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## Relationships between institutional success and length of tenure in a Kenyan irrigation scheme

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**Abstract:** In a context of higher reliance on irrigation schemes to ensure food security, it is crucial to understand institutional success of water resource management. In addition to other factors explored in great depth by the CPR literature, the actions of long-term appropriators contribute to the success of institutions. However, only a limited amount of work has attempted to examine the actual relationship between length of tenure and institutional success. To examine these relationships, we analyze a long-enduring CPR, the Mwea irrigation scheme (MIS) in Kenya, a network created in the 1950s and whose appropriators have held different lengths of tenure. We explore payment of operation and maintenance (O&M) fees of 71 irrigation units over two consecutive years. We examine 422 household surveys in eight out of the 71 irrigation units on the practice of institutions. We find that length of tenure impacts institutional success by influencing the behaviors of appropriators. Appropriators with longer tenure promote institutional success by provisioning the resource in a more sustainable manner through achieving high payments of O&M fees. Relatively dissatisfied with the implementation of the rules, they use formal and informal means to criticize institutions and to promote institutional change and adaptation. In contrast, appropriators with shorter tenure achieve lower payments of O&M fees, they complain less, and are more satisfied with the existing implementation of the rules. They are satisfied with the *status quo*. Hence, it is through the pressure of experienced appropriators that institutions such as the MIS evolve and adapt to become more successful.

**Keywords:** Common-pool resources, institutional success, irrigation scheme, Kenya, length of tenure, water

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## 1. Introduction

In a global context of climate change and increased water scarcity, the development of successful irrigation schemes in sub-Saharan Africa where rainfed agriculture still prevails could significantly support food security (Burney et al. 2013; Elliott et al. 2014). However, developing successful irrigation schemes is highly challenging. Policy makers and resource users must solve key collective action problems: they must acquire and manage the physical infrastructure necessary to utilize the resource; they must manage the resource sustainably; and they must cope with the asymmetric positions of the head-starters and the tail-enders (Janssen et al. 2011). Although there is no agreed-upon definition of what successful or sustainable governance is, there is a common understanding that “*successful institutions [are] those that last over time, constrain users to safeguard the resource, and produce fair outcomes*” (Agrawal 2001). Successful institutions structure the appropriation and provisioning of the resource in order to achieve these objectives.<sup>1</sup> This work builds on established literature on institutional success to enrich the narrative that links institutional success and appropriators’ lengths of tenure.

We ask how appropriators with various length of tenure frame institutional success. More specifically, we investigate how groups of farmers and individual appropriators with different lengths of tenure provision the resource and assess the implementation of the rules in place in the Mwea Irrigation Scheme (MIS) in Kenya. Created in 1953, the MIS is a long-enduring irrigation scheme whose institutions have greatly evolved over time to become more and more successful and whose appropriators have held differing lengths of tenure. This case study is ideally suited to analyze the distinct roles of appropriators with various lengths of tenure in shaping institutional success.

To answer our research question, we analyze scheme-wide payments of O&M fees in 71 irrigation units and household surveys on the perception of institutions conducted in eight out of the 71 irrigation units. We then discuss how this analysis enhances our understanding of the relationships between institutional success and length of tenure. Adding to our understanding of the general relationships between

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<sup>1</sup> Here, appropriation and provision are respectively understood following Ostrom (1990) as, on the one hand, “the process of withdrawing resources units from a resource system” and, on the other, as the amount of inputs required in the form of labor, material, or money to appropriate the resource.

length of tenure and the success and adaptive capacity of institutions established by past literature, this paper provides a more complete image of the role of appropriators with differing lengths of tenure. This work suggests that appropriators with longer tenure promote institutional success by provisioning and appropriating the resource in a sustainable manner. They also foster the adaptation of institutions by formally and informally mobilizing against institutional failures.

## 2. Literature review

Since the 1980s, a large body of research has explored the conditions needed for successful collective action and sustainable use of the resource in irrigation schemes and other common pool resources (CPRs). Researchers have shown that CPRs can be successfully governed, and have postulated conditions favoring success in CPR management (Wade 1988; Ostrom 1990; Baland and Platteau 1996). One of the earliest and most influential was Ostrom's eight "design principles" for the sustainable management of CPRs – research that led to much new empirical investigations and lab experiments on irrigation schemes (Ostrom 1990; Cole and McGinnis 2015). More recent work has emphasized the importance of ecological and technical infrastructure in addition to the original eight design principles in order to successfully govern CPRs (Agrawal 2001; Anderies et al. 2016; McCord et al. 2017b).

Theoretical, empirical, and experimental work has investigated relationships between long-enduring CPRs, successful and adaptive institutions, and the roles of appropriators. For North (2005), institutional success is primarily characterized by "adaptive efficiency" and the ability of governance actors to create institutions that are flexible over time. Ostrom (1990, 2001) asserts that the capacity of appropriators to mobilize past experiences and to both construct flexible institutions and adapt to new conditions characterize long-enduring institutions. Appropriators adapt and transform institutions over time to enhance success and adaptive capacity (Greif 2014). This research all points to the important role of CPR appropriators in allowing the resource to persist over time and the institutions to evolve and become more successful. Over time, it is the appropriators who shape the success of the institutions through a process of trial and error.

However, little research has been done on the role of appropriators with different lengths of tenure in institutions governing CPRs. In fact, this factor is critical because crafting institutions is not a one-shot effort but is a long-term development to which newcomers may be less proficient than appropriators with longer tenure. (Ostrom 1990; Lam 1998). New settlers can learn about and accept institutions over time, but they can also be disruptive and exacerbate conflicts over the resource (Ostrom 2001). Given the physical and institutional complexity of irrigation schemes, individual farmers need to learn how to appropriate and provision the resource successfully. As Lam (1998) summarizes it, "*as time goes by, individuals in an irrigation system will settle in a working order that presumably will improve performance of the system*". Yet, to date, limited attention has been paid to the mechanics of individual and collective learning, to what happens "as

time goes by.” In a context of rapid and exponential turnover of CPR appropriators driven by migrations and the ongoing construction of irrigation infrastructure (Mandri-Perrot and Bisbey 2016), it is crucial to better understand the role that length of tenure plays in shaping mechanics influencing institutional success.

As discussed above, there is no agreed-upon definition or metrics of what constitutes successful institutions. However, a number of variables can be used as indicators of successful institutions that guarantee adequate provision and appropriation of the resource. Applied to irrigation schemes, successful institutions foster adequate provision of the resource by structuring adequate levels of payments of O&M fees and participation in communal work such as canal repairs. Payment of O&M fees is one of the crucial ways in which appropriators provision the resource and ensure appropriate access to water (Lankford 2012). Without appropriate payment of O&M fees, it is impossible to guarantee the sustainability of an irrigation scheme (Lam 1998). In other words, satisfactory levels of payment of O&M fees demonstrate, at least in part, the functioning of successful institutions.

Appropriators’ perception of institutions can also be used as a measure of institutional success. Their views on the institutions affects the appropriation of the resource and the overall success of the irrigation scheme (Small and Svendsen 1990; Shivakotti 2002). Appropriators need to agree with and internalize the practice of the rules in order to contribute to the functioning of the institutions (Lam 1998). Despite the important role of appropriators’ perception of the success and fairness of institutions in shaping sustainable CPR management, limited work has investigated farmers’ perspective on irrigation schemes. When assessing the performance of irrigation schemes, appropriators’ assessments have in many cases been overlooked or only considered as a way to complement expert-based assessments (Yakubov 2011). In the same ways that the variables described above can be used as proxies to measure institutional success, others have been highlighted by past literature as shaping institutional success.

Three main groups of characteristics contributing to institutional success have been highlighted by past literature: physical attributes and access to the resource, institutional and social attributes of the appropriators, and governance regimes at multiple scales of governance (Lam 2001). While multi-scale governance regimes are central to the sustainable governance of CPRs such as irrigation schemes, this paper focuses at the local level on the institutional and social attributes of resource appropriators and the resource’s physical attributes and accessibility.<sup>2</sup>

Physical attributes and suitable access to the resource influence payment of O&M and appropriators’ perception of success and fairness of institutions. Appropriators are more willing to invest in the CPR and perceive institutions more favorably when the resource is neither too abundant nor too scarce (Uphoff 1986). They are satisfied with the institutions and provision the resource ade-

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<sup>2</sup> Including recognition of local governance schemes by higher levels of governance and polycentric institutions, (Ostrom 1990). For a detailed investigation of how broader governance regimes have evolved and shaped local institutions in the MIS, see Baldwin et al. (2016).

quately when there is a significant chance of getting a return back from the investment. The good condition of the resource, as well as the manageable size of the resource and predictability of water flows, encourages cooperation and proper governance (Lam 2001). Asymmetries in water allocation between head-starters and tail-enders in an irrigation scheme lead to spatial differences in provision of the resource that can impede cooperation and institutional success (Ostrom and Gardner 1993). The quality of the physical infrastructure for irrigation also defines provisioning of the resource and users' satisfaction (Lam 2001; Kemerink et al. 2016; McCord et al. 2017b).

Institutional and social attributes of the appropriators also shape institutional success. Salience of the resource for appropriators largely defines institutional success (Agrawal 2001). Appropriators are more likely to invest in the difficult crafting of the rules if they are dependent on the resource for their livelihood. Sociocultural homogeneity among appropriators, trust and reciprocity, and a common understanding of how the resource should be managed enhance institutional success (Lam 2001; Ostrom 2001). When assets differ, appropriators with larger assets may be more willing to invest in shaping successful institutions (Shivakotti 2002). Beyond heterogeneity of endowment, homogeneity of identities and interests are key in supporting long-enduring CPRs (Agrawal 2001).

Additional institutional and social attributes shape the capacity of appropriators to provision and appropriate the resource in an adequate manner. First, the length of tenure of appropriators shapes the ways in which they provision the resource and assess the institutions in place (Ostrom 2001). Appropriators with a longer tenure have more practice with rules fundamental to the functioning of irrigation schemes, such as payment of O&M fees. In addition, appropriators who actively participate in institutions build up social capital and promote institutional success. Research shows that the number of community meetings attended by appropriators correlates positively with the state of the resource and institutional success (Agrawal and Yadama 1997). The opportunity to air grievances bolsters reciprocity norms and fosters institutional success by increasing the level of contact among appropriators (Ostrom 2005). Airing grievances or critiquing the implementation of institutions helps prevent violence in the same way conflict resolution mechanisms do. A system with a robust capacity for farmers to air grievances allows space for these kinds of discussions, which promote a spirit of democracy, dissipate frustration and anger, and promote institutional learning. In the same manner, the ability to informally complain and reach out to local leaders help deescalate conflicts and participate in the success of the CPR (Ostrom 2005).

### 3. Background information

#### 3.1. The Mwea Irrigation Scheme: institutional changes and physical growth

The Mwea Irrigation Scheme (MIS), a CPR managed by appropriators with diverse levels of institutional experience, has a long and unique history of

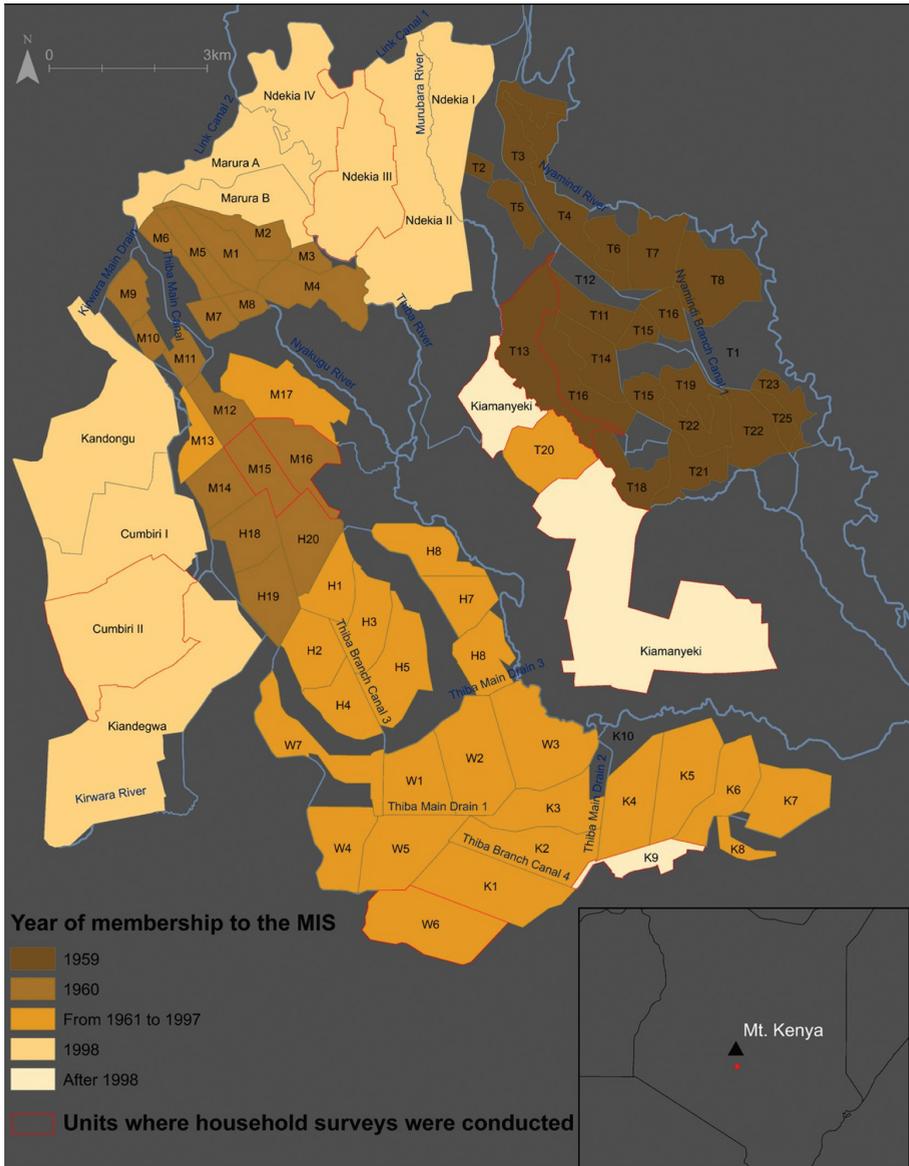


Figure 1: Growth of the Mwea irrigation scheme.

institutional changes and physical growth. The MIS is located on the eastern slopes of Mount Kenya, about 100 km northeast of Nairobi (Figure 1). The local climate is semiarid, with 300 to 500 mm of precipitation annually and both short and long rainy seasons. More than 80% of the rice consumed in Kenya originates from the Mwea area, which is the largest rice-growing area in East Africa. The

26,000 acres under irrigation are cultivated by over 7000 households. Households produce rice as a commodity that they sell on local markets. No other commodity crops are cultivated. Irrigation water is used for rice production. Water for irrigation is extracted from the Nyamindi and Thiba rivers via gravity-fed intake weirs that distribute water throughout the scheme's 71 irrigation units (National Irrigation Board 2018).

The institutions governing access to water for irrigation have changed considerably over the course of the scheme's history (Baldwin et al. 2016). The scheme was built by political detainees from the 1953 Mau Mau rebellion under British colonial rule (Elkins 2005). Under colonial rule, and after Kenya gained independence in the mid-1960s, large-scale irrigation schemes not only produced food and provided employment but were also used to allocate land to the growing landless population (Chambers 1969). The postcolonial government of Kenya embraced the top-down colonial approach to governance and created the National Irrigation Board (NIB) to administer irrigation schemes such as the MIS (Chambers and Morris 1973). Tenant farmers had little ability to amend scheme rules, appeal managers' decisions, or otherwise provide input into scheme governance. When the NIB was in power, farmers lacked basic property rights and had to sell their agricultural products below market price to subsidize other irrigation schemes that were failing. They endured the scheme managers' regular failure to monitor water use, sanction improper water use, and solve water use conflicts among tenants (Kenya Human Rights Commission 2000). The scheme managers' comprehensive powers left farmers hamstrung and vulnerable, particularly during the frequent droughts of the 1980s and 1990s. During the 1997 drought, a violent farmers' revolt to protest against the low buying price of rice put an end to the top-down rule of the NIB.

Since the 1997 revolt, the MIS has experienced significant institutional learning and change, which has resulted in a more sustainable institutional design (Baldwin et al. 2016). In the aftermath of the turmoil in Mwea, Kenya's Ministry of Agriculture granted the Mwea Rice Grower Multipurpose (MRGM), a cooperative of farmers, sole management of the scheme. The first years of MRGM governance were relatively successful, with land preparation completed on schedule for the first time in the scheme's history and record rice prices of KSh. 30 per kilogram in 2000 (The NIB offered only KSh. 18 per kilogram in 1998). However, farmers lacked the funds and technical knowledge necessary to maintain the scheme's infrastructure. In 2003, in order to maintain rice production, the Mwea Water User Association (MWUA, formerly MRGM) and the NIB began to share management of the irrigation scheme, with the NIB handling infrastructure operation and maintenance (a task for which the tenant farmers were inadequately trained), while the farmers retained control over most day-to-day operations. Since 2003, relative peace and economic well-being have characterized the life of farmers in the MIS for the first time since it was created in the late 1950s.

Mwea farmers are facing new challenges, however. Pressure on water resources posed by illegal abstractors, the projected physical expansion of the

scheme and construction of the Thiba mega dam, as well as aging infrastructure are threatening the status quo. In addition, new national water irrigation legislation implementing water user associations (WUAs) across the country and calling for payment for water provision will soon be implemented in the MIS. This is likely to deeply impact local farmers and institutions (Baldwin et al. 2016; Dell'Angelo et al. 2016; Kemerink et al. 2016; McCord et al. 2017a; Baldwin et al. 2018).

Along with the institutional changes that have occurred over the years, the physical footprint of the scheme has expanded to reach its current size of 26,000 acres under irrigation. Infrastructure development supported by international donors and the construction of artisanal canals by illegals abstractors both drove the expansion of the MIS. In 1959, the British built the Tebere section fed by the Nyamindi canal system, in 1960 they built the Thiba and Mwea sections along the Thiba canal system. With the financial support of the UK and West Germany, additions to the Thiba canal systems were made in 1963, 1969, and 1970 to create the Karaba and Wamumu sections of the scheme. As the irrigation infrastructure was being built, farmers who legally owned land on the outskirts of the scheme started to illegally abstract water from the scheme's canals and drains by building their own canals to irrigate their fields (Serede et al. 2014). After 1998, those farmers, called "out-growers" by those within the scheme, joined the scheme and formed the Curukia and Ndekia sections. In 2012, other out-growers in the Kiamaneyki section joined the scheme and became a part of the Thiba canal system. In a similar process in 2013, K9 joined the Karaba section. At the time the data presented here were collected, other groups of out-growers were negotiating to join the scheme. The construction of a new Thiba dam will lead to a significant physical expansion of the scheme in the near future.

Current institutional practices reflect a mix of top-down and bottom-up arrangements, in which the MWUA and the NIB share the governance of the scheme. The MWUA is primarily in charge of collecting the O&M fees, performing the day-to-day maintenance of the facilities, setting up irrigation and cropping schedules, and guaranteeing the daily operation of the MIS. On the other hand, the NIB is responsible for major maintenance and expansion projects. The NIB also provides technical expertise to the MWUA for setting irrigation and cropping schedules, as well as monitoring the state of the MIS. Elected MWUA executive committee members, NIB managers, and branch canal representatives together form the water management committee. The water management committee regulates, plans, controls, and administers the irrigation process. As such, the committee allocates irrigation groups that define when irrigation units will be receiving water each year. The executive committee also organizes a general assembly monthly during the irrigation season and holds annual general body meetings where general policy matters are discussed, funds for O&M are allocated, and the annual budget and audit of accounts are approved. Meetings are held before and during the cropping

season to prepare cropping plans and plan the water budget, maintenance schedule, and infrastructure repairs. Executive committee members are also members of the advisory dispute subcommittee, along with the manager of the NIB, the district commissions of Mwea East and Mwea West, senior scheme managers, local chiefs, and farmers' representatives.

In order to farm and irrigate their fields, MWUA members must meet different sets of obligations depending on their land ownership status. MWUA members who are tenants on NIB land must pay a one-time membership fee as well as annual operation and maintenance (O&M) fees proportional to the amount of land they irrigate. Members in the out-grower areas also pay a one-time membership fee, but they maintain their own canals and therefore do not pay the same O&M fees as the NIB tenants do. Each MWUA member belongs to an irrigation unit. To receive water for irrigation, each unit must reach 60% of the required O&M payment. All members are required to pay a one-time membership fee to the MWUA. Members are also required to use irrigation water efficiently, participate in communal work on irrigation and drainage systems, follow the cropping program, and attend MWUA and unit meetings. Members have the right to be consulted about the maintenance and cropping programs. They also elect members of the executive committee and leaders at the branch level.

### 3.2. Case study sites

Eight irrigation units within the MWUA were selected because they vary in terms of length of tenure, access to water, size, and challenges faced by the appropriators. The selected irrigation units represent a wide array of situations relative to length of tenure and access to water. Three of the units are on NIB land and have long tenure and practice: T13, M15/16, and W6. T13 is a 190-acre irrigation unit that is part of the original Tebere river irrigation system, which was built between 1954 and 1959. It has good access to water because it occupies the third position on the main Nyamindi canal. When the unit was created in 1959, each tenant was given four acres of land. At the time of data collection some four-acre parcels were still farmed by the original tenants, but most parcels had been subdivided into smaller parcels farmed by the descendants of the original tenants. This has led to increased pressure on the land and conflicts around issues of inheritance. The next unit, M15/16, has a significantly different profile. It is a 96-acre irrigation unit created in 1964 on the Thiba's main canal in the Tebere section. M15/16 is located at the end of the Thiba's main canal, downstream from several units. The original small units of M15 and M16 decided to merge to have more influence over the allocation of water when the MWUA took over the management of the scheme in the late 1990s. However, disputes over water allocation and land subdivision still plague farming in the unit. Finally, W6 was built in 1970 and extracts water from the Thiba Branch Canal IV. It is a small unit of 59 acres that occupies the antepenultimate position on the branch canal and periodically lacks access to water due to its downstream location. Disputes over land subdivision are

frequent. The unit also suffers from illegal abstraction of water by descendants of the original tenants who farm on the outskirts of the unit.

The next three units were formed when out-growers joined the scheme in the aftermath of the 1997 riots: Ndekia III, Cumbiri II, and Ng'othi. Ndekia III is a 200-acre unit where farmers own their land and created their own water user association in the 1980s to abstract water from the Nyamindi link canal via an artisanal canal system that they built. They are in the third position on the canal and benefit from an adequate amount of water. Cumbiri II is a large unit of 424 acres where farmers had started abstracting water from the drain of the Thiba section in the 1980s. They are the last abstractors on the drain and therefore often face water scarcity. Ng'othi also joined in 1998 and is a smaller unit of 98 acres. They are downstream of most units on the Nyamindi section and also often face water scarcity.

The final two units joined very recently or were in the process of joining the scheme at the time of data collection: Kiamaneyki and K9. Kiamaneyki is a large unit of 800 acres that officially joined the scheme in 2012. The residents there started building their own canals in 1985 to get water from the drainage of T20. Since they became MWUA members, they now extract water from the Thiba Rumble Weir and thus have more reliable access to water. Finally, K9 started to develop irrigation canals in 1999 after having illegally farmed 110 undeveloped acres of NIB land in the aftermath of the 1997 riots. They crafted artisanal canals and created their own WUA. They abstract water from the Thiba branch canal and rarely face water scarcity. However, their location in a lower elevation area makes them vulnerable to floods. At the time of data collection, they had just joined the MWUA in order to gain more reliable access to water and were still contributing O&M to their own informal WUA.

## 4. Methods

Data was collected both at the scale of all the 71 irrigation units of the MIS to assess dynamics at the collective level and at the scale of individual households in a subset of 8 units to assess dynamics at the individual level.

### 4.1. Relationships between institutional success and length of tenure at the unit level

Data collected in the 71 irrigation units was used to assess relationships between length of tenure and institutional success at the unit level (Tables 1 and 2). We used percentage of payment of operation and maintenance (O&M) fees as an indicator of institutional success at the unit level. As indicated above, in order to have access to water for irrigation, each unit must reach 60% of the required O&M payment, meaning that 60% of the tenants or land-owners in each unit must pay O&M fees. We collected data relative to the percentage of payment of O&M fees for 71 irrigation units for the 2011 and 2012 cropping seasons. Data was collected at the MWUA's offices on the scheme. 2011's cropping season was successful throughout the MIS. In contrast, the 2012 cropping season was disrupted

Table 1: Descriptive statistics for irrigation units.

	Mean (SD) or No. (%)
Outcomes	
Paid O&M 2011 (%)	79.5 (19)
Paid O&M 2012 (%)	76.9 (16.6)
Covariates	
Year of membership	1969.6 (13.9)
Acres irrigated	268.4 (136.4)
Irrigation group	
1	35 (49.3%)
2	21 (29.6%)
3	4 (5.6%)
4	11 (15.5%)
Location	
Nyamindi	17 (23.6%)
Thiba	45 (62.5%)
Curukia	6 (8.3%)
Ndekia	4 (5.6%)

Table 2: ANOVA for 2011 and 2012 operation and maintenance fee payment.

	O&M 2011		O&M 2012	
	Mean (SD)	<i>p</i> -Value	Mean (SD)	<i>p</i> -Value
Irrigation Group		<0.001		0.325
1	87.7 (13.4)		80.5 (13.8)	
2	78.3 (16.8)		73.5 (14.3)	
3	84.2 (19.1)		76.5 (15.6)	
4	56.5 (19.7)		72 (26.4)	
Location		<0.001		0.27
Nyamindi	79 (15.6)		69.8 (13.2)	
Thiba	84.7 (16.2)		79.3 (16.4)	
Curukia	53.2 (19)		78.7 (17.1)	
Ndekia	63 (24.5)		75.7 (26.8)	

Note: *p* Values were obtained using ANOVA.

by repairs conducted on the main canal of the Tebere section. Percentage of payment of O&M fees is treated as the outcome variable.

Other variables that measure physical attributes and access to the resource as well as institutional and social attributes of the appropriators are treated as covariates. To measure physical attributes and access to the resource of the different units, we collected data on the size (in acres) of the irrigation units and the order in which units receive water during the cropping season (water is allocated by irrigation group, with group 1 being allocated water first and group 4 being allocated water last). To measure institutional and social attributes, we collected data relative to the length of tenure measured both in terms of the date at which units

Table 3: Multiple linear regression model for 2011 and 2012 operation and maintenance fee payments.

	O&M 2011			O&M 2012		
	Coefficient	SE	<i>p</i> -Value	Coefficient	SE	<i>p</i> -Value
Intercept	-46.96	960.09	0.961	-129.31	866.73	0.882
Year of membership	0.07	0.49	0.891	0.1	0.44	0.814
Acres irrigated	-0.01	0.02	0.707	-0.02	0.02	0.298
Irrigation Group						
2	-9.32	4.65	0.049	-6.7	4.2	0.115
3	-4.6	8.81	0.603	-5.89	7.95	0.462
4	-38.34	25.52	0.138	-61.23	23.04	0.01
Location						
Thiba	6.03	5.7	0.295	12.52	5.15	0.018
Curukia	6.84	19.1	0.722	67.35	17.25	<0.001
Ndekia	15.9	20.35	0.438	62.5	18.37	0.001

joined the MIS and the location on the scheme, since the historical expansion of the scheme is highly interconnected with its physical expansion. Both variables are used interchangeably as measures of length of tenure but their role in shaping payment of O&M fees is measured differently since the first is a continuous variable whereas the second is a categorical variable.

We first compute descriptive statistics for percent of payment of O&M fees and covariates. Percent of payment of O&M fees, the outcome variable, is used as a proxy of institutional success. Year of membership, number of acres irrigated, irrigation group, and location on the schemes are used as covariates to measure physical and social attributes (Table 1). Then, we explore simple relationships between the covariates and the outcomes using ANOVA for categorical predictors and *t*-tests for continuous predictors. We discuss tests for homogeneity of variance as well as results from post hoc testing. Finally, we test multiple linear regression models for percentage of O&M payment in 2011 and 2012 to determine the effect of each predictor after controlling for the others (Table 3).

#### 4.2. Relationships between institutional success and length of tenure at the appropriators' level

422 household surveys located in 8 units were analyzed in order to assess the relationships between length of tenure and institutional success at the appropriators' level (Figure 1). Households surveyed were selected to represent a variety of positions from head-starters, to tail-enders and to farms in between. Semi-directed interviews were conducted by enumerators in English or in the local vernacular language. We measured appropriators' satisfaction with the rules in place to govern access to membership, land, and water as indicators of institutional success at the level of the appropriators (Tables 4 and 5).

Table 4: Household survey results.

	Mean (SD) or No. (%)
<b>Outcomes</b>	
Membership rules are well implemented	
Strongly disagree	25 (6.6%)
Disagree	23 (6.%)
Neutral	6 (1.6%)
Agree	23 (6.%)
Strongly agree	304 (79.8%)
Rules that govern access to land are well implemented	
Strongly disagree	7 (1.8%)
Disagree	5 (1.3%)
Neutral	1 (0.3%)
Agree	8 (2.1%)
Strongly agree	363 (94.5%)
Rules that govern access to water are well implemented	
Strongly disagree	19 (4.9%)
Disagree	23 (5.9%)
Neutral	4 (1%)
Agree	25 (6.4%)
Strongly agree	317 (81.7%)
<b>Covariates</b>	
Household size	4.05 (1.9)
Number of acres under irrigation	2.07 (2.9)
Years of membership to the MIS	14.67 (14.3)
Unit number	
Cumbiri II	45 (11.4%)
K9	57 (14.5%)
KIA	49 (12.5%)
M16	50 (12.7%)
Ndekia III	50 (12.7%)
Ng'othi	42 (10.7%)
T13	50 (12.7%)
W6	50 (12.7%)
Amount of income from farming	
All	232 (59%)
Most	135 (34.3%)
Some	19 (4.8%)
Little	5 (1.3%)
None	2 (0.5%)
Farmed here entire life	
Yes	241 (61.5%)
No	151 (38.5%)
Dispute in the past year	
No	347 (89.2%)
Yes	42 (10.8%)
Aired a grievance in the past year	
No	91 (23.3%)
Yes	300 (76.7%)
If yes, number of grievances aired	2.48 (2.9)
Attended a meeting in the past year	
No	54 (13.8%)
Yes	337 (86.2%)
If yes, number of meetings attended	3.04 (3.3)

Table 4 (continued)

	Mean (SD) or No. (%)
Contacted a unit leader in the past year	
No	50 (12.8%)
Yes	341 (87.2%)
Contacted a chief in the past year	
No	240 (61.4%)
Yes	151 (38.6%)
Contacted a member of parliament in the past year	
No	379 (96.9%)
Yes	12 (3.1%)
If yes, number of times contacting leader/chief/parliament	4.03 (4.5)

Other variables that measure physical attributes and access to the resource as well as community and social attributes of the appropriators are treated as covariates. To measure physical attributes and access to the resource of the appropriators, we collected data on the number of acres farmed on irrigated MIS land. To measure social attributes of the appropriators, we collected data relative to the size of the household, years of membership to the MIS, proportion of the household's income derived from farming on irrigated MIS land, and local collective action. For data in this last category, heads of household were asked if they had aired grievances about the MIS to neighbors or friends in the past year and at what frequency. They were also asked if they had participated in community meetings in the past year and at what frequency, and if they had experienced disputes over land or water in the past year and at what frequency. Finally, they were asked if they had contacted leaders to discuss both land and water-related issues at different scales of governance (local leader, Chief, Member of Parliament), and at what frequency.

Summary statistics of all variables are displayed below, including counts and percentages for categorical variables and means and standard deviations for continuous variables. Because the distribution of the outcome variables is skewed, with most observations falling in the "strongly agree" category, we recoded them such that "strongly disagree" and "agree" were collapsed into a single category. Similarly, for the income variable, "some", "most", and "all" are collapsed into a single category. Finally, we perform a logistic regression Wald's test for continuous covariates and a chi-square test for the categorical variables to assess their impact on the outcome variable. Appropriators' satisfaction with rules relative to membership as well as water and land allocation, the outcome variables, are used as a proxy of institutional success. Household size, number of acres under irrigation, unit number, amount of income from farming, lengths of farming on the MIS, occurrence of a disputes, airing of grievances, attendance of meetings, and contact of a local leader are used as covariates to measure physical and social attributes (Table 5).

Table 5. Results of the logistic regression Wald's test for continuous covariates and chi-square tests for the categorical variables.

	Membership rules			Land rules			Water rules			p-Value
	Does not strongly agree mean (SD) or No. (%)	Strongly agree mean (SD) or No. (%)	p-Value	Does not strongly agree mean (SD) or No. (%)	Strongly agree mean (SD) or No. (%)	p-Value	Does not strongly agree mean (SD) or No. (%)	Strongly agree		
Household size	4.12 (2.34)	4.01 (1.73)	0.654	5.29 (3.47)	3.98 (1.72)	0.004	4.23 (2.4)	4 (1.72)	0.365	
Nb. of acres irrigated	1.96 (1.48)	2.1 (3.2)	0.697	2.13 (2.01)	2.07 (2.97)	0.93	1.81 (1.54)	2.13 (3.14)	0.401	
Years of membership	15.5 (15.05)	14.3 (14.04)	0.547	17.2 (16.99)	14.4 (14.08)	0.391	15.4 (14.99)	14.6 (14.22)	0.675	
Unit number			0.014			0.001			0.005	
Cumbiri II	6 (13.3%)	39 (86.7%)		1 (2.3%)	43 (97.7%)		3 (6.8%)	41 (93.2%)		
K9	7 (14.3%)	42 (85.7%)		1 (1.8%)	53 (98.1%)		6 (11.1%)	48 (88.9%)		
KIA	12 (25%)	36 (75%)		1 (2%)	48 (97.9%)		13 (27.1%)	35 (72.9%)		
M16	13 (26.5%)	36 (73.5%)		2 (4.1%)	47 (95.9%)		15 (30%)	35 (70%)		
Ndekia III	8 (16%)	42 (84%)		2 (4.2%)	46 (95.8%)		7 (14%)	43 (86%)		
Ng'othi	3 (7.1%)	39 (92.7%)		0 (0%)	42 (100%)		3 (7.14%)	39 (92.9%)		
T13	18 (36.7%)	31 (63.3%)		9 (18.7%)	39 (81.2%)		14 (28%)	36 (72%)		
W6	10 (20.4%)	39 (79.6%)		5 (10%)	45 (90%)		10 (20%)	40 (80%)		
Income from farming			0.563			0.302			0.924	
None	46 (20.7%)	176 (79%)		15 (6.6%)	212 (93%)		42 (18.5%)	185 (81%)		
Little	24 (18.1%)	109 (82%)		4 (3%)	128 (96%)		25 (18.5%)	110 (81%)		
Some to all	7 (26.9%)	19 (73.1%)		2 (8%)	23 (92%)		4 (15.4%)	22 (84.6%)		
Farmed MIS entire life			0.272			0.318			0.012	
Yes	52 (22%)	184 (78%)		15 (6.4%)	219 (94%)		53 (22.3%)	185 (78%)		
No	25 (17.4%)	119 (83%)		6 (4%)	143 (96%)		18 (12.1%)	131 (88%)		
Dispute			0.878			0.595			0.501	
Yes	8 (19.5%)	33 (80.5%)		3 (7.3%)	38 (92.7%)		6 (14.6%)	35 (85.3%)		
No	69 (20.5%)	267 (79%)		18 (5.3%)	321 (95%)		65 (19%)	278 (81%)		
Aired a grievance			0.073			0.041			0.144	
No	24 (26.7%)	66 (73.3%)		1 (1.1%)	87 (98.9%)		21 (23.3%)	69 (76.7%)		
Yes	52 (18%)	237 (82%)		20 (6.8%)	274 (93%)		49 (16.5%)	247 (83%)		
Number of grievances	2.27 (3.2)	2.51 (2.92)	0.532	3.95 (3.73)	2.35 (2.52)	0.015	2.46 (3.63)	2.49 (2.8)	0.951	

Table 5 (continued)

	Membership rules			Land rules			Water rules			<i>p</i> -Value
	Does not strongly agree mean (SD) or No. (%)	Strongly agree mean (SD) or No. (%)	<i>p</i> -Value	Does not strongly agree mean (SD) or No. (%)	Strongly agree mean (SD) or No. (%)	<i>p</i> -Value	Does not strongly agree mean (SD) or No. (%)	Strongly agree	<i>p</i> -Value	
Attended a meeting			0.645			0.955				0.166
No	9 (17.6%)	42 (82.3%)		3 (5.7%)	50 (94.3%)		6 (11.3%)	47 (88.7%)		
Yes	67 (20.4%)	261 (80%)		18 (5.5%)	311 (94%)		64 (19.2%)	269 (81%)		
Contacted leader			0.316			0.256				0.228
Number of meetings			0.536			0.028				0.872
No	3.27 (5.1)	3 (2.81)		5 (9.23)	2.95 (2.7)		2.99 (5.01)	3.06 (2.89)		
Yes	12 (25.5%)	35 (74.5%)		1 (2.1%)	48 (98%)		6 (12%)	44 (88%)		
Contacted chief			0.079			0.601				0.829
No	53 (22.9%)	178 (77%)		14 (5.9%)	220 (94%)		42 (17.8%)	194 (82%)		
Yes	23 (15.5%)	125 (84%)		7 (4.7%)	141 (95%)		28 (18.6%)	122 (81%)		
Contacted parliament			0.875			0.527				0.893
No	74 (20%)	294 (80%)		20 (5.4%)	352 (95%)		68 (18.2%)	306 (82%)		
Yes	2 (18.2%)	9 (81.8%)		1 (10%)	9 (90%)		2 (16.7%)	10 (83.3%)		
Number of contacts	3.88 (3.97)	4.1 (4.69)	0.704	5.33 (6.14)	3.94 (4.45)	0.234	5.06 (7.72)	3.83 (3.56)		0.079

## 5. Results

### 5.1. Relationships between institutional success and length of tenure at the unit level

The analysis of the data collected at the level of the 71 units shows that payment of O&M fees in 2011 is slightly higher (mean=79.5) than it is in 2012 (mean=76.9) (Table 1). On average, the size of irrigated land in each unit is 268.4 with a standard deviation of 136.4. Most survey respondents are in irrigation group 1 (49.3%) with the remainder in group 2 (29.6%), group 4 (15.5%), and group 3 (5.6%). The majority of respondents are located in the Thiba section (62.5%), followed by the Nyamindi (23.6%), Curukia (8.3%), and Ndekia (5.6%) sections.

The ANOVA models for the 2011 and 2012 payment of O&M fees reveal that both categorical variables (*irrigation group number* and *location*) are significant in the 2011 O&M model whereas none are significant in the 2012 O&M model (Table 2). Bartlett's test of equal variance did not reject the null hypothesis of homogeneity for either variable in 2011. The test was also not significant for *location* in 2012, but it was significant for *irrigation group number* in 2011,  $p=0.04$ . A Kruskal-Wallis test confirmed the non-significance of *irrigation group number* for the 2012 data. Boxplots (not shown) did not identify any concerning outliers.

*Irrigation group number* is significantly related to the payment of 2011 O&M fees ( $p<0.001$ ). Post hoc pairwise comparisons using Tukey's HSD adjustment for multiple comparisons found that group 4 was significantly different from group 1 ( $p<0.001$ ), group 2 ( $p=0.002$ ), and group 3 ( $p=0.018$ ). The remaining pairwise comparisons were not significant. *Location* is also important ( $p<0.001$ ). In this model, location is used as a proxy for length of tenure given the development of the physical expansion of the scheme over time. Post hoc pairwise comparisons using Tukey's HSD method found that the mean difference between Curukia and Nyamini was significant ( $p=0.010$ ), as was the difference between Curukia and Thiba ( $p<0.001$ ). The other pairwise comparisons were not significant. In contrast, neither *irrigation group number* nor *location* is significantly related to the payment of 2012 O&M fees. Mean payments range from 72 to 80.5 for the four irrigation groups and from 69.8 to 79.3 for the four irrigation sections.

T-tests reveal a slight negative relationship between *unit size* and 2011 payments ( $p=0.048$ ); with larger units making smaller O&M payments. There also appears to be a negative trend between *year joined* and payment amount, which suggests that those who joined later made smaller payments. This relationship is significant ( $p<0.001$ ). Similarly, *irrigation unit size* is negatively correlated with 2012 payments ( $p=0.002$ ): higher land size corresponds to lower payments. There is no statistically significant relationship between *year joined* and 2012 payments even though units with more length of tenure in the Thiba section achieved a higher percentage of payment of O&M fees than those in Curukia and Ndekia. Units in Nyamindi paid a lower percentage of O&M fees in 2012 due to canal repairs disrupting access to water during the cropping season.

A multiple linear regression model for the payments of 2011 O&M fees shows that group 2 made significantly lower payments than did group 1 ( $p=0.049$ ; Table 3), though no pairwise comparisons are significant in post hoc analysis based on the model's marginal means. No other variables are statistically significant within the model. Changing the baseline group used for the location variable did not produce any significant results.

The multiple linear regression model for the payments of 2012 O&M fees shows that group 4 has a statistically significant coefficient, with those in group 4 making significantly smaller payments than those in group 1 ( $p=0.01$ ). Post hoc pairwise comparisons based on the model's estimated marginal means did not find other significant differences after a Bonferroni adjustment for multiple comparisons. In addition, Thiba ( $p=0.018$ ), Curukia ( $p<0.001$ ), and Ndekia ( $p=0.001$ ) sections made significantly higher payments than did the Nyamindi section. A post hoc analysis of Bonferroni pairwise comparisons based on the model's estimated marginal means also found a significant difference between Curukia and Thiba ( $p=0.914$ ). The difference between Ndekia and Thiba was right at the cut-off for significance ( $p=0.05$ ).

## **5.2. Relationships between institutional success and length of tenure at the level of the appropriators**

The household survey conducted in a subset of 8 units reveals that most appropriators strongly agree that membership rules (79.8%), as well as rules that govern access to land (94.5%) and to water (81.7%) are well implemented (Table 4). The average household size is 4 persons. Respondents farm an average 2.07 acres of irrigated land and have been MIS members for an average of 14.7 years. Household survey respondents are evenly spread among the eight irrigation units. Most households (93.4%) receive all or most of their income from farming irrigated land. A majority of heads of household (61.5%) have farmed their current fields for their entire life. Most households (76.7%) have aired a grievance in the past year (about three times per year on average), but only a few (10.8%) have been involved in a dispute. The majority of heads of household (86.2%) have attended about three community meetings in the past year. Most heads of household have contacted a local leader in the past year (87.2%), but fewer have contacted the Chief (38.6%) or a Member of Parliament (3.1%).

The results of the logistic regression Wald's test for continuous covariates and chi-square test for the categorical variables show that whether respondents believe that membership rules are well implemented is significantly correlated with unit number ( $p=0.014$ ; Table 5). Appropriators in the Ng'othi (92.9%), Cumbiri 2 (86.7%), and K9 (85.7%) units are most likely to answer "strongly agree", while those in the T13 unit are the least likely (63.3%). All other variables are insignificant at the 5% level.

Similarly, whether respondents believe that rules governing access to land are well implemented is highly significantly correlated with unit number ( $p=0.001$ ). A vast majority of appropriators in the Ng'othi (100%), K9 (98.1%), Kiamaneyki

(97.9%), Cumbiri II (97.7%) units are most likely to answer “strongly agree”, while those in the T13 unit are the least likely (81.2%). Whether or not the individual has aired a grievance ( $p=0.041$ ) and the number of grievances ( $p=0.015$ ) that they have aired in the past year is significantly negatively related to this outcome, with those who report airing grievances being less likely to strongly agree. Number of meetings attended is negatively related to this outcome ( $p=0.028$ ); those who responded “strongly agree” average three meetings while those who did not respond “strongly agree” had attended an average of five meetings. Household size is also significantly related ( $p=0.004$ ), with those in larger households being less likely to agree that land access rules are well implemented.

Once again, whether respondents believe that rules governing access to water are well implemented is highly correlated with unit number ( $p=0.005$ ). Appropriators in the Cumbiri 2 (93.2%) and the Ng’othi (92.9%) units are most likely to answer “strongly agree”, while those in the M15/16 (70%), T13 (72%), and Kiamaneyki (72.9%) unit are the least likely. Whether or not the individual has farmed there their entire life is also significantly related to this outcome ( $p=0.012$ ). Those who had farmed there their entire life are less likely to strongly agree that the rules governing access to water are well implemented.

## 6. Discussion

Our work shows that units with longer lengths of tenure provision the resource with high payments of O&M fees, thereby contributing to institutional success. In units that joined the MIS early on, appropriators contribute to the payment of O&M fees largely beyond the required 60%. In contrast, appropriators in irrigation units that joined the scheme later on, in particular those who joined after 1998, make slightly lower payments of O&M fees while still reaching the minimum required 60% of payment of O&M fees. This suggests that appropriators with a long tenure on the MIS have had the opportunity to learn to provision the resource not only adequately but beyond the minimum requirement (Lam 1998). By doing so they create and preserve a good reputation and position in the scheme (Megyesi 2016). Less experienced appropriators may have yet to fully measure the importance of creating and preserving a good reputation in the scheme in order to guaranty a good position in the cropping schedule and a more reliable access to water. Units that joined the MIS later on are also larger. Unit leaders may struggle to mobilize appropriators to achieve high percentages of O&M fees payments. They may need more time to foster collective action and provision the resource with high percentages of payments of O&M fees (Ostrom 2001).

In a manner that is consistent with past literature, this study shows that adequate access to the resource impacts institutional success. Indeed, access to the resource early on and in a reliable manner significantly defined rate of O&M fees payment in 2011. Units in irrigation groups that received water early on in the cropping season were more likely to achieve higher payments of O&M fees because appropriators knew that they would have satisfactory access to the

resource. However, when adequate access is not achieved, units appear to achieve lower rates of O&M fee payments. In 2012, the poor condition of the main canal in the Nyamindi section may explain the lower payment of O&M fees there. This result emphasizes the importance of proper infrastructure and ecological conditions in the smooth functioning of institutions (Anderies et al. 2016).

Although appropriators with longer lengths of tenure tend to better provision the resource, they are also more critical of the rules in place. Indeed, heads of household in older units as well as those with larger households and more mouths to feed are less satisfied with the implementation of rules relative to membership, land allocation, and water distribution than were those in units that joined the MIS more recently. In 2012, more experienced units withheld payment of O&M fees as a form of protest against the poor management of the canal repairs by the MWUA and the NIB. Households that had joined the MIS more recently were still enthusiastic about the scheme and experienced an improvement in their quality of life and farming practices. This is a phenomenon that has been observed in other surveys of farmers who had recently joined a WUA (Koç et al. 2006). Similarly, heads of household who had farmed in the MIS or adjoining land their entire life were less satisfied than others who had previously farmed elsewhere or had a different occupation. Not only were they less satisfied with the implementation of fundamental rules, they were more likely to air grievances, to reach out to their leaders, and to attend meetings to discuss the nature and the implementation of local institutions. They more fully used the variety of formal and informal institutions in place to discuss what they viewed as institutional deficiencies (Ostrom 1990).

Taken together, these results compose a more complex picture of the relationship between appropriators' length of tenure and institutional success as well as institutional capacity for adaptation (Mutambara et al. 2016; Romano 2017). Adding to our current knowledge of the general relationship between length of tenure and the adaptive capacity of institutions, this work provides a more complete image of the role of appropriators with different lengths of tenure. Appropriators with longer tenure promote institutional success by provisioning and appropriating the resource in a sustainable manner. They also foster the adaptation of institutions by formally and informally mobilizing a wide array of means of protest against institutional failures. By airing grievances, participating in community meetings, and contacting community leaders, experienced appropriators support the adaptive capacity of local institutions. Institutions must change with the times, and even stable institutions continue to improve under the pressure of appropriators with long tenure while appropriators with shorter tenure learn to practice local institutions.

## 7. Conclusion

This work expands upon existing literature on institutional success by analyzing the role of appropriators' length of tenure in shaping institutional success in CPR situations. In addition to other factors first explored by the seminal

works of Wade (1988), Ostrom (1990), and Baland and Platteau (1996) and later studied in great depth in the CPR literature, appropriators' length of tenure contributes to the success of local institutions. However, a limited amount of work has explored what happens "*as time goes by*" and how length of tenure impacts institutional success. This work explores what happens "*as time goes by*" in an irrigation scheme where appropriators have very distinct lengths of tenure. To answer our research question, we conducted our analysis in the Mwea irrigation scheme (MIS) in Kenya, an irrigation scheme that has expanded over time since the 1950s and where appropriators have different lengths of tenure. We analyzed payment of operation and maintenance (O&M) fees for 71 irrigation units over two consecutive years. We also examined the results of 422 household surveys on the practice of institutions conducted in eight irrigation units with distinct lengths of tenure.

This work suggests that "*as time goes by*" and as appropriators have a longer tenure in local institutions, their behavior and perceptions evolve. Appropriators with longer tenure promote institutional success by provisioning and appropriating the resource in a sustainable manner by achieving high payments of O&M fees. Their relative dissatisfaction with the implementation of the rules and their high reliance on formal and informal ways to complain and criticize institutions promotes institutional change and adaptation (Ostrom 2005). In contrast, appropriators with shorter tenure achieve lower payments of O&M fees, they complain less, and are more satisfied with the implementation of the rules. They are satisfied with the *status quo*.

Hence, at the level of the irrigation scheme, it is the appropriators with a longer tenure who foster the adaptation of institutions by formally and informally protesting against institutional weaknesses and failures while complying with the rules in place. In the history of the MIS, this process of complaining and protesting is part of the successful continuation of this institution. Relative dissatisfaction is tied to the entitlement of appropriators with long tenure whose contributions well above 60% adequately provision the resource. Success does not mean that everyone is happy but that people appropriate and provision the resource and use means of protest to exercise their entitlement. It is under the pressure of these experienced appropriators that institutions can evolve and adapt to become more successful (Mutambara et al. 2016; Romano 2017).

This research indicates that analyzing the individual profiles of appropriators can help illuminate the details of institutional dynamics within a CPR. As with all survey-based research, there is a risk that respondents were answering in a socially desirable way to the questions about satisfaction with the institutions. To alleviate such biases and deepen this analysis, future work should aim at conducting a longitudinal study over a long period of time, using both surveys and more in-depth interviews. Studies should continue to explore the role of different appropriators by analyzing for instance how age or gender affects the behavior of appropriators as well as collective outcomes.

In a context of increased water scarcity, irrigation schemes governed by WUAs can support the rationalization of water use and improve food security. As this research suggests, they can only accomplish these objectives if farmers are deeply involved in local institutions, not only to correctly appropriate and provision the resource but also to critique the rules in place and promote the adaptation of institutions.

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