). *The character of consciousness.* New York: New York: Oxford University Press.

Chenoweth, J. (2008). A re-assessment of indicators of national water scarcity. *Water International, 33*(1), 5-18. http://dx.doi.org/10.1080/02508060801927994.

Collins, T.W., Bolin, B. Characterizing vulnerability to water scarcity: The case of a groundwater-dependent, rapidly urbanizing region. *Environmental Hazards, 7*(4), 399 418. http://dx.doi.org/10.1016/j.envhaz.2007.09.009.

Comito, J., Wolseth, J., Morton, L.W. (2013). Stewards, businessmen, and heroes? Role conflict and contradiction among row-crop farmers in an age of environmental uncertainty. *Human Organization, 72*(4), 283-292.

Cornwall, A. (2008). Unpacking 'participation': Models, meanings and practices. *Community Development Journal, 43*(3), 269-283. http://dx.doi.org/10.1093/dcj/bsn010.

Craig, R.K. (2012). Defining Riparian rights as 'property' through takings litigation: is there a property right to environmental quality? *Environmental Law, 42*(1), 115-155.

Cumming, G.S. (2016). Heterarchies: Reconciling networks and hierarchies. *Trends in Ecology & Evolution, 31*(8), 622-632. http://dx.doi.org/10.1016/j.tree.2016.04.009.

Cuthill. M., (2010). Strengthening the 'social' in sustainable development: Developing a conceptual framework for social sustainability in a rapid urban growth region in Australia. *Sustainable Development, 18,* 362-373. http://dx.doi.org/10.1002/sd.397.

Davies, M.I.J. (2009). Wittfogel's dilemma: Heterarchy and ethnographic approaches to irrigation management in Eastern Africa and Mesopotamia. *World Archeology, 41*(1), 16-35. http://dx.doi.org/10.1018/00438240802666465.

Dell'Angelo, J., McCord, P.F., Gower, D., Carpenter, S., Caylor, K.K. (2016). Community water governance on Mount Kenya: An assessment based on Ostrom's design principles of natural resource management. *Mountain Research and Development, 36*(1), 102-115.

Donohew, Z. (2009). Property rights and western United States water markets. *The Australian Journal of Agricultural and Resource Economics, 53*, 85-103. http://dx.doi.org/10.1111/j.1467-8489.2007.00427.x.

Elbakidze, L., Shen, X., Taylor, G., Mooney, S. (2012). Spatiotemporal analysis of prior appropriations water calls. *Water Resources Research, 48.*

http://dx.doi.org/10.1029/2011WR010609,2012.

Erkuş-Öztürk, H., Eraydin, A. (2010). Environmental governance for sustainable tourism development: Collaborative networks and organization building gin the Antalya tourism region. *Tourism Management, 31*(1), 113-124. http://dx.doi.org/10.1016/j.tourman.2009.01.002.

Falkenmark, M. (1986). Fresh water – Time for a modified approach. *Ambio, 15,* 192-200.

Fan, H., He, D., Wang, H. (2015). Environmental consequences of damming the mainstream Lancang-Mekong River: A review. *Earth-Science Reviews, 146,* 77-91. http://dx.doi.org/10.1016/j.earscirev.2015.03.007.

Folke, C., Carpenter, S., Elmqvist, T., Gunderson, L., Holling, C.S., Walker, B. (2002). Resilience and sustainable development: Building adaptive capacity in a world of transformations. *AMBIO: A Journal of the Human Environment, 31*(5), 437-440. http://dx.doi.org/10.1579/0044-7447-31.5.437.

Forouzani, M., Karami, E., Zamani G.H., Moghaddam, K.R. (2013). Agricultural water poverty: Using Q-methodology to understand stakeholders' perceptions. *Journal of Arid Environments, 97*, 190-204. http://dx.doi.org/10.1016/j.jaridenv.2013.07.003.

Gleditsch, N.P., Furlong, K., Hegre, H., Lacina, B., Owen, T. (2006). Conflicts over shared rivers: Resources carcity or fuzzy boundaries? *Political Geography, 25,* 361-382. http://dx.doi.org/10.1016/j.polgeo.2006.02.004.

Grantham, T.E., Mezzatesta, M., Newburn, D.A., Merenlender, A.M. (2014). Evaluating tradeoffs between environmental flow protections and agricultural water security. *River Research and Applications, 30,* 315-328. http://dx.doi.org/10.1002/rra.2637.

Great Lakes Commission. (2015). Annual Report of the Great Lakes Regional Water Use Database. https://waterusedata.glc.org/pdf/2015-Water-Use-Report-Gallons-Liters FINAL.pdf.

Groenfeldt, D., Schmidt, J. (2013). Ethics and water governance. *Ecology and Society, 18*(1), 14-23.

Gupta, J., Vegelin, C. (2016). Sustainable development goals and inclusive development. *International Environmental Agreements: Politics, Law and Economics, 16*(3), 433-448. http://dx.doi.org/10.1007/s10784-016-9323-z.

Hall, N.D. (2011). Oil and freshwater don't mix: Transnational regulation of drilling in the Great Lakes. *Boston College Environmental Affairs Law Review, 38*(2), 305-316.

Hancock, M.E., Amankwaa, L., Revell, R.A., Mueller, D. (2016). Focus group data saturation: A new approach to data analysis. *The Qualitative Report, 21*(11), 2124-2130.

Hardelin, J., Lankoski, J. (2015). Climate change, water and agriculture: Challenges and adaptation strategies. *EuroChoices, 14*(2), 10-15. http://dx.doi.org/10.1111/1746 692X.12085.

Hecker, A. (2011). Specialization, implicit coordination and organizational performance: Trading off common and idiosyncratic knowledge. *Review of Managerial Science, 5*(1), 19-47. http://dx.doi.org/10.1007/s11846-010-0043-4.

Hiedanpää, J., Jokinen, A., Jokinen, P. (2012). Making sense of the social: human-nonhuman constellations and the wicked road to sustainability. *Sustainability: Science, Practice & Policy, 8*(1), 40-49.

Howe, P.D., Leiserowitz, A. (2013). Who remembers a hot summer or a cold winter? The asymmetric effect of beliefs about global warming on perceptions of local climate conditions in the U.S. *Global Environmental Change, 23,* 1488-1500. http://dx.doi.org/10.1016/j.gloenvcha.2013.09.014.

Huffaker, R., Whittlesey, N., Hamilton, J.R. (2000). The role of prior appropriation in allocating water resources into the 21st century. *Water Resources Development, 16*(2), 265-273.

Huffman, J.L. (2009). Comprehensive river basin management: The limits of collaborative, stakeholder-based, water governance. *Natural Resources Journal, 49*(1), 117-149.

Huh, W.T., Lall, U. (2013). Optimal crop choice, irrigation allocation, and the impact of contract farming. *Production and Operations Management, 22*(5), 1126-1143. http://dx.doi.org/10.1111/poms.12007.

Jaeger, W.K., Plantinga, A.J., Chang, H., Dello, K., Grant, G., Hulse, D., McDonnell, J.J., Lancaster, S., Moradkhani, H., Morzillo, A.T., Monte, P., Nolin, A., Santelmann, M., Wu, J. (2013). Toward a formal definition of water scarcity in natural-human systems. *Water Resources Research, 49*(7), 4504-4517. http://dx.doi.org/10.1002/wrcr.20249.

Jarvis, W.T. (2013). Water scarcity: Moving beyond indexes to innovative institutions. *Groundwater, 51*(5), 663-669. http://dx.doi.org/10.1111/gwat.12059.

Jonker, C.M., Robu, V., Treur, J. (2007). An agent architecture for multi-attribute negotiation using incomplete preference information. *Autonomous Agents and Multi-Agent Systems, 15,* 221-252. http://dx.doi.org/10.1007/s10458-006-9009-y.

Kates, R.W., Parris, T.M., Leiserowitz, A.A. (2005). What is sustainable development? Goals, indicators, values, and practice. *Environment, 47*(3), 8-21.

Kelley, L. (2016). Michigan State University Extension. Personal Communication.

Kim, J., Ivanov, V.Y., Fatichi, S. (2016). Climate change and uncertainty assessment over a hydroclimatic transect of Michigan. *Stochastic Environmental Research and Risk Assessment, 30,* 923-944. http://dx.doi.org/10.1007/s00477-015-1097-2.

Kitzinger, J. (1995). Qualitative research. Introducing focus groups. *BMJ, 311*, 299-302.

Koebele, E.A. (2015). Assessing outputs, outcomes, and barriers in collaborative water governance: A case study. *Journal of Contemporary Water Research & Education, 155,* 63-72. http://dx.doi.org/10.1111/j.1936-704X.2015.03196.x.

Krueger, R.A., Casey, M.A. (2009). *Focus Groups: A Practical Guide for Applied Research.* Thousand Oaks, California: Sage Publications, Inc.

Larson, K.L., White, D.D., Gober, P., Harlan, S., Wutich, A. (2009). Divergent perspectives on water resource sustainability in a public-policy-science context. *Environmental Science & Policy, 12,* 1012-1023. http://dx.doi.org/10.1016/.envsci.2009.07.012.

Laurent, S.J. (2002). Michigan Right to Farm Act: Have revisions gone too far. *Law Review of Michigan State University Detroit College of Law, 2002*(1), 213-242.

Lautenberger, M.C., Norris, P.E. (2016). Private rights, public interests and water use conflicts: Evolving water law and policy in Michigan. *Water Policy, 18*(4), 903-917. http://dx.doi.org/10.2166/wp.2016.037.

Lemos, M.C., Agrawal, A. (2006). Environmental governance. *Annual Review of Environment and Resources, 31*, 297-325.http://dx.doi.org/10.1146/annurev.energy.31.042605.135621.

Licht, J.F. (2011). Do we really want to know? The potentially negative effect of transparency in decision making on perceived legitimacy. *Scandinavian Political Studies, 34*(3), 183-201. http://dx.doi.org/10.1111/j.1467-9477.2011.00268.x.

Liu, Y., Pan, X., Li, J. (2015). Current agricultural practices threaten future global food production. *Journal of Agricultural and Environmental Ethics, 28*(2), 203-216. http://dx.doi.org/10.1007/s10806-014-9527-6.

Lockwood, M., Davidson, J., Curtis, A., Stratford, E., Griffith, R. (2010). Governance principles for natural resource management. *Society & Natural Resources, 23*(10), 986-1001. http://dx.doi.org/10.1080/08941920802178214.

Loos, J., Abson, D.J., Chappell, M.J., Hanspach, J., Mikulcak, F., Tichit, M., Fischer, J. (2014). Putting meaning back into "sustainable intensification". *Frontiers in Ecology and the Environment, 12*(6), 356-361. http://dx.doi.org/10.1890/130157.

Lubell, M. (2004). Collaborative watershed management: A view from the grassroots. *The Policy Studies Journal, 32*(3), 341-358.

Lusche, D. (2016). Department of Geography, Environmental, and Spatial Sciences, Michigan State University. Personal Communication.

Malley, Z. J.U., Taeb, M., Matsumoto, T., Takeya, H. (2008). Linking perceived land and water resources degradation, scarcity and livelihood conflicts in southwestern Tanzania: Implications for sustainable rural livelihood. *Environment, Development and Sustainability, 10*(3), 349-372. http://dx.doi.org/10.1007/s10668-006-9069-9.

Mangrio, M.A., Mirjat, M.S., Leghari, N., Buriro, R.A., Talpur, M.A., Shaikh, I.A., Mirjat, M.U. (2015). Evaluating farmers perceptions and technical approach regarding ground water extraction in lower Sindh. *Science International, 27*(1), 371-476.

Marchildon, G.P., Wheaton, E., Fletcher, A.J., Vanstone, J. (2016). Extreme drought and excessive moisture conditions in two Canadian watersheds: comparing the perception of farmers and ranchers with the scientific record. *Natural Hazards, 82*(1), 245-266. http://dx.doi.org/10.1007/s11069-016-2190-7.

Martin-Carrasco, F., Garrote, L., Iglesias, A., Mediero, L. (2013). Diagnosing causes of water scarcity in complex water resources systems and identifying risk management actions. *Water Resources Management, 27*(6), 1693-1705. http://dx.doi.org/10.1007/s11269-012
0081-6.

McCall, M.K., Dunn, C.E. (2012). Geo-information tools for participatory planning: Fulfilling the criteria for 'good' governance? *Geoforum, 43,* 81-94. http://dx.doi.org/10.1016/j.geoforum.2011.07.007.

McGinnis, M.D., Ostrom, E. (2014). Social-ecological system framework: initial changes and continuing challenges. *Ecology and Society, 19*(2), 30. http://dx.doi.org/10.5751/ES 06387-190230.

McGuire, J., Morton, L.W., Cast, A.D. (2013). Reconstructing the good farmer identity: Shifts in farmer identities and farm management practices to improve water quality. *Agricultural and Human Values, 30*(1), 57-69. http://dx.doi.org/10.1007/s10460-012-9381-y.

McKinny, M. (2001). What do we mean by consensus? Some defining principles. In: *Across the Great Divide.* Brick, P., Snow, D., Van de Wettering, S. Washington DC: Island Press, 102-111.

Meerganz von Medeazza, G. (2004). Water desalination as a long-term sustainable solution to alleviate global freshwater scarcity? A north approach. *Desalination, 169*(3), 287-301. http://dx.doi.org/10.1016/j.desa1.2004.04.001.

Mehta, L. (2007). Whose scarcity? Whose property? The case of water in western India. *Land Use Policy, 24,* 654-663. http://dx.doi.org/10.1016/j.landusepol.2006.05.009.

Meinzen-Dick, R., Raju, K.V., Gulati, A. (2002). What affects organization and collective action for managing resources? Evidence from canal irrigation systems in India. *World Development, 30*(4), 649-666.

Memon, A., Weber, E.P. (2010). Overcoming obstacles to collaborative water governance: Moving toward sustainability in New Zealand. *Journal of Natural Resources Policy Research, 2*(2), 103-116. http://dx.doi.org/10.1080/19390451003643593.

Mildner, S.A., Lauster, G., Wodni, W. (2011). Scarcity and abundance revisited: A literature review on natural resources and conflict. *International Journal of Conflict and Violence, 5*(1), 155-172.

Miller, S. (2016). Michigan State University Extension. Personal Communicatin.

Morgan, D.L. (1996). Focus groups. *Annual Review of Sociology, 22,* 129-152.

Murphy, K. (2012). The social pillar of sustainable development: A literature review and framework for policy analysis. *Sustainability: Science, Practice & Policy, 8*(1), 15-29.

Murtinho, F., Tague, C., de Bievre, B., Eakin, H., Lopez-Carr, D. (2013). Water scarcity in the Andes: A comparison of local perceptions and observed climate, land use and socioeconomic changes. *Human Ecology, 41,* 667-681.
http://dx.doi.org/10.1007/s10745
013-9590-z.

Natural Resources and Environmental Protection Act. Mich. Comp. Laws § 324. 32725.

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

Naimen, R.J., Dudgeon, D. (2011). Global alteration of freshwaters: Influences on human and environmental well-being. *Ecological Research, 26,* 865-873. http://dx.doi.org/10.1007/s11284-010-0693-3.

New, T., Xie, Z. (2008). Impacts of large dams on riparian vegetation: Applying global experience to the case of China's Three Gorges Dam. *Biodiversity Conservation, 17,* 3149-3163. http://dx.doi.org/10.1007/s10531-008-9416-2.

Noemdoe, S., Jonker, L., Swatuk, L.A. (2006). Perceptions of water scarcity: The case of Genadendal and outstations. *Physics and Chemistry of the Earth, 31,* 771-778. http://dx.doi.org/10.1016/j.pce.2006.08.003.

Oberkircher, L., Hornidge, A.K. (2011). "Water is life" – farmer rationales and water saving in Khorezm, Uzbekistan: A lifeworld analysis. *Rural Sociology, 76*(3), 394-421. http://dx.doi.org/10.1111/j.1549-0831.2011.00054.x.

O'Donnell, A.B., Lutfey, K.E., Marceau, L.D., McKinlay, J.B. (2007). Using focus groups to improve the validity of cross-national survey research: A study of physician decision making. *Qualitative Health Research, 17*(7), 871-981. http://dx.doi.org/10.1177/1049732307305257.

Oh, Y., Bush, C.B. (2016). Exploring the role of dynamic social capital in collaborative governance. *Administration & Society, 48*(2), 216-236. http://dx.doi.org/10.1177/0095399714544941.

Olmedo, A. (2014). From England with love … ARK, heterarchies and global 'philanthropic governance'. *Journal of Education Policy, 29*(5), 575-597. http://dx.doi.org/10.1080/02680939.2013859302.

Olson, M. (1965). *The logic of collective action: Public gods and the theory of groups.* Cambridge, Massachusetts: Harvard University Press.

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

Ostrom, E. (2007). A diagnostic approach for going beyond panaceas. *Proceedings of the Academy of Sciences of the United States of America, 104*(39), 15181-15187. http://dx.doi.org/10.1073/pnas.0702288104.

Ostrom, E. (2008). Institutions and the environment. *Economic Affairs, 28*(3).

Ostrom, E. (2009). A general framework for analyzing sustainability of social-ecological systems. *Science, 325,* 419-422.

Padowski, J.C., Jawitz, J.W. (2009). The future of global water scarcity: Policy and management challenges and opportunities. *The Whitehead Journal of Diplomacy and International Relations, 10*(2), 99-114.

Padowski, J.C., Jawitz, J.W. (2012). Water availability and vulnerability of 225 large cities in the United States. *Water Resources Research, 48*, W12529. http://dx.doi.org/10.1029/2012WR012335.

Paganelli, C.S. (2007). Creative judicial misunderstanding: Misapplication of the public trust doctrine in Michigan. *Hastings Law Journal, 58*(5), 1095-1121.

Pahl-Wostl, C., Craps, M., Dewulf, A., Mostert, E., Tabara, D., Taillieu, T. (2007). Social learning and water resources management. *Ecology and Society, 12*(2), 1-19.

Perkins, J.R., Beckley, T., Comeau, L., Stedman, R.C., Rollins, C.L., Kessler, A. (2017). Can distrust enhance public engagement? Insights from a national survey on energy issues in Canada. *Society & Natural Resources,* 1-15. http://dx.doi.org/10.1080/08941920.2017.1283076.

Perveen, S., James, L.A. (2011). Scale invariance of water stress and scarcity indicators: Facilitating cross-scale comparisons of water resources vulnerability. *Applied Geography, 31,* 321-328. http://dx.doi.org/10.1016/j.apgeog/2010.07.003.

Plieninger, T. (2006). Habitat loss, fragmentation, and alteration – quantifying the impact of land-use changes on a Spanish dehesa landscape bu sue of aerial photography and GIS. *Landscape Ecology, 21*, 91-105. http://dx.doi.org/10.1007/s10980-005-829-1.

Post, C. (2010). Exploring working-class consciousness: A critique of the Theory of 'Labor Aristocracy'. *Historical Materialism, 18*, 3-38. http://dx.doi.org/10.1163/15692061X550596.

Pretty, J. (2003). Social capital and the collective management of resources. *Science, 302*(5652), 1912-1914. http://dx.doi.org/10.1126/science.1090847.

Rabiee, F. (2004). Focus-group interview and data analysis. *Proceedings of the Nutrition Society, 63*(4), 655-660. http://dx.doi.org/proxy1.cl.msu.edu/10.1079/PNS2004399.

Reed, D.B. (2008). America's aging farmers: Tenacious, productive, and underresearched. *Journal of Agromedicine, 13*(2), 69-70. http://dx.doi.org/10.1080/10599240802293942.

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.* http://ascelibrary.org/doi/abs/10.1061/41143(394)37.

Rijsberman, F.R. (2006). Water scarcity: Fact of fiction? *Agricultural Water Management, 80,* 5 22. http://dx.doi.org/10.1016/j.agwat.2005.07.001.

Rittel, H.W.J., Webber, M.M. (1973). Dilemmas in a general theory of planning. *Policy Sciences, 4,* 155-169.

Rothwell, E. (2010). Analyzing focus group data: Content and interaction. *Journal for Specialists in Pediatric Nursing, 15*(2), 176-180.

Rubin, J., Rubin, I.S. (1995). *Qualitative interviewing: The art of hearing data.* Thousand Oaks, CA: Sage Publications.

Ryan, K.E., Gandha, T., Culbertson, M.J., Carlson, C. (2014). Focus group evidence: Implications for design and analysis. *American Journal of Evaluation, 35*(3), 328-345. http://dx.doi.org/10.11771098214013508300.

Sandler, T. (2010). Common-property resources: Privatization, centralization, and hybrid arrangements. *Public Choice, 143,* 317-324. http://dx.doi.org/10.1007/s11127-010-9620 y.

Schmitz, C., Lotze-Campen, H., Gerten, D., Dietrich, J.P., Bodirsky, B., Biewald, A., Popp, A. (2013). Blue water scarcity and the economic impacts of future agricultural trade and demand. *Water Resources Research, 49,* 3601-3617. http://dx.doi.org/10.1002/wrcr.20188.

Scott, T. (2015). Does collaboration make any difference? Linking collaborative governance to environmental outcomes. *Journal of Policy Analysis and Management, 34*(3), 537-572. http://dx.doi.org/10.1002/pam21836.

Seadon, J.K. (2010). Sustainable waste management systems. *Journal of Greater Production, 18*, 1639-1651. http://dx.doi.org/10.1016/j.jclepro.2010.07.009.

Seedang, S., Norris, P.E. (2011). Water withdrawals and water use in Michigan. *Michigan State University Extension, Extension Bulletin WQ-62.*

Sharma, V., Orindi, V., Hesse, C., Pattison, J., Anderson, S. (2014). Supporting local climate adaptation planning and implementation through local governance and decentralized finance provision. *Development in Practice, 24*(4), 579-590. http://dx.doi.org/10.1080/09614524.2014.907240.

Sim, J. (1998). Collecting and analyzing qualitative data: Issues raised by the focus group. *Journal of Advanced Nursing, 28*(2), 345-352.

Singh, A. (2015). Soil salinization and water logging: A threat to environment and agricultural sustainability. *Ecological Indicators, 57*, 128-130. http://dx.doi.org/10.1016/j.ecolind.2015.04.027.

Sirin, C.V. (2011). Scarcity-induced domestic conflict: Examining the interactive effects of environmental scarcity and 'ethnic' population pressures. *Civil Wars, 13*(2), 122-140.

http://dx.doi.org/10.1080/13698249.2011.576141.

Stack, N.T. (2010). The Great Lakes Compact and an Ohio constitutional amendment: Local protectionism and regional cooperation. *Boston College Environmental Affairs Law Review, 37*(2), 493-522.

Tauer, M.D. (2011). Evolution of the doctrine of equitable apportionment – Mississippi v. Memphis. *The University of Mississippi Law Review, 41*(4), 897-924.

Tang, J., Folmer, H., Xue, J. (2013). Estimation of awareness and perception of water scarcity among farmers in the Guanzhong Plain, China, by means of a structural equation model. *Journal of Environmental Management, 126,* 55-62. http://dx.doi.org/10.1016/j.jenvman.2013.03.051.

Taylor, S.J., Bogdan, R. (1998). *Introduction to qualitative research methods: A guidebook and resource.* New York, NY: John Wiley & Sons, Inc.

Theisen, O.M. (2008). Blood and soil? Resource scarcity and internal armed conflict revisited. *Journal of Peace Research, 45*(6), 801-818.

Uphoff, U., Wickramasinghe, M.L., Wijayaratna, C.M. (1990). Optimum participation in irrigation management: Issues and evidence from Sri Lanka. *Human Organization, 49*(1), 26-40.

Urquijo, J., de Stefano, L. (2016). Perception of drought and local responses by farmers: A perspective from the Jucar river basin, Spain. *Water Resources Management, 30*(2), 577 591. http://dx.doi.org/10.1007/s11269-015-1178-5.

Vermeylen, S. (2010). Resource rights and the evolution of renewable energy technologies. *Renewable Energy, 35,* 2399-2405. http://dx.doi.org/10.1016/j.renene.2010.03.017.

Vodden, K. (2015). Governing sustainable coastal development: The promise and challenge of collaborative governance in Canadian coastal watersheds. *The Canadian Geographer, 59*(2), 167-180. http://dx.doi.org/10.1111/cag.12135.

Weber, E.P., Belsky, J.M., Lach, D., Cheng, A.S. (2014). The value of practice-based knowledge. *Society and Natural Resources, 27,* 1074-1088. http://dx.doi.org/10.1080/08941920.2014.919168.

Wheeler, S.A., MacDonald, D.H., Boxall, P. (2017). Water policy debate in Australia: Understanding the tenets of stakeholders' social trust. *Land Use Policy, 63*, 246-254. http://dx.doi.org/10.1016/j.landusepol.2017.01.035.

White, S.S., Selfa, T. (2013). Shifting lands: Exploring Kansas farmer decision-making in an era of climate change and biofuels production. *Environmental Management, 51*, 379-391. http://dx.doi.org/10.1007/s00267-012-9991-6.

Wurbs, R.A., Walls, W.B. (1989). Water rights modeling and analysis. *Journal of Water Resources Planning and Management, 115*(4), 416-430.

Zeng, Z., Liu, J., Savenije, H. (2013). A simple approach to access water scarcity integrating water quantity and quality. *Ecological Indicators, 34*, 441-449. http://dx.doi.org/10.1016/j.ecolind.2013.06.012.

Zorn, T.G., Seelbach, P.W., Rutherford, E.S. (2012). A regional-scale habitat suitability model to assess the effects of flow reduction on fish assemblages in Michigan streams. *Journal of the American Water Resources Association, 48*(5), 871-895. http://dx.doi.org/10.1111/j.1752-1688.2012.00656.x.