

The evolution of norms and their influence on performance among self-governing irrigation systems in the Southwestern United States

Kelsey C. Cody

Institute of Behavioral Sciences, University of Colorado at Boulder, USA

kelsey.cody@gmail.com

Abstract: Irrigation is important for global food supply and is vulnerable to climate change. Internalized cultural norms are important for the performance of Common Pool Resource (CPR) regimes such as irrigation systems, but much is unknown about the role of norms in shaping irrigation performance. This paper applies multi-level selection (MLS) theory and CPR theory to a stratified, semi-random sample of 71 irrigation systems of distinct cultural origins in the Upper Rio Grande Basin of the United States to test hypotheses related to the role of norms in irrigation system form and function. Results show that internalized norms of cooperation are strongly associated with the rules and technologies adopted by irrigators, the frequency of water use violations, average crop production, and the equality of crop production. Systems with internalized norms of cooperation have adopted rules and technologies which are associated with increased care for the commons, public goods, and higher equality between irrigators. Further, agents designated as monitors of CPR use have different effects depending on whether irrigators possess cooperative or competitive norms. Notably, the presence of monitors that enforce rules that are incongruent with norms is associated with increased water use violations and lower average crop production. These findings add weight to the growing body of work giving greater attention to cultural context when analyzing user-governed CPR regimes and climate resilience, and further illustrate the compatibility of MLS theory with other prevailing theories in CPR research.

Keywords: Climate change, common pool resources, culture, evolution, irrigation, norms

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I. Norms, rules, and irrigation performance in self-governing irrigation systems

Cultural norms are an important and under-studied factor in the management of user-governed common pool resources (CPRs) such as irrigation systems (Poteete et al. 2010; Vollan and Ostrom 2010; Vollan et al. 2013). Norms are codes of behavior which are socially enforced as opposed to legally enforced; there is no prescribed punishment for violating them, but violators usually face some form of informal social punishment (Ostrom 2000). Punishments such as public shaming and social exclusion apply costs, ultimately offsetting important benefits drawn from the group such as access to resources and social status and networks (Richerson et al. 2002; Creanza et al. 2017; Waring et al. 2017). Social sanctions have been shown to be highly influential for human behavior (Falk et al. 2012). Additionally, norms can become internalized, leading to innate psychological preferences for certain behaviors, even absent external incentives (Ghate et al. 2013; Gavrillets and Richerson 2017). From the evolutionary perspective of Multi-Level Selection (MLS) Theory, internalized norms have important benefits for groups in their contests with other groups (Richerson et al. 2002; van den Bergh and Gowdy 2009; Waring et al. 2017). Norms can be very strongly held, though even new entrants to a CPR regime with different norms can quickly learn and adhere to new ones (Smith 2016). Therefore, norms matter because they shape the decisions made by CPR users (Ostrom 2000).

From a governance perspective, norms influence the efficacy of external interventions and shape how local resource users respond to shocks, including price fluctuations, climate-related events, and external governance interventions

(Kinzig et al. 2013; Rode et al. 2015; Roth et al. 2015). Without a better understanding of how norms and multiple sources of authority work in a CPR, governance actors may make decisions that undermine the sustainability of CPRs and harm adaptation to climate change (Brunsa et al. 2001; Meinzen-Dick and Pradhan 2002; Skjølsvold 2010; Hoogesteger 2015). In the case of irrigation systems, this could lead to food insecurity, mass migration, and conflict (Gleick 2014; Meinzen-Dick 2014). However, testing norms in the field and through experiments is difficult and there is insufficient empirical evidence to make robust predictions of outcomes based on differences in norms (Poteete et al. 2010). Evidence of the role norms might play in climate change adaptation is also lacking, although some suggestive studies exist (Chhetri et al. 2012; Laube et al. 2012; Arunrat et al. 2017).

Given this, what is the role of norms in the adoption of rules and technologies by self-governing irrigation systems and what is their impact on irrigation performance in drought? Theory would predict: (1) internalized norms shape institutional and technological configurations, and (2) the same institutional and technological configuration will produce different outcomes depending on the underlying norms of the population. This paper investigates how norms influence irrigation systems by utilizing data from a stratified, semi-random sample of 71 irrigation systems in the Upper Rio Grande Basin (URGB) of the United States. Two distinct waves of colonization from the 17th through the 20th centuries by Europeans – first by Hispanic irrigators who mingled their practices with Native Americans and later by Anglo irrigators who imposed their legal and market system on Hispanics to varying degrees – and a drought from 2011 to 2014 allow for tests of how norms work under similar rules.

2. The evolution and influence of norms in the Upper Rio Grande Basin

2.1. Theoretical basis for the evolution of cooperation in groups

Behavior motivated by norms is relevant for irrigation because collective action is influenced by norms and is necessary to build, operate, and maintain irrigation systems (Ostrom 2000). From the perspective of CPR Theory, norms may be more or less other-regarding and communitarian (i.e. pro-social, typified by altruism) or self-centered and individualistic (i.e. anti-social, typified by rational egoism), generating cooperative or competitive behavior (Poteete et al. 2010; Volland and Ostrom 2010; Waring et al. 2017). The cultural evolution and CPR literature have increasingly relied on MLS Theory (Richerson et al. 2002; Wilson et al. 2013; Creanza et al. 2017; Waring et al. 2017), and has established that norms, operationalized as internalized heuristics of expected behavior, can partly explain boundedly rational individual motivations to act collectively (Poteete et al. 2010; Rustagi et al. 2010; Carballo et al. 2014). Drawing on this literature, this study conceives of cooperative and competitive behavior as existing along a continuum,

ranging from pure altruism to pure rational egoism (Ostrom 2000). Therefore, where evidence of cooperative norms is lacking, competitive norms can be said exist in greater proportion. For example, a cooperative norm in the irrigation context would favor contributions of labor and materials for system maintenance, whereas a competitive norm would favor withholding labor and materials. Therefore, without defined rules requiring contributions to maintenance, evidence of higher contributions to maintenance would therefore be evidence of cooperative norms.

Under the standard assumptions of MLS theory, selection favors competition, because competitive norms lead individuals to maximize their net benefits at the expense of others (Nowak 2006). However, cooperative norms can evolve when individuals garner net benefits – either materially, psychologically, or through elevated status and expanded mate choice – from actions that benefit others and are costly in the short term (Ostrom 2000; Poteete et al. 2010). For example, punishing non-cooperators is costly to the punisher in the short-term, but may bring long-term, group-level benefits which extend to the individual and outweigh the short-term individual costs (van den Bergh and Gowdy 2009; Rustagi et al. 2010). Conversely, competitive norms can evolve where greater net benefits can be garnered through behaviors which do not regard the wellbeing of others (Nowak 2006). In the irrigation context, high levels of individual material wealth, high system turnover and thus a low likelihood of reputation development or kin interactions, or geographic hierarchies created by the canal network may make social relationships relatively unimportant for individual performance, leading to more selfish behavior. As a general matter, cooperative norms evolve in contexts where collective action generates net benefits for individuals due to kin relationships, direct and indirect reciprocity, structured populations, or group-level interactions (Nowak 2006; van den Bergh and Gowdy 2009; Wilson et al. 2013; Creanza et al. 2017).

2.2. Evolving cooperative norms through historical selection pressures

Despite vast individual and subgroup variation (Lamba and Mace 2011), people who derive from different cultural groups, or who experience divergent histories, may internalize different norms (Prediger et al. 2011; Henrich 2014). There are many contextual mechanisms which select for norms of cooperation or competition (Richerson et al. 2002; van den Bergh and Gowdy 2009; Gintis 2011; Creanza et al. 2017; Gavrillets and Richerson 2017; Waring et al. 2017). Such mechanisms can vary by group to the extent that these groups' contexts have differed over long periods of time, leading to the transmission and internalization of different norms (Tucker and Taylor 2007; Prediger et al. 2011; Henrich 2014; Talhelm et al. 2014). Four contextual features of importance for this study are used to explain the internalization of cooperative or competitive norms.

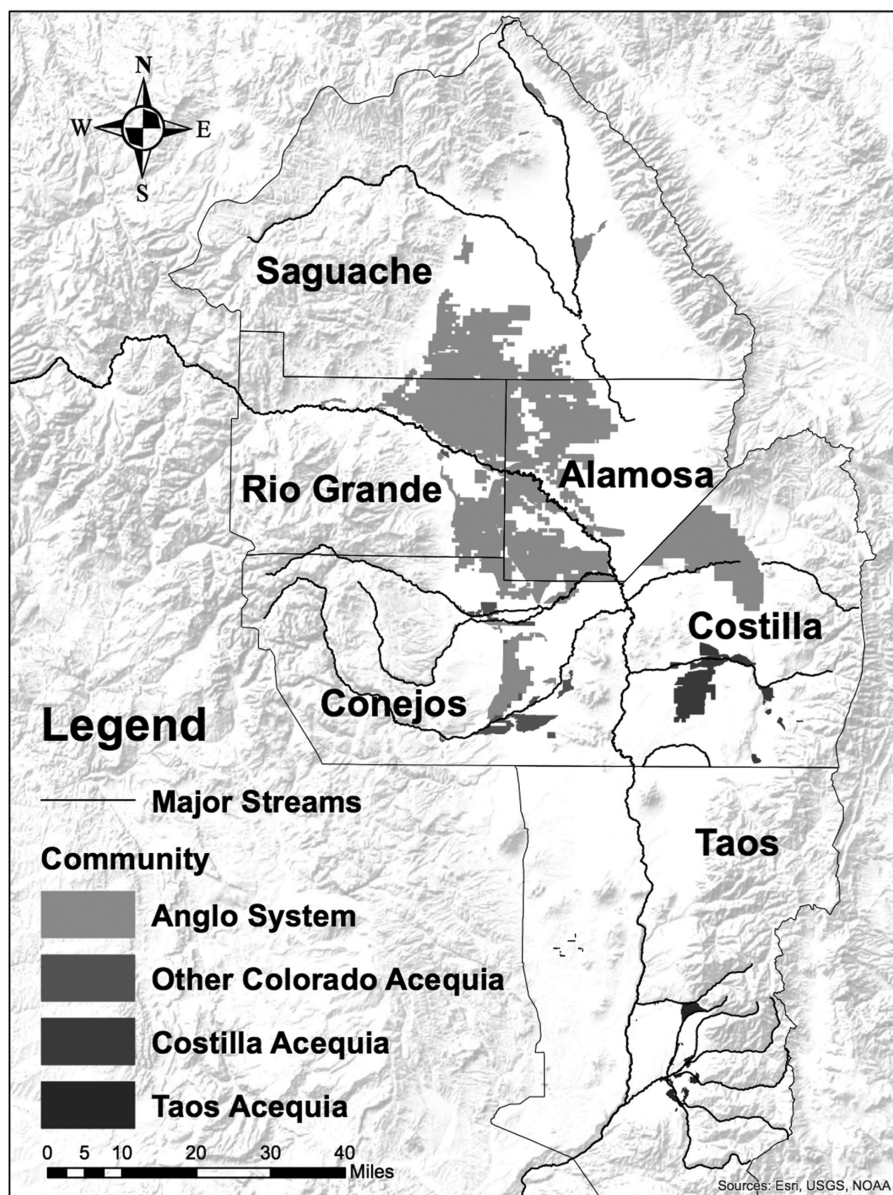
First, functionalist approaches to human behavior imply that whether irrigation produces crops for subsistence or for the market will shape the norms

irrigators internalize over time (Tucker and Taylor 2007; Henrich 2014; Waring et al. 2017). In a competitive market context, success in the market generates wealth; enables the purchase of labor, tools, and calories; and improves status, attracts mates, and supports offspring (Tucker and Taylor 2007; Creanza et al. 2017). In such a context, individuals who internalize competitive norms will outperform those who do not, leading to increased transmission of competitive norms. Subsistence economies, in contrast, necessitate increased cooperation (Ghate et al. 2013); ensuring the survival of community members is paramount, since it is the community from which wealth, labor, tools, calories, and mates are drawn (Richerson et al. 2002; Carballo et al. 2014). Therefore, irrigators who inhabit a subsistence economy are more likely to internalize cooperative norms.

Second, when resources cannot easily be monopolized using available technologies – such as when resources are large, physically diffuse, or fugitive and when mechanized equipment is unavailable – it is costly to compete with others by attempting to exclude them, favoring cooperation (Ostrom 1990; Schlager et al. 1994; Jaeggi et al. 2016). Third, when hierarchy is low – whether due to relatively equal coalition sizes, an equal distribution of technologies, or the legal requirement to hold property in common – cooperation can be favored due to the costliness of competition (Waring and Bell 2013; Jaeggi et al. 2016). And fourth, in interactions between groups, a group comprised of competitors will undermine their collective efforts, leading to worse outcomes for all in the group compared to groups of cooperators capable of achieving higher levels of collective action (Richerson et al. 2002; van den Bergh and Gowdy 2009; Makowsky and Smaldino 2016; Waring et al. 2017).

2.3. Brief history of Hispanic and Anglo irrigation in the Upper Rio Grande Basin

In light of this, the URGB is an ideal place to test the influence of norms on institutional and technological configurations and irrigation performance. Hispanic irrigators using the *acequia* system of irrigation have occupied the study area (Map 1) since the late 1600s (Rivera 1998). *Acequias* are a common property irrigation system that has evolved over hundreds of years, if not thousands, primarily for subsistence purposes (Rodriguez 2006). Originating in the Middle East and North Africa and brought to the Iberian Peninsula following the decline of the Roman Empire, the Spanish later established *acequias* in their American colonies, mingling them with subsistence Native American irrigation methods (Hutchins 1928; Rodriguez 2006). In the 1870s, market-oriented Anglo-American homesteaders began to colonize the study area, leading to cash replacing barter and greater technological and market intensification and infrastructure, such as rail and banking. Because of unique historical and geographic circumstances, the *acequia* communities of this area experienced different degrees of Anglo-American influence and can be categorized accordingly (Table 1).



Map 1: Patterns of European colonization, Counties, and major streams in the URGB.

The most consequential Anglo influences are with respect to *de facto* water rights and land tenure. After being founded by the Spanish using distinct institutions, the United States imposed both the grid-based Public Land Survey

Table 1: Historical origins and legal context of URGB irrigation systems.

Irrigation system traits	Taos <i>acequias</i>	Costilla <i>acequias</i>	Conejos <i>acequias</i>	Anglo systems
Earliest irrigation	1670s	1850s	1850s	1870s
Recognition in US law	1850s	2000s	2000s	1870s
<i>De facto</i> water rights in past between systems	<i>Repartimiento</i>	<i>Repartimiento</i>	<i>Repartimiento</i>	Prior appropriation
<i>De facto</i> water rights in present between systems	<i>Repartimiento</i>	Prior appropriation	Prior appropriation	Prior appropriation
<i>De facto</i> water rights in past within systems	Need and prior use	Need and prior use	Need and prior use	Pro-rata shares
<i>De facto</i> water rights in present within systems	Need and prior use	Need and prior use	Pro-rata shares	Pro-rata shares
Irrigated land tenure	Vara strips	Vara strips	PLSS	PLSS
Sample size	18	12	18	23

The sample contains one *acequia* in Rio Grande County, but is included within Conejos County for simplicity. Additional descriptive statistics available from the author on request.

System (PLSS) and private water rights in the form of the Prior Appropriation Doctrine on most counties (Rivera 1998). However, the PLSS was not imposed in Taos or Costilla counties, allowing for the continuation of the distinct “long lots” and the corresponding hydrologic and social relationships of the *acequias*. Private water rights were not *de facto* imposed in Taos (Cox 2010; Smith 2014), whereas in Colorado *acequias* and Anglo systems are indistinguishable from each other from 1984 to 2014 with regards to the influence of Prior Appropriation on water diversion duration and amount and irrigated area (Cody 2018).

Importantly, the vast majority of *acequias* in Taos and Costilla counties continue to allocate water within their irrigation systems using traditional negotiated methods based on need and prior use; once diverted into the *acequia*, water is the *de facto* common property of irrigators using an *acequia* in those counties. However, due in part to the disruption of the long lots and Colorado’s administration of the Conejos River under the Rio Grande Compact, the vast majority of *acequias* in Conejos County allocate water within their irrigation systems based on individual farmers’ private water rights. Despite legislation written by *acequia* leadership passed in 2009, *acequias* in Colorado historically lacked legal recognition, creating a context where their norms and traditional practices conflicted with law (Rivera 2010; Lindner 2012; Davidson and Guarino 2015). In New Mexico, in contrast, *acequias* were integrated into Territorial and later State law and still practice *repartimiento*, negotiated sharing of water between *acequias* not based on Prior Appropriation (Cox 2010; Smith 2014). Therefore, in Taos, water is *de facto* common property both before and after being diverted. On Anglo systems, water

is considered private property both before and after being diverted normatively and in law (Goldstein and Hudak 2017).

2.4. Summary of reasoning for differences in internalized norms in the Upper Rio Grande Basin

Literature, history, and theory suggest that irrigators on *acequias* have more heavily internalized norms of cooperation, while irrigators on Anglo systems have more heavily internalized norms of competition. Recent studies of *acequias* (Hicks and Peña 2003; Turner et al. 2016; Gunda et al. 2018) identify underlying cooperative norms as essential to their function, while recent studies of Anglo farmers in the study region (Cody et al. 2015; Smith et al. 2017; Smith 2018) identify underlying competitive norms that have required extensive interventions to overcome in efforts to halt a tragedy of the commons in groundwater. Peña (2017) has also identified direct normative conflicts between Anglos and Hispanics in Costilla county related to land and water rights.

Organizations such as the mutual aid society *La Sociedad Protección Mutua de Trabajadores Unidos* (The Society for the Mutual Protection of United Workers) and the lay religious society *Los Penitentes* (The Penitent Ones) reinforce trust and reciprocity, provide social insurance and protection, and promote a selfless moral character monitored by God (Cox et al. 2014). They also provide opportunities to establish a cooperative reputation and reinforce other-regarding preferences. At the same time, annual irrigation community traditions among *acequias* such as *La Limpieza* (The Cleaning), where all land owners and their families participate directly in ditch maintenance, and *La Día de San Isidro* (The Day of Saint Isidro), a parade led by a priest and followed by a feast which marks the beginning of irrigation season and celebrates the patron saint of farmers, similarly reinforce identification with the community, reciprocity through mutual provision of food, and the links between selfless moral character, behaviors around water, and piety. Anglos in the study area have no such community traditions around ditch maintenance or the start of irrigation season. These functions are generally achieved through the centralized purchase of labor and supplies and a proclamation from the Office of the State Engineer, respectively, and can be accomplished with minimal interpersonal interaction for greater economic efficiency.

The essence of the evolutionary argument is that the greater preponderance of cooperative norms among *acequias* derives from their distinct origins in subsistence economies, and because for hundreds of years their technologies, laws, and community structure made it relatively more challenging for individuals to monopolize resources and attain substantially increased bargaining power. For example, Hispanic farmers traditionally split land between their sons, rather than consolidating their holdings with the eldest son like Anglos. Hispanic irrigators also lacked much military protection and needed to act collectively to survive Native American raids and defend their land against Anglo colonization

(Rivera 2010). Conversely, Anglo's orientation towards markets, private property, and technological intensification of agriculture made it relatively easier to monopolize resources, generate stronger hierarchies, and reward competitive behavior. Anglos also benefitted from substantial military protection, and therefore did not need to organize as a group for defense to the same extent as Hispanics.

2.5. Open questions on the effects of norms on irrigation performance

The role of internalized norms in determining irrigation performance is not entirely clear (Poteete et al. 2010). However, norms have been observed to affect behavior important for irrigation where enforced rules are also in place. For example, norms can supplant rules (Ostrom 2000). An internalized norm against anti-social behavior, such as stealing water, may make a rule unnecessary, even if a rule against stealing is still technically enforceable (Kinzig et al. 2013). In contrast, enforcement of a rule against stealing may reduce stealing if the norm against it is not internalized, and cooperation is merely conditional on the assurance that others are also not stealing (Rustagi et al. 2010). Norms can also be crowded-out by rules, where a rule undermines intrinsic motivations and leads to worse outcomes (Kinzig et al. 2013; Rode et al. 2015). For example, enforcement of a rule against stealing could release irrigators from internalized moral responsibility, making getting caught, as opposed to stealing, the bad result (Rode et al. 2015). Such a rule could also be seen as a sign of distrust, leading irrigators to conclude that they will be the "sucker" if they don't steal (Ostrom 2000). In contrast, crowding-in, or reinforcing, a norm could occur if a rule is seen as a reminder to do the right thing (Rode et al. 2015). On balance, the literature implies that individuals who are more intrinsically competitive will likely respond with more cooperative behavior if rules enforcing cooperative behavior are in place (Ostrom 2000; Rustagi et al. 2010), while individuals who are more intrinsically cooperative will likely respond with little to no increase in cooperative behavior and may even show declines due to crowding-out (Kinzig et al. 2013; Rode et al. 2015). This appears to be supported in the field, where externally imposed rules that are not congruent with local cooperative norms produce worse commons management (Ostrom 2000; Kamran and Shivakoti 2013; Volla et al. 2013; Hoogesteger 2015).

2.6. Expectations of internalized norms in the Upper Rio Grande Basin's irrigation systems

To answer the main questions regarding the role of norms in the adoption of rules and technologies and norms' impact on irrigation performance in drought, multiple hypotheses were generated (Table 2). The presence of a monitoring agent was chosen to test these hypotheses because of its global ubiquity (Ostrom 1990; Mabry 1996), central importance to commons management (Cox et al. 2010), and because its major function is to encourage cooperative

Table 2: Hypotheses, rationales, and supporting literature.

Hypothesis	Rationale	Key literature
H1: Hispanic irrigation systems will adopt rules and technologies that promote equality and collective action at higher frequencies than Anglo systems.	Historical selective pressure for cooperative norms drives their internalization, and these norms then drive the adoption of rules and technologies that promote collective action and deter competitive behavior.	Richerson et al. 2002; Nowak 2006; Tucker and Taylor 2007; Prediger et al. 2011; Ghate, et al. 2013; Carballo et al. 2014; Henrich 2014; Talhelm et al. 2014; van der Kooij et al. 2015; Jaeggi et al. 2016; Makowsky and Smaldino, 2016; Gavrillets and Richerson 2017
H2: Where rules are congruent with competitive norms, as with Anglo systems, monitoring agents will reduce water use violations, improve average crop production, and decrease crop production equality.	Internalized norms of competition will amplify the deterrent effect of enforcement, and monitoring agents enforcing competitive rules will generate higher average crop production at the expense of the equality of crop production.	Ostrom 2000; Rustagi et al. 2010; Kinzig et al. 2013; Cody et al. 2015; Rode et al. 2015; Smith et al. 2017; Smith 2018
H3: Where rules are congruent with cooperative norms, as with <i>acequias</i> from Costilla and Taos, monitoring agents will have no effect or a negative effect on water use violations, decrease average crop production, and increase crop production equality.	Internalized norms of cooperation will render the deterrent effect of enforcement negligible or deleterious due to crowding-out, monitoring agents enforcing cooperative rules will generate more equal crop production at the expense of average crop production due to crowding-in.	Ostrom 2000; Rustagi et al. 2010; Falk et al. 2012; Kinzig et al. 2013; Smith 2014; Rode et al. 2015; Turner et al. 2016; Gunda et al. 2018
H4: Where competitive rules are incongruent with cooperative norms, as with <i>acequias</i> from Conejos, monitoring agents will increase water use violations, reduce average crop production, and reduce crop production equality.	Attempts to enforce rules counter to norms will generate conflict as irrigators actively oppose the rules and as monitoring agents fail to effectively enforce water allocations, leading to a breakdown of collective action.	Ostrom 2000; Kamran and Shivakoti 2013; Vollan et al. 2013; Hoogesteger 2015; Rode et al. 2015

behavior on the irrigation system. In this study, monitoring agents are usually peers elected by irrigators. Monitors are tasked with administering water based on the *de facto* water rights established between irrigators on the same system, checking the water use of irrigators, and enforcing rules when they are violated. Monitors are also often leaders of the irrigation system, settling disputes, coordinating maintenance, and interfacing with other irrigation systems and government entities.

3. Methods using surveys and spatial data to assess the role of norms

This observational study tests whether irrigation systems founded as *acequias* differ meaningfully in their structure and function from those founded by Anglos. *Acequia* status was assigned to systems founded prior to 1880 and carrying a Spanish name (e.g. *la del rio*, *Salazar ditch*, *acequiacita*). Key data sources included: Colorado Department of Natural Resources' (DNR) Decision Support Systems, U.S. Geological Survey (USGS), U.S. Natural Resources Conservation Service (NRCS), New Mexico's Office of the State Engineer (OSE), Taos County Assessor (TCA), GoogleEarth Engine, and the 2010 US Census. Institutional, agronomic, hydrologic, and other data were gathered from a stratified, semi-random sample of 71 irrigation systems in 2013 (Table 3). All analyses have been informed by qualitative data collected through key stakeholder interviews, primary source analysis, and direct observation during site visits from 2012 to 2017.

3.1. Methods for hypothesis one

To test H1, which predicts that internalized norms of cooperation will lead *acequias* to adopt features which are more likely to promote equality and collective action, it must first be established that there is good evidence that norms of cooperation have been internalized. Therefore, before analyzing the data quantitatively, qualitative data obtained through direct observation, irrigation manager surveys, and key stakeholder interviews are given to contextualize the quantitative results that follow.

For quantitative analysis, 13 features which ought to engender higher levels of cooperation were identified (Table 4). Each irrigation system was then assessed for the number of features they exhibited in 2013. Features which should generate equality, increase mutual accountability, benefit the common resource or infrastructure, increase reliance on the common resource or infrastructure, or generate or allow more equal access to public goods (e.g. trust, institutions, food security, ecosystem services) should promote cooperation (Poteete et al. 2010) and therefore serve as evidence of cooperative norms.

First, Hierarchical Cluster Analysis (HCA) using Euclidean distance measures and complete linkages was run to determine if cultural and geographic

Table 3: Variable names, data sources and descriptive statistics.

Variable name	Data source	Descriptive stats
Independent variables		
Acequia	OSE; DNR	N: 71 PERCENT <i>ACEQUIA</i> : 67.6
Ditch type	OSE; DNR	N: 71 ANGLO: 23 OTHER COLORADO <i>ACEQUIAS</i> : 18 COSTILLA <i>ACEQUIAS</i> : 12 TAOS <i>ACEQUIAS</i> : 18
Monitoring agent	2013 Survey	N: 71 PERCENT WITH MONITOR: 71.2
Control variables		
Fewer days of water available than normal in 2012	2013 Survey	N: 71 Min: -200 Med: -30 Mean: -45.7 Max: 61 SD: 54.5
Days water is normally available	2013 Survey	N: 71 Min: 15.0 Med: 134.0 Mean: 137.1 Max: 274.0 SD: 68.5
Rotate water delivery in scarcity	2013 Survey	N: 71 PERCENT ROTATING IN SCARCITY: 76.1
Normally rotate water delivery	2013 Survey	N: 71 PERCENT NORMALLY ROTATING: 59.2
Labor required	2013 Survey	N: 71 PERCENT REQUIRE LABOR: 40.8
Inter-system sharing arrangements present	2013 Survey	N: 71 PERCENT SHARING: 22.5
High capacity groundwater wells present	2013 Survey	N: 71 PERCENT WITH WELLS: 45.1
Vegetable gardens present	2013 Survey	N: 71 PERCENT WITH GARDENS: 25.4
Long lots present	2013 Survey	N: 71 PERCENT LONG LOTS: 31.0
Change water allocations in scarcity	2013 Survey	N: 71 PERCENT CHANGING ALLOCATIONS: 78.9
Percent Hispanic	2010 US Census	N: 71 Min: 0.0 Med: 41.8 Mean: 40.5 Max: 100.0 SD: 24.0
Water not allocated by private rights	2013 Survey	N: 71 PERCENT NOT ALLOCATING BY PRIVATE RIGHTS: 46.5

Table 3 (continued)

Variable name	Data source	Descriptive stats
Dependency ratio	2010 US Census	N: 71 Min: 0.0 Med: 23.5 Mean: 25.1 Max: 88.9 SD: 12.5
Hold annual meeting	2013 Survey	N: 71 PERCENT WITH ANNUAL MEETING: 80.3
Percent renters	2010 US Census	N: 71 Min: 0.0 Med: 17.2 Mean: 17.5 Max: 50.00 SD: 9.6
Percent hydric soils	NRCS	N: 71 Min: 0.0 Med: 17.1 Mean: 18.7 Max: 63.3 SD: 16.1
Average farm area in hectares	OSE; TCA; DNR	N: 69 Min: 0.4 Med: 38.9 Mean: 77.9 Max: 669.9 SD: 121.9
System area in hectares	OSE; TCA; DNR	N: 71 Min: 8.3 Med: 256.3 Mean: 3036.8 Max: 47475.7 SD: 7850.4
Sprinkler irrigation present	2013 Survey	N: 71 PERCENT SPRINKLER IRRIGATED: 46.5
Bylaws present	2013 Survey	N: 71 PERCENT WITH BYLAWS: 67.6
US state	2013 Survey	N: 71 PERCENT NEW MEXICO: 25.4
Per capita voting present	2013 Survey	N: 71 PERCENT VOTE PER CAPITA: 78.9
Dependent variables		
Frequency of water use violations	2013 Survey	N: 71 Never: 31 Less than Once Per Year: 19 Once Per Year: 11 More than Once Per Year: 8 Often: 2
2011–2014 Average system average NDVI in july	GoogleEarth Engine; USGS Landsat	N: 71 Min: 0.0859 Med: 0.4499

Table 3 (continued)

Variable name	Data source	Descriptive stats
2011–2014 Average system spatial standard deviation of NDVI in July	GoogleEarth Engine; USGS Landsat	Mean: 0.4316
		Max: 0.6434
		SD: 0.1199
		N: 71
		Min: 0.0431
		Med: 0.2081
		Mean: 0.2080
		Max: 0.3110
		SD: 0.0590

The methods used to measure these variables are available from the author on request.

Table 4: 13 features that ought to improve collective action on an irrigation system.

Feature	Taos <i>acequias</i> (percent)	Costilla <i>acequias</i> (percent)	Conejos <i>acequias</i> (percent)	Anglo systems (percent)
No high capacity groundwater wells	100.0	83.3	45.4	13.0
No sprinklers	88.9	75.0	50.0	17.4
Per capita voting	94.4	91.7	88.9	52.2
Labor required for water access	88.9	66.7	11.1	13.0
Rotational water delivery	88.9	83.3	61.1	21.7
Water not allocated by private rights	94.4	83.3	27.8	4.3
Changing water allocations in scarcity	94.4	75.0	66.7	78.3
Monitoring agent present	100.0	66.7	55.6	65.2
Annual meeting	100.0	66.7	66.7	82.6
Long lots present	100.0	33.3	0.0	0.0
Vegetable gardens present	88.9	16.7	0.0	0.0
Ongoing inter-system sharing arrangements	55.6	16.7	5.6	13.0
Bylaws present	100.0	33.3	55.6	69.6

The presence of these features is used to assess the relative preponderance of cooperative norms as opposed to competitive norms. The percentage of each ditch type which possess the trait in question is also given. More information on how and why these variables were selected is available from the author on request.

clusters (i.e. ditch types) emerge from the distribution of the 13 features from Table 4. Principal components analysis (PCA) was also used to further corroborate and visualize these relationships. This allows the analytical process to generate groupings endogenously rather than impose the groupings on the data.

Second, cultural and geographic groupings based on historical settlement patterns and contemporary law are imposed on the data. The distribution of the 13 features (Table 4) is described and assessed for significance using pairwise

regressions across the four geographic and cultural groups: *acequias* from Taos, Costilla, and Conejos Counties, and Anglo systems.

Third, it could be argued that these features (Table 4) exist on an irrigation system for reasons pertaining geographic, economic, or demographic factors rather than norms. To test whether the number of features differs between Taos, Costilla, and Conejos *acequias* and Anglo systems while accounting for other important factors, a Poisson regression was run using the number of features from Table 4 as the dependent variable (DV). The following control variables were included (Equation 1): (1) Days of normal water availability (WATNORM – natural logarithm transformed to better fit the assumption of normality); (2) Percent hydric soils (PERHYD); (3) Irrigation system acreage (ACRES – natural logarithm transformed to better fit the assumption of normality); (4) Percent Hispanic population (PERHISP); (5) Percentage renters (PERRENT); (6) Average farm acreage (AVEFARMSIZE); (7) Percent population unavailable for labor (i.e. dependency ratio, those aged under 10 and 65 or over) (DEPRAT). The last five variables serve as proxies for wealth. Larger irrigation systems, all else equal, have a larger base of capital and labor to draw upon. Furthermore, Hispanics in this region tend to be less materially wealthy, as do renters and those with smaller farms. Finally, a higher dependency ratio implies lower wage-earning potential, less available labor, and greater expenditures on dependents. An alternative specification was also run, where Costilla *acequias* and Taos *acequias* were binned together as a single covariate.

Equation 1. *Predicting institutional and technological features.*

$$y_i = \beta_0 + \beta_1 \text{CONEJOS}_i + \beta_2 \text{COSTILLA}_i + \beta_3 \text{TAOS}_i + \beta_4 \text{AVEFARMSIZE}_i \\ + \beta_5 \log(\text{ACRES})_i + \beta_6 \log(\text{WATNORM})_i + \beta_7 \text{PERHYD}_i + \beta_8 \text{PERHISP}_i \\ + \beta_9 \text{PERRENT}_i + \beta_{10} \text{DEPRAT}_i + \varepsilon_i$$

Fourth, to test whether the presence of each individual feature could be attributed to the presence of cooperative norms, Logit regressions were run following Equation 1 with each of the features in Table 4 as a dichotomous DV.

3.2. Methods for hypothesis two, three, and four

Following tests of H1, regressions were performed to test H2, H3, and H4 (Equation 2). Equation 2 uses variables deemed important for predicting the DVs in the literature, having a strong effect in preliminary analysis (pairwise regressions, ANOVAs), and lacking multi-collinearity (variance inflation factors ≤ 5.0). New variables include: US state of the irrigation system (STATENM), deviation from days of normal water availability in the 2012 drought as a proxy for drought sensitivity (NORM2012), sprinkler presence (SPRINK), adoption of bylaws

(BYLAW), changing water allocations in water scarcity (SHRSRC), and rotational water delivery in water scarcity (ROTSRC).

Equation 2. *Predicting irrigation outcomes.*

$$\begin{aligned}
 y_i = & \beta_0 + \beta_1 \text{COSTILLA\&TAOS}_i + \beta_2 \text{CONEJOS}_i + \beta_3 \text{MDDR}_i \\
 & + \beta_4 \text{COSTILLA\&TAOS}_i * \text{MDDR}_i + \beta_5 \text{CONEJOS}_i \\
 & * \text{MDDR}_i + \beta_6 \text{ROTSRC}_i + \beta_7 \text{SHRSRC}_i + \beta_8 \text{PERHISP}_i \\
 & + \beta_9 \text{DEPRAT}_i + \beta_{10} \text{SPRINK}_i + \beta_{11} \text{PERRENT}_i \\
 & + \beta_{12} \text{PERHYD}_i + \beta_{13} \text{BYLAW}_i + \beta_{14} \text{NORM2012}_i \\
 & + \beta_{15} \log(\text{ACRES})_i + \beta_{16} \text{STATENM}_i + \varepsilon_i
 \end{aligned}$$

Equation 2 includes an interaction between an irrigation system's status as an *acequia* from Conejos (CONEJOS) and an *acequia* from Taos or Costilla (COSTILLA\&TAOS) with the presence of a monitoring agent (MDDR). Anglo systems are the reference level. For *acequias* in Costilla and Taos, all but three monitoring agents administer water according to traditional common property norms, as do all *acequias* there without monitors. All Anglo system monitors allocate water based on private rights, and only one Anglo system without a monitoring agent does not. By contrast, rules and norms are in conflict within Conejos *acequias* due in part to state law; all but one monitoring agent among them enforces private rights to water, while only half of the systems without monitors enforcing private rights. Bearing in mind the qualitative data introduced above, it is reasonable to believe that traditional common property norms still prevail among many irrigators on systems that administer water based on private rights, despite direct and indirect state influence on their affairs.

The first regression, a Logit, tests whether or not water use violations occur once per year or more as a dichotomous DV. Ordinary Least Squares (OLS) regression was then used to predict the mean Normalized Difference Vegetation Index (NDVI) for an irrigation system, a proxy for overall crop production ranging from zero to one collected by remote sensing and retrieved from GoogleEarth Engine. Mean NDVI in the month of July in the years 2011–2014 was modeled because July has peak crop growth and lacks cloud obstruction. 2011–2014 were used because the survey was conducted in 2013 and because all years were drought years to some degree. Mean July NDVI was scaled (mean-centered, divided by standard deviation) to ease interpretation of the results. OLS is also used to test H2, H3, and H4 to predict the mean spatial standard deviation of NDVI in July of each year. This was also scaled for ease of interpretation.

Several robustness checks were done. Regressions were run with Taos removed to check if results were sensitive to the inclusion of data from New Mexico. To account for spatial auto-correlation, spatial error models were also run. Finally, regressions were run with all *acequias* aggregated together and compared to Anglo systems. However, tests of H3 and H4 were not possible when

aggregating all *acequias* and that this aggregation would bias results and increase standard errors for *acequias* due to meaningful differences between Conejos *acequias* and the others. Despite this, the robustness checks all agree with the results presented below.

4. Results

4.1. Tests of H1: irrigation system features are significantly associated with norms

4.1.1. Qualitative analysis of H1: distinct norms have been internalized

There is qualitative evidence that norms of cooperation and competition have been internalized on Hispanic and Anglo irrigation systems, respectively. In addition to the historical evidence presented above, a greater emphasis on cooperation and community integrity among *acequias* and a greater emphasis on competitive behaviors and individual economic performance among Anglo systems was detected through direct observation, open ended survey questions, and key stakeholder interviews.

These trends are especially apparent in the social enforcement of water rights. With regards to water use violations, Anglos noted that “everyone borrows water,” “there’s always someone up to something,” and “it’s just part of the system.” Competitive norms among Anglos stipulating private pro-rata shares of water within an irrigation system tended to be enforced through graduated sanctions such as verbal confrontation, social shaming, locking of private headgates, and revocation of pro-rata shares (the latter two being performed by the Ditch Rider or board of the irrigation system). Rarely, the power of law was invoked, such as calling the Sheriff to register a formal complaint or engaging in a lawsuit. Rather, if the above social mechanisms failed, more extreme social measures were taken, such as: pouring herbicide in the ditch leading to an offender’s field, shocking crops; clogging the ditch with debris and trash, requiring tedious labor to remove; and shooting cows, inflicting a direct economic loss while also threatening violence. These enforcement mechanisms appeared to be somewhat effective deterrents to the temptation to take more water than owed. As one Ditch Rider said, “[You] Don’t want to be on [the] bad side of neighbor and get shot.” *Acequias* also experienced violations of the norms around the negotiated allocations of water, but water was described as being taken in “neighborly amounts” with the recognition that the farmers “have to live together.” While there were certainly instances of frequent violations by the “usual suspects” and at least one sibling feud, tensions tended to resolve themselves after a conversation with the *mayordomo*, social shaming at the annual meeting, a fine of \$50–100 per violation, or having water cut off for a period of time, usually one turn in the rotation. While one *mayordomo* acknowledged that, “We have our arguments and discussions,” these disputes – “often miscommunication,” as could be expected in a system based around negotiation – rarely escalated to vigilante sabotage of

infrastructure (e.g. “tear up gear,” as reported by one Anglo), and no threats of violence were reported.

The interaction of the norms of Anglo irrigators and the norms of Hispanic irrigators is also instructive as to whether divergent norms have been internalized. A *mayordomo* in Conejos County indicated that once Anglos bought land on his relatively small *acequia*, cooperation broke down. He said the Anglos believed the water right on their deed reflected an absolute amount of water that was their private property to which they were fully entitled under any circumstances, and that they had no responsibilities to others on the system. As a result, ditch maintenance costs fell entirely to the *mayordomo* and infrastructure declined accordingly. Water sharing also ceased to occur. The Anglos did not come to meetings, physically withheld bylaws and other necessary paperwork, and refused to respond to letters requesting cooperation. They also called upon the state to intervene and do away with a cornerstone of *acequia* water governance: rotational water delivery, which ensures every farmer receives a share of water in turns. No social pressure had altered these circumstances, and the *mayordomo* lamented that he was not wealthy enough to pursue legal actions to force even their minimum legally required responsibilities to ditch maintenance.

4.1.2. Quantitative analysis of H1: distinct norms are associated with different features

HCA corroborates the geographic and cultural groupings expected from theory and history (Table 1) and illustrates the cultural relationships between individual irrigation systems (Figure 1). Taos presents a distinct cluster, and Costilla is most closely related to Taos. Conejos *acequias* fall along a continuum ranging from being more closely related to Costilla *acequias* to being more closely related to Anglo systems, which themselves are relatively distinct.

PCA supports the distinctions between the clusters, showing more convincingly than Figure 1 that Anglo systems are different from most *acequias* (Figure 2).

Figure 3 shows that *acequias* have higher frequencies of the features identified in Table 4. As *acequias* became more exposed to Anglo influence, the average occurrence of these features falls from Taos, to Costilla, to Conejos. Pairwise Poisson regressions with a suppressed intercept reveal that all ditch types are significantly different ($p < 0.01$) from each other with respect to the count of the 13 features from Table 4.

Independent of the effects of other important variables included in Equation 1, Poisson regressions reveal *acequias* from Costilla ($p < 0.05$) and Taos ($p < 0.01$) are significantly positively associated with the number of features from Table 4 as compared to Anglo systems.¹ However, Conejos *acequias* show no significant difference from Anglo systems. These relationships are consistent whether or

¹ Full results of all regressions and other statistical analyses are available from the author on request.

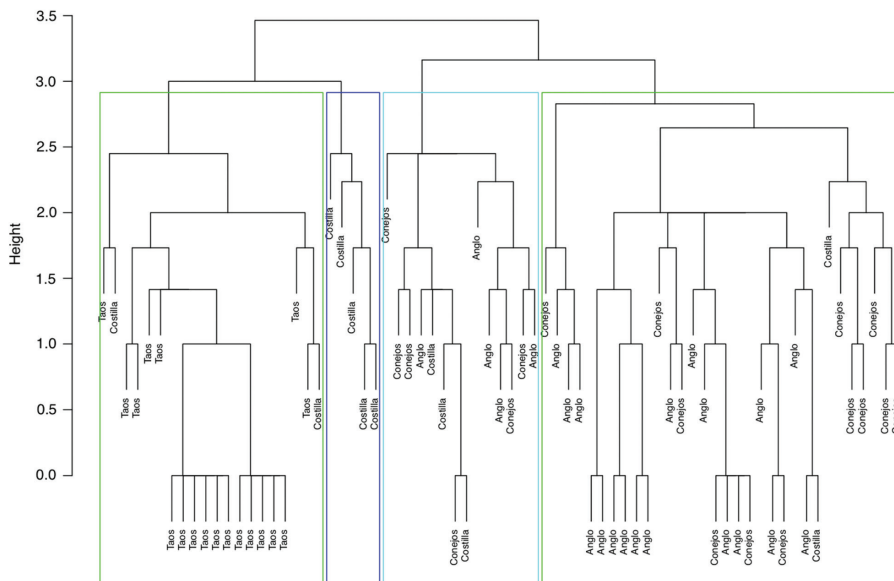
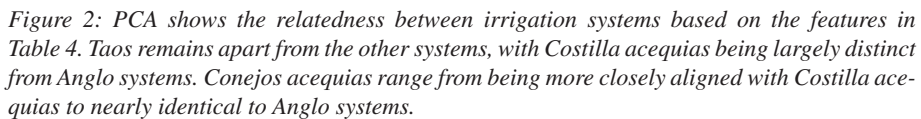


Figure 1: Relatedness between irrigation systems based on the features in Table 4. Taos acequias all fall within the same cluster, with some Costilla acequias interspersed. A small cluster of Costilla acequias also emerges, and all but two of the remaining Costilla acequias falls within a third cluster which is two thirds Hispanic. Anglo systems and Conejos acequias make up the vast majority of the final cluster, which has a sub-cluster comprised entirely of acequias.

not Costilla acequias are grouped with Taos acequias. Using different reference groups reveals that Taos acequias are significantly different ($p < 0.01$) from all others, as are Costilla acequias ($p < 0.05$). No other variables in Equation 1 significantly predict the DV.

Logit regressions also support the hypothesis that norms of cooperation have been internalized on acequia systems, despite features of acequias in Conejos county having converged to some extent with Anglo systems in response to legal and market pressure. Although insignificant for some features, the Logits reveal that the most consistent association with the adoption of any of the 13 features is the irrigation system's cultural origin and subsequent history. These relationships are consistent whether or not Costilla acequias are grouped with Taos acequias. The only other variable included in Equation 1 that significantly predicts more than two DVs is the acreage of the irrigation system.

The weight of the qualitative and quantitative evidence suggests that relatively more cooperative norms have been internalized on acequias while relatively more competitive norms have been internalized on Anglo systems, and that these norms have manifested in irrigation system features congruent with these norms.



Regressions reveal significant interactions between the presence of a monitoring agent and norms. The regressions show that aside from cultural factors, only the irrigated area of the system significantly ($p < 0.05$) increases water use violations. Irrigated area also significantly ($p < 0.01$) decreases mean NDVI and increases the standard deviation of NDVI. The use of sprinklers and higher water availability in drought also significantly ($p < 0.01$) increase mean NDVI. Finally, percentage of renters and percent Hispanic are weakly significantly ($p < 0.1$) associated with higher standard deviation of NDVI.

Figures 4–6 make the results clearer in relation to the hypotheses. Figure 4 supports H2, H3, and H4. The predicted probability of water misuse is higher with a monitoring agent than without on Conejos *acequias*. A plausible interpretation is that irrigators on Conejos *acequias*, where water is being allocated by

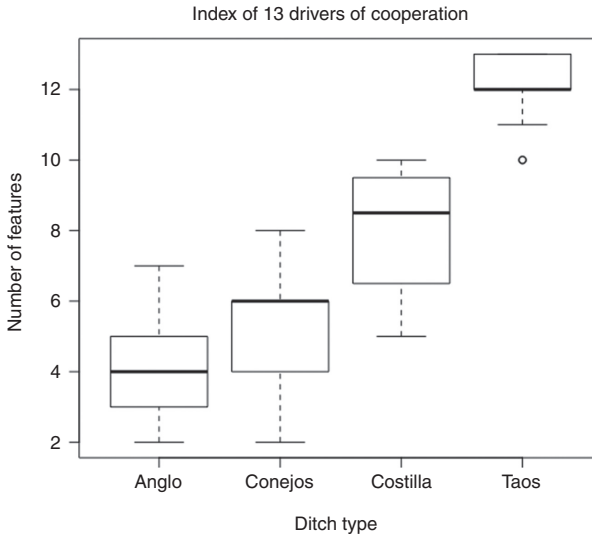


Figure 3: Geographic and cultural distribution of cooperation-engendering features from Table 4. The differences between all ditch types are significant ($p < 0.01$).

rules that are in tension with norms, may be flouting what they view as illegitimate rules. In contrast, a monitoring agent is associated with essentially identical levels of water misuse among *acequias* from Costilla and Taos, suggesting no crowding-out, and lower water misuse among Anglo systems, suggesting effective deterrence.

Figures 5 and 6 should be considered together, since both assess different features of crop production which may be interdependent. That is, system-wide average crop production may be driven partially by differences in the equality of crop production across the system (Smith 2014). Results for Anglo systems show that a monitoring agent is associated with higher average crop production, supporting H2, and no difference in the equality of crop production, contradicting H2. A parsimonious interpretation is that monitoring agents on Anglo systems ensure water is delivered in line with law and norms which emphasize individual rights to water and economic efficiency, and that this allows irrigators to maximize crop growth on the most productive lands. The lack of change in crop production equality combined with greater average production with a monitoring agent suggests that without a monitoring agent some water is wasted, neither increasing equality nor average crop production.

Results for Taos and Costilla *acequias* show lower average crop production and lower inequality with a monitoring agent than without, supporting H3. Based in and congruent with cooperative norms, the monitoring agent enforces negotiations around water allocation and delivery which result in these *acequia* trading

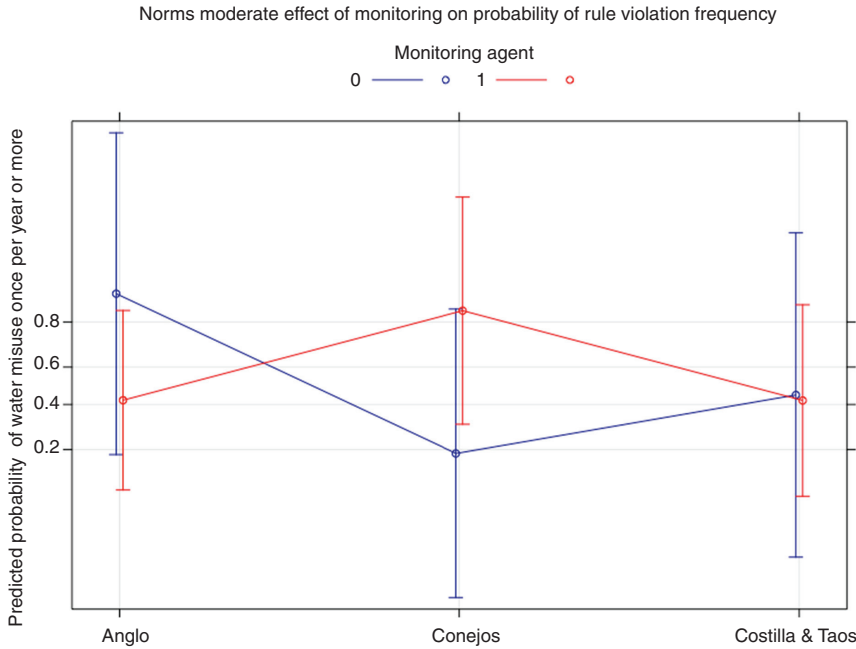


Figure 4: Predicted probability of water misuse occurring once per year or more due to an interaction between a monitoring agent and different ditch types. 95% confidence intervals.

higher average crop production for more equal crop production. In contrast to Anglo systems, water not used to increase average production is not wasted, it is redirected towards greater equality. Where a monitoring agent is absent, the negotiated delivery and allocation system used by *acequias* may be relatively more influenced by competition due a lack of enforcement, leading to higher average crop production but greater inequality. After all, while norms may be more cooperative on average on *acequias*, selfish temptation is still present. Systems without a monitoring agent to enforce greater equality would be more likely to see that temptation realized, and thus produce lower equality and, conversely, higher average crop production. Notably, that competition does not result in increased water use violations, suggesting the negotiated water allocations are the source of the increased inequality.

Finally, Conejos *acequias* have worse average production when a monitoring agent is present, supporting H4, with no differences in crop production equality, contradicting H4. Like the increased water use violations under a monitoring agent observed in these *acequias*, this loss of production may be due to the discord resulting from allocating water along private rights deemed illegitimate by a sufficient percentage of irrigators. There is no evidence of a tradeoff between average production and the equality of production on Conejos *acequias*. This suggests that

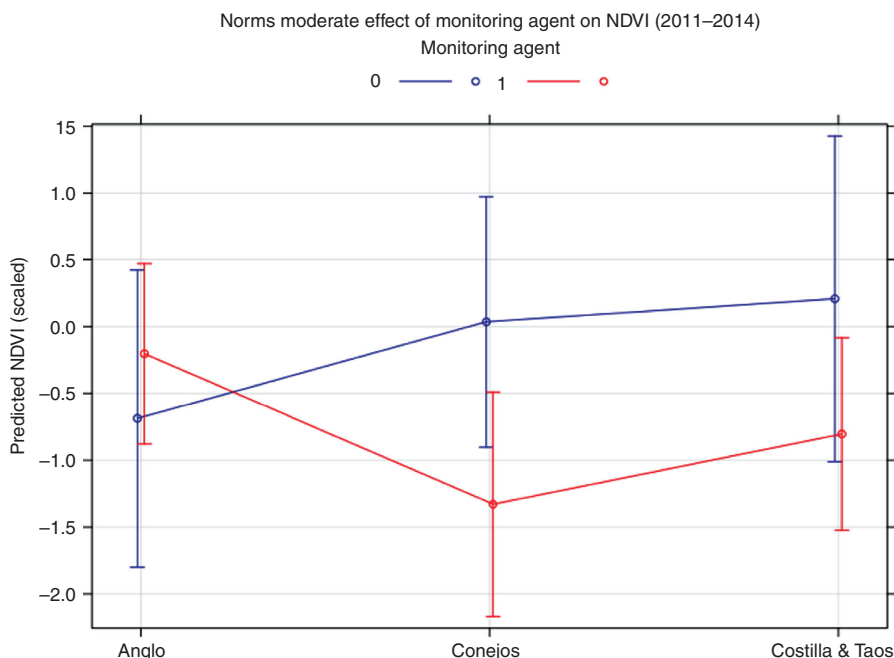


Figure 5: Predicted average NDVI over the study period due to an interaction between a monitoring agent and different ditch types. 95% confidence intervals.

monitoring agents of Conejos *acequias* are simply unable to effectively enforce private water rights, leading to wasted water.

The results from tests of H2, H3, and H4 for water use violations, average crop production, and equality of crop production are summarized in Table 5.

5. Discussion: the importance and relevance of norms in context

With regards to the evolution of norms, the differences between the Anglo and Hispanic irrigation models (typified by Taos *acequias*) provide evidence that selection pressures generated by legal, economic, technological, and ecological context can drive the internalization of norms that improve group and individual relative fitness (Richerson et al. 2002; Wilson et al. 2013; Waring et al. 2017). The geographic gradient of features that ought to engender cooperation which has emerged over the past 150 years is further evidence that irrigating communities adapt their physical and institutional features to local contexts (van der Kooij et al. 2015). The convergence between some Colorado *acequias* and the Anglo model of irrigation is largely the consequence of state law and globalized commodity markets providing pressure to alter ditch operations among *acequias* (Randhir 2016). Absent legal protection similar to that afforded by New Mexican

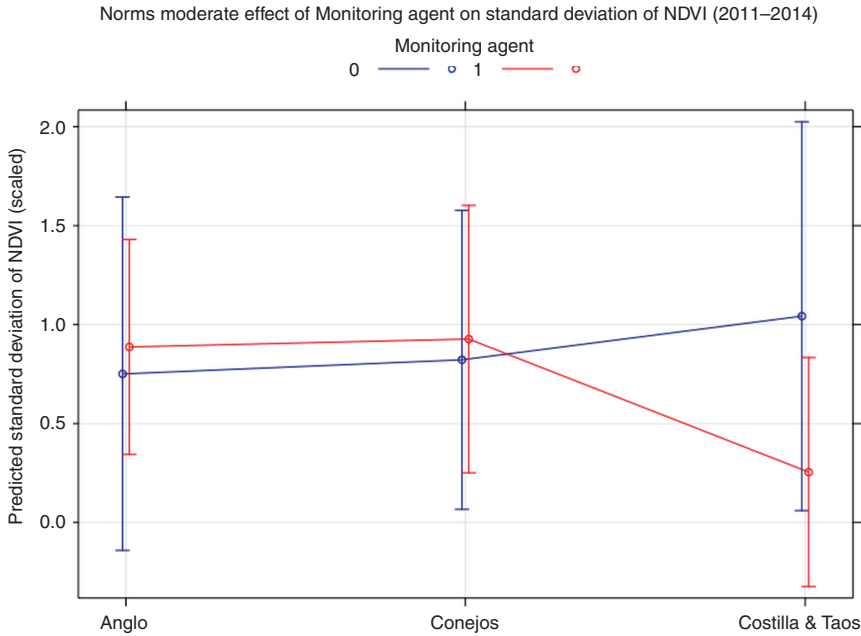


Figure 6: Predicted average spatial standard deviation of NDVI over the study period due to an interaction between a monitoring agent and different ditch types. 95% confidence intervals.

law, it may not be feasible for *acequias* to survive in Colorado without adaptations which fundamentally alter their identity. Therefore, a closer look at the results is warranted.

The features in this study which already show no significant differences in their distribution, particularly in Colorado, are largely collective choice and constitutional rules (Ostrom 2005), such as the presence of bylaws, an annual meeting, per capita voting, and labor requirements for membership. It appears that these features are less influenced by differences in norms and are driven more by the selection pressures on all irrigation systems in Colorado and other contextual features. In contrast, the features which were most distinct between *acequias* and Anglo systems were operational rules dealing directly with irrigation: the ways in which water was acquired (*repartimiento* v. Prior Appropriation, groundwater wells present or not), moved through the system (rotational delivery or not, privately allocated or not), and applied to the land (flooding v. sprinklers). This implies that even if new technologies such as wells and sprinklers are available that generate improved economic efficiencies for individuals, irrigation systems may not adopt them if they would disrupt pro-social norms that provide community cohesion. Despite the legal ability to interfere, it would be politically challenging, especially given the recent *acequia* recognition law, for Colorado to do away with rotational delivery or force the adoption of wells, sprinklers, and

Table 5: Results with respect to norms, water rights, and monitoring.

Ditch type	Norms	Water rights	Monitoring agent	Water use violations	Average crop production	Equality of crop production
Anglo systems	Competitive	Pro-rata shares	Yes	(-)	(+)	(=)
			No	(+)	(-)	(=)
Conejos <i>acequias</i>	Cooperative	Pro-rata shares	Yes	(+)	(-)	(=)
			No	(-)	(+)	(=)
Costilla & Taos <i>acequias</i>	Cooperative	Need and prior use	Yes	(=)	(-)	(+)
			No	(=)	(+)	(-)

The sign in parenthesis indicates the direction of differences observed between systems with a monitoring agent and no agent when compared to the same Ditch Type.

pro-rata shares. However, in a changing climate with potentially higher commodity prices, there will be even greater pressure on individuals to adopt more selfish technologies and demand changes to water allocation rules that maximize individual profit. Without adequate reinforcement of norms or benefits drawn from the community, these operational rules could tip towards the Anglo model, which is well adapted to the market and handles shortages largely through technology. That said, there is evidence that *acequias* retain traditional coping mechanisms based in shared sacrifice (Hicks and Peña 2003) that could avoid this conclusion.

The differences in irrigation performance identified in this study are instructive in efforts to understand how climate change might impact irrigation systems. It does not appear that a monitoring agent crowds-out cooperative norms on *acequias* in Taos and Costilla, as some literature suggests is possible (Kinzig et al. 2013; Rode et al. 2015), but rather may be crowding-in cooperative norms (Rode et al. 2015) and generating more equal crop production at the expense of average crop production (Smith 2014). It also appears that social sanctioning is sufficient to achieve rule compliance where norms are cooperative (Falk et al. 2012), but not to achieve more equal crop growth. Therefore, it appears that for *acequias* that have not been dramatically disrupted by Anglo institutions, a monitoring agent may be very important for reinforcing cooperative norms and ensuring shared benefits of self-governance as aridity worsens. However, where cooperative norms are in conflict with private rights to water among Conejos *acequias*, a monitoring agent enforcing private rights is associated with an increase in water use violations and lower average crop production, similar to previous findings where norms and rules conflicted (Kamran and Shivakoti 2013; Vollar et al. 2013; Hoogesteger 2015). In this instance, a monitoring agent could be an impediment to successful adaptation to climate change and may even be a catalyst for changes to *acequias* which deviate from cooperative norms. It appears there is a tremendously difficult challenge ahead for Conejos *acequias*, where norms and rules will need to be adjusted to accommodate each other, local and global climate change, and impending groundwater regulations (Smith et al. 2017).

6. Conclusion: norms evolve to influence irrigation performance

This study has implications for CPR governance in both developed and developing countries, in particular governance of irrigation systems under water stress (Skjølsvold 2010). It also generates new questions about the role of norms in an increasingly integrated economy where CPR use and governance are local but products of the CPR are sold in a global market (Randhir 2016). Results demonstrate that self-governing irrigation systems with internalized norms of cooperation tend to implement rules and adopt technologies which aim to sustain the commons, provide public goods, and promote equality between irrigators, all of which improve resilience of the global food supply to climate change. However, they may be less competitive in a global market due to lower average crop production. Furthermore, the role of norms in shaping the features of self-governing irrigation systems interacts with market and legal context. Enforcing rules which are congruent with community norms generate better rule compliance and performance, but enforcing rules that are incongruent with norms leads to worse outcomes.

In light of these results, it may be warranted to legally recognize or otherwise support self-governing CPR regimes which, following investigation, meet the normative goals of the user community in terms of resource production (e.g. average crop growth) and social cohesion (e.g. water use violations, crop production equality) (Skjølsvold 2010; Hoogesteger 2015). In an era of climate change, interventions need to be carefully coordinated with the target community in order to diagnose specific problems that can be solved while maintaining adaptive norms (Meinzen-Dick 2014). State law (e.g. Colorado's *acequia* recognition law, New Mexican water law) and non-state actors (e.g. The Acequia Assistance Project of CU Boulder Law School) could play a supportive rather than prescriptive role in assisting self-governing irrigation systems to achieve climate change adaptation.

This study adds weight to the growing body of work giving greater attention to cultural context when analyzing user-governed CPR regimes and climate change resilience, and further illustrates the compatibility of MLS Theory with other prevailing theories in CPR research. Future work might address questions of long-term resilience to climate change as it relates to tradeoffs between market integration and subsistence modes of production, as well as how competitive norms interface with enforced common property rights.

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