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Community Water Governance on Mount Kenya: An Assessment Based on Ostrom's Design Principles of Natural Resource Management

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Kenyan river basin governance underwent a pioneering reform in the Water Act of 2002, which established new community water-management institutions. This article focuses on community water projects in the Likii Water Resource Users Association in the Upper Ewaso Ng'iro River basin on Mount Kenya, and the extent to which their features are consistent with Ostrom's design principles of natural resource management. Although the projects have developed solid institutional structures, pressures such as hydroclimatic change, population growth, and water inequality challenge their ability to manage their water resources. Institutional homogeneity across the different water projects and congruence with the design principles is not necessarily a positive factor. Strong differences in household water flows within and among the projects point to the disconnection between apparently successful institutions and their objectives, such as fair and equitable water allocation.

Keywords: *Mountain water governance; community-based water management; institutional fit; Ostrom's 8 design principles; household water flow; Kenya water reform.*

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Introduction

In 2002, Kenya undertook a water policy reform that drastically reshaped its institutional arrangements, incorporated in the 2002 Water Act (Government of Kenya 2002) and translated into a recognized legal model for river basin governance. An early success of this reform was the mitigation, and in many cases resolution, of conflicts between upstream and downstream users (Baldwin et al 2015).

The reform was driven by 2 main factors: the difficulty and expense of operating and monitoring the centralized pre-2002 system, which manifested the symptoms of a centralized "prediction and control regime" (Pahl-Wostl 2007), and the impossibility of, and conflict between, downstream and upstream water users (Aarts and Rutten 2012), occasionally involving damage to infrastructure, violent threats, and physical confrontations.

Kenya developed its new river basin governance system in a participatory manner. The inclusion of water experts, nongovernmental organizations, and community representatives in the drafting of the 2002 Water Act produced an institutional architecture that is consistent with recommendations in the literature for creating sustainable governance systems. However, some authors point to critical problems with the act, such as the exclusion of rural poor people, pastoralists, and other marginalized actors from its benefits (Mumma 2005; Robinson et al 2010).

Mount Kenya communities face 2 challenges to the "institutional fit" (Young 2002) of the Water Act reform and to the success of this or any water governance system: rapid population growth and hydroclimatic change. In our area of study, the upper Ewaso Ng'iro River basin, the population increased from 50,000 in 1960 to 500,000 in 2000 (Ngigi et al 2007), and population growth has continued since then. Daily records for Laikipia County show a decline in rainfall frequency and an increase in rainfall magnitude over the last half century (Franz et al 2010); total rainfall in central Kenya is predicted to decrease while average temperatures increase (USGS 2010). Taken together, these trends have important implications for regional water governance through their effect on irrigation demand and river flow. This scenario is problematic for water projects lacking adequate storage facilities, because river water will be less available when it is needed most, during the dry intervals between storms. The challenge posed by these 2 trends—increased irrigation demand and lower water availability during high-demand periods—is heightened by a third element, the challenge of equitably distributing water resources. This is particularly the case in the study area, given that historically, perceptions of water inequality and injustice on Mount Kenya have engendered conflict and violence.

The complex social landscape of Mount Kenya makes water governance a particularly sensitive issue. Perceived water inequality is a serious threat to the governing systems in the region that can affect multiple dimensions of water use. There are water availability and allocation differences between upstream and downstream users, different kinds of users (eg large-scale commercial farms and smallholder farmers), different community water projects (CWPs), and different households in the same CWP. This is problematic, as inter- and intragroup inequalities are consistently correlated with negative outcomes in common-pool resource governance (Andersson and Agrawal 2011). Unequal access to natural resources in sub-Saharan Africa, in particular land and water, is associated with conflicts among different pastoralist tribes as well as between different categories of users and river basin tensions between upstream and downstream groups (Derman et al 2007).

In a context like this, institutional adaptation is particularly important. However, resource governance regimes evolve over time and, among other factors, are strongly affected by the development and state of technological infrastructure, which often leads to technological lock-in (Pahl-Wostl 2009). A similar problem is the phenomenon of institutional lock-in (ie institutional arrangements do not adapt to changing situations because of a series of factors), wherein institutional regimes lose their fit.

Although river water governance takes place at multiple levels, a particularly important level at which to analyze resource management dynamics is the CWP because it represents the organizational structure where water is managed by multiple users through common property regimes. This paper explores CWP-related institutional and management issues with a focus on 5 CWPs in the Likii Water Resource Users Association (WRUA). It analyzes both institutional dynamics and household water flows using Ostrom's (1990) design principles for natural resource management as a diagnostic framework to investigate CWPs' governance outcomes with a particular focus on water allocation inequality.

Study area

The study area discussed in this paper coincides with the Likii River WRUA. This area includes 1 of the tributaries of the upper Ewaso Ng'iro River basin, which extends from the northwest foothills of Mount Kenya (Figure 1) to the semiarid Laikipia plateau and the arid northern lowlands and is characterized by strong biophysical and social gradients. Annual mean precipitation ranges from more than 1000 mm at higher elevations to about 475 mm at lower elevations < 100 km away (Notter et al 2007). This precipitation gradient parallels a strong land-use and social gradient from upstream intensive commercial agriculture and smallholder farms to downstream pastoralism. The area's ethnic composition is also heterogeneous, with predominantly traditional agriculturalist groups such as Meru and Kikuyus engaged in smallholder farming in the upper and middle areas, white Kenyans and European investors operating large-scale commercial farms growing flowers and cash crops for export, and agropastoralist groups such as Maasai and Samburu in the lower areas. Likii WRUA is composed of 9 CWPs, 2 large-scale commercial farms, 1 wildlife conservancy, and the Nanyuki Water and Sewerage Company. The 5 CWPs included in this study are members of the Likii WRUA (Figure 2).

CWPs are groups of smallholder households connected to a pipe network providing water for domestic use and irrigation. Smallholder households in the investigated CWPs primarily cultivate maize, potatoes, and beans for subsistence and for local markets. Typically, household field sizes in the study area range between 0.4 and 1.2 ha (McCord et al 2015). Membership in a water project is usually obtained by paying a 1-time membership fee to contribute to the expense of building the piped water network and a monthly fee to support its maintenance. CWPs are composed of a varying number of households and have an elected management committee in charge of the governance and allocation of water resources within the community. CWP boundaries do not always perfectly match those of other administrative units; therefore, it is possible for a CWP to cover only part of a village or other administrative area.

Theoretical background

Scholars of natural resource management have found a correlation between success and longevity of common-pool resource systems, such as community-based irrigation systems, and a set of institutional characteristics. Ostrom (1990) identified 8 "design principles" characterizing best practices and describing rules and structures of robust institutions associated with sustainable governance of common-pool resources. These 8 design principles relate to the boundaries of the system; congruence with local conditions; opportunities for collective choice and local self-determination; approaches to monitoring, sanctions, and conflict resolution; and incorporation of multiple, nested layers of organization. Cox et al (2010), using a probabilistic rather than

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FIGURE 1 On the way to Mount Kenya. (Photo by Jampel Dell'Angelo)

deterministic approach, found good empirical support for Ostrom's principles as a diagnostic baseline to understand outcomes resulting from biophysical and social interactions in the management of common-pool resources. Wade (1988) and Baland and Platteau (1996) recognized a set of similar principles.

With regard to community-based irrigation systems, a number of authors have argued that a shift from centralized to decentralized, participatory, community-based systems is desirable (Coward 1979; Wade 1988; Ostrom 1992; Lam 1998). Decentralized community-based systems operate on multiple levels of governance in collaboration and reciprocal recognition (Geertz 1959; Coward 1977, 1979; Siy 1982; Ostrom 1992; Cox 2014). Moreover, there is evidence that the size of the group affects the outcome of irrigation management. Small and medium-sized groups, having fewer transaction costs and stronger reputation-building mechanisms and being directly involved and affected, are generally more functional and adaptive to changing conditions than large schemes (Ostrom et al 1994; Araral 2009).

A high degree of adaptability is required to navigate and govern the rapid socioecological transformations that characterize rural areas affected by hydroclimatic change such as those in the semiarid tropics. The capacity of a system to cope with change without losing future options (Folke et al 2005) is strongly challenged when multiple socioecological stressors coexist. In particular, in order to account for the complexity of water systems on multiple levels and to facilitate rapid changes to cope with the uncertainty that characterizes this complexity, riverine governance should move from technical to flexible and adaptive management (Pahl-Wostl 2007). Adaptive river basin governance has the main features of complex adaptive systems, that is, a high degree of self-organization and distributed control. The adaptive dynamics of water governance systems are determined both by the allocation of water and by the requirements of different actors (Pahl-Wostl 2007). Different actors, often with diverging or conflicting perspectives, negotiate the definition of social priorities in river basin governance.

A successful adaptive system should be based on an active process of social learning characterized by reflexivity, involvement, and participation of actors at multiple scales. Institutional design often prevents systems from adapting and from experimenting with new solutions (Pahl-Wostl 2002). In such situations, which could be characterized as experiencing institutional lock-in, collective learning represents an option for improving management procedures and increasing adaptive capacity.

In systems with a multitude of actors, such as river basin governance, there is a high probability that conflicts rather than collective learning will heavily influence institution building, and conflict can undermine the potential for collective action (Van Laerhoven and Andersson 2013). In relation to water management, there is empirical evidence that unequal access to water resources in situations of scarcity leads to tensions and conflicts (Liniger et al 2005).

Water governance in mountains has social and biophysical features that result in particular institutional challenges (see Mountain Research and Development 2013). However, despite the acknowledged importance of mountain systems as water resource bases, the role of water governance in mountainous areas remains relatively underinvestigated (Molden et al 2013).

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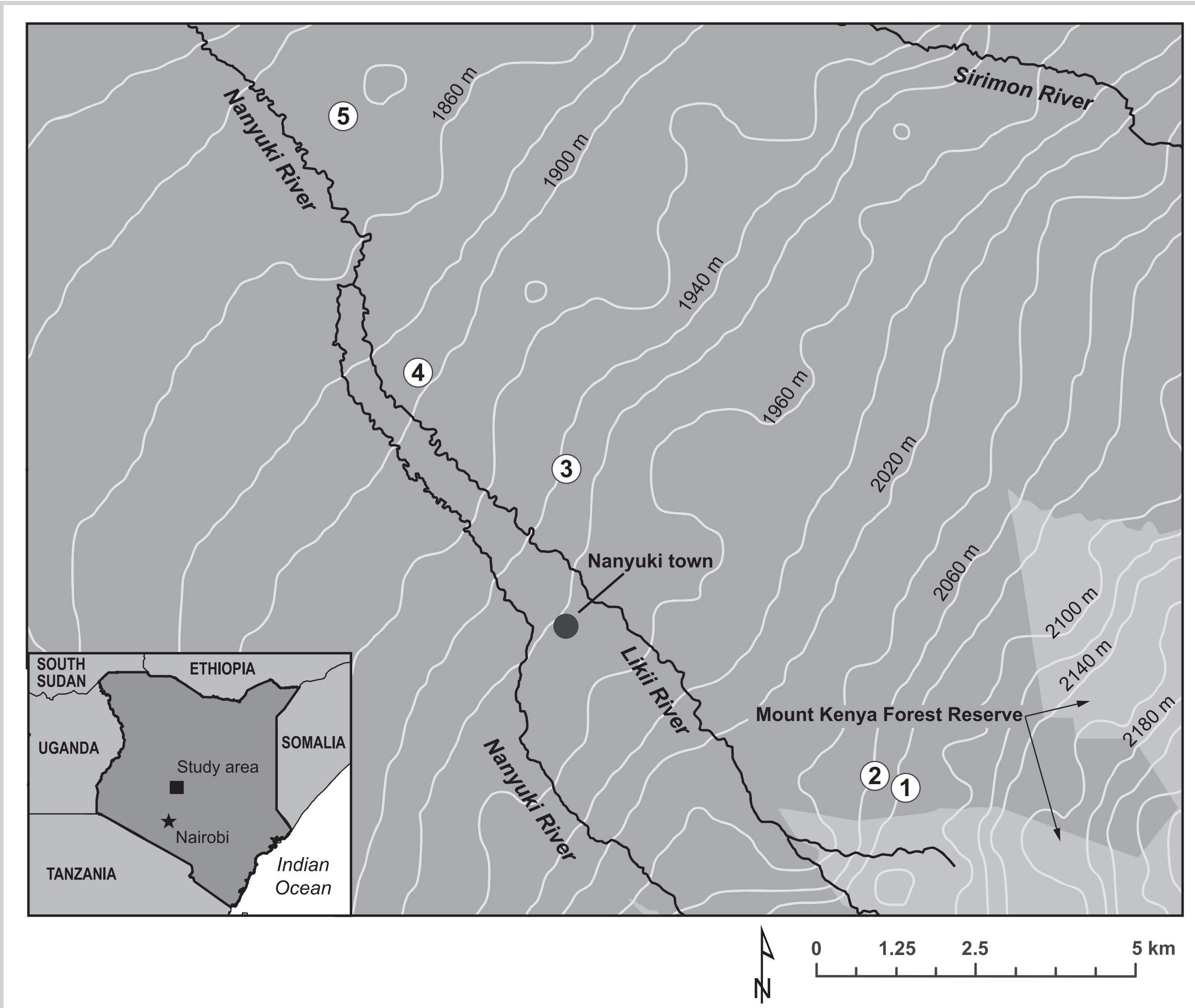
FIGURE 2 Location of CWPs investigated during the study. (Map by Paul McCord)



Methods

This paper is based on a multimethod approach to socioecological water systems analysis. A team of eco-hydrologists and social scientists designed a protocol of biophysical and social data collection that took place during June–December 2013. Throughout the process, the active participation of local stakeholders was critical. The results presented here, which formed part of a larger fieldwork effort that included 5 river basins, are limited to the Likii River basin and the Likii WRUA. We focused on CWPs that were active members of the Likii WRUA. The 5 CWPs presented here represent different upper-stream and downstream portions of the Likii River. In each CWP, 30 households were selected for semistructured interviews. We also interviewed members of every CWP management committee. The manager interviews and questionnaires addressed general socioeconomic conditions in the CWP's jurisdiction as well as specific aspects of institutional structure and function, such as composition and management committees, rules and agreements, monitoring and sanctioning approaches, and water rotation schedules.

The biophysical data gathered included water project mapping and water flow measurements. We mapped distribution pipes—using a Hemisphere XF101 Differential Global Positioning System (GPS) receiver (~2 m accuracy) and a Garmin Oregon 400t GPS receiver (~10 m accuracy)—from a vehicle and, in less accessible

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TABLE 1 Ostrom's 8 design principles for natural resource management of common-pool resources.[a]

Ostrom's design principles	Operationalization
1. Clear boundaries	Individuals or households who have the right to use the common-pool resource are clearly defined
2. Congruence with local conditions	Rules restricting time, place, technology, and quantity of resource use are well adapted to local conditions
3. Collective-choice arrangements	Most individuals affected by the rules can participate in modifying them
4. Monitoring	Common-pool resource conditions and use are monitored by the users themselves or by people accountable to the users
5. Graduated sanctions	Users who violate resource-related rules are likely to be assessed penalties that correspond to the seriousness and context of the offense
6. Conflict-resolution mechanisms	Users and officials have rapid access to low-cost local arenas for resolving conflicts among users and conflicts between users and officials
7. Recognition of the right to organization	The rights of users to devise their own institutions are not challenged by external governmental authorities
8. Nested governance	Appropriation, provision, monitoring, enforcement, conflict resolution, and governance are organized in multiple, nested layers

[a]Adapted from Ostrom (1990).

areas, by foot. The collaboration of CWP piped network caretakers was particularly important in this mapping, as they guided members of the research project and provided information on the size of the pipes, number of users, and rotation schedules. The project selected a purposive sample of households in each of the 5 water projects in order to take water measurements over a 6-month period. Households were selected from the beginning, middle, and end of the water project pipeline. We determined the optimal point for measurement and monitored 10–19 households in each CWP for a 6-month period starting in July 2013. The location of every measurement point was marked with a GPS receiver and added to a geographic information system, where it could be overlaid with additional spatial data. Household flows were measured by using a stopwatch to time the filling of an 18-L bucket. We trained local stakeholders to conduct this measurement consistently across the different water projects.

Results

CWP management and Ostrom's design principles

Institutions, defined as "enduring regularities of human action in situations structured by rules, norms, and shared strategies, as well as by the physical world" (Crawford and Ostrom 1995: 582), are fundamental determinants of the sustainability of social–ecological systems. Wade (1988), Ostrom (1990), and Baland and Platteau (1996) have laid the foundations for the analysis of sustainable governance of common-pool resources. With their comparative studies they have investigated what institutional features are likely to be associated with sustainable collective use of natural resources. In particular, Elinor Ostrom, based on extensive studies of long-enduring governing institutions of common-pool resources, identified 8 "design principles" (Table 1) that synthesize the institutional regularities of sustainable natural resource management across different systems such as fisheries, forests, and community irrigation projects (Ostrom 1990, 2009; Anderies et al 2004).

The interpretation of these principles in the literature on natural resource management has been diverse. Some scholars have understood them as a normative blueprint, whereas others have focused on their heuristic or diagnostic potential. This paper, in line with Cox et al (2010), uses the 8 design principles to study the similarities and differences in institutional arrangements across different CWPs in the same WRUA. In other words, we do not assess the institutional performance of the projects based on the correspondence between their management rules and the principles, but we use the principles to compare and analyze their institutional characteristics.

The data gathered from interviews with executive members of the CWP management committees show that their institutional structures generally reflect the 8 design principles. This correspondence is summarized in Tables 2 and 3 and discussed in more detail below.

Principle 1: Clear boundaries: This principle refers to the need to define both the physical extent of the resource and the group of individuals with the right to use the resource (Cox et al 2010). The CWPs investigated for this

TABLE 2 Survey results in relation to Ostrom's design principles 1–4.

Principle	Community Water Project				
	1	2	3	4	5
1. Clear boundaries					
How land rights are obtained	Purchased	Purchased	Purchased	Purchased	Purchased
Source of water	Likii River	Likii River	Likii River, boreholes	Likii River	Likii River
Membership qualifications	Land ownership, fees, permission from chairperson and committee	Land ownership, fees	Land ownership, fees	Land ownership, fees	Land ownership, fees, labor contribution, attendance at CWP meetings
Water sharing with other communities	Streams and rivers	Streams and rivers	Streams and rivers	Streams and rivers	Streams and rivers
2. Congruence with local conditions					
Nature of water right	Period of time	Period of time	Fixed amount	Period of time	Period of time
How water is allocated	Rotational	Rotational	Rotational	Rotational during scarcity, otherwise no restrictions	Rotational
Change in water allocation during scarcity?	Yes	Yes	Yes	Yes	Yes
3. Collective-choice arrangements					
Water-sharing agreements with other communities	For water from river	For water from river	For water from river	For water from river	For water from river
4. Monitoring					
Headgate gauge?	Yes	Yes	Yes	Yes	Yes
Compliance monitored	By CWP management committee members	By community members and scheme management committee members	By CWP management committee members	By community members, CWP management committee members, and chiefs	By scheme management committee members
Sanctions for noncompliance	Water cut off	Water cut off	Water cut off	Data not available	Water cut off, user expelled from scheme if refuses to pay fee for multiple years

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TABLE 3 Survey results in relation to Ostrom's design principles 5–8.[a]

Principle	Community Water Project				
	1	2	3	4	5
5. Graduated sanctions					
Consequence for first nonpayment	Water cut off	Warning	Pay missed amount the following month	Water cut off	Water cut off
Consequence for continuing nonpayment	Water cut off	Water cut off	Water cut off	Water cut off	Water cut off, fine, loss of membership
Consequence for not meeting labor duties	Water cut off	Fine	Data not available	Water cut off	Water cut off, fine, loss of membership
Consequence for illegal pumping	Data not available	Data not available	Fine or imprisonment	Fine	WRUA takes the pump or sues
Consequence for pipe tampering	Closure of pipe, expulsion from CWP	Data not available	Closure of pipe, expulsion from CWP	Closure of pipe, expulsion from CWP	Fine
Party responsible for enforcing water use rules	Committee	CWP's general meeting	Committee, chief	Water project management committee	Data not available
6. Meaningful conflict-resolution mechanisms					
Does participation prevent conflict?	Yes	Yes	Yes	Yes	Yes
Are there complaints about water access?	No	Yes	Yes	Yes	Yes
What if another community violates water sharing agreements?	Report to WRUA and WRMA	Report to WRUA and WRMA	Report to WRUA and WRMA	Report to WRUA and WRMA	Report to WRUA
7. Recognition of the right to organization					
Is CWP's management authority respected?	Yes	Yes	Yes	Yes	N/A
8. Nested governance					
Water-sharing agreements with other communities	For water from rivers	For water from rivers	For water from rivers	For water from rivers	For water from rivers
Who establishes agreements	WRUA	WRUA, WRMA	WRUA	WRUA, WRMA	WRUA

[a]N/A, Not Applicable.

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study have clear criteria that potential users must meet before they can qualify for membership and the right to withdraw water. The main criteria for membership are payment of membership fees, payment of monthly fees, and land ownership in the area covered by the piped network. Two CWPs also require permission from the management committee and the contribution of labor and time. At the CWP level, there are clearly identified resource boundaries. However, at the river-basin level, all of the CWPs draw from the same general source and need to create higher-level technical and institutional boundaries. This is the level of governance where the WRUA has the authority to define the boundaries. WRUA management committees, on which all WRUA members are represented, agree on water allocation using rotation schedules and different diameters of intake pipes for different members according to their typology and characteristics (eg population size of the CWP).

Principle 2: Congruence with local conditions: This principle requires that rules concerning the time, place, method, and amount of resource extraction must be appropriate to local conditions (Cox et al 2010). It relates to the concept of fit between a set of institutions and an environment or ecosystem (Ekstrom and Young 2009). We investigated how water is distributed and how the system changes during droughts. In irrigation systems, this is a good measure of how institutions reflect local biophysical patterns. All of the CWPs in the study allocate water on a rotating basis, and 4 of the 5 allot water access for specific units of time. All adjust water allocation in response to scarcity. The rationing and rotation procedures are negotiated in a participative way and not imposed by an external authority. This increases the congruence between the rules and strategies adopted and local social and biophysical conditions.

Principle 3: Collective-choice arrangements: Under this principle, resource users impacted by operational rules can participate in modifying those rules (Cox et al 2010). In-depth interviews with CWP management committee members and WRUA executive members, and review of bylaws and other documentation, revealed that bottom-up representation is a fundamental feature of the Likii subcatchment governance (see Dell'Angelo et al 2014). Every CWP elects the management committee executive members and the chair of the committee, who then represents the CWP on the WRUA management committee, which is the main legislative body. This provides a system and procedure by which the people affected by the rules can participate in setting or modifying them. Our interviews inquired about the CWPs' ability to enter into agreements with other communities within the WRUA regarding water extraction from the Likii River, which shows the level of institutional coordination across different projects.

Principle 4: Monitoring: This principle requires that users' behavior is monitored, and that the monitors either are accountable to the users or are themselves users (Cox et al 2010). Effective monitoring takes place at the CWP level, where the management committee members and caretakers of the project are able to verify the correct functioning and water use. The sampled CWPs have clear monitoring regimes, including the use of headgate gauges to monitor community-level appropriation as well as monitoring of individual users by the CWP management committee members. Some CWPs also reported that community members actively engaged in monitoring.

Monitoring is also a central aspect of WRUA governance. Monitoring is implemented by the WRUA's technical officer and personnel, but there are strong limitations to its effectiveness for several reasons, including lack of personnel, the size of the area that needs to be monitored, and the frequency of unregulated water abstraction. For this reason, although the WRUA has established a rotation system for water allocation that should ideally determine the amount of water abstracted from the river, the lack of monitoring capacity at the river-basin level makes it challenging to enforce these water use limits at the river-basin level.

Principle 5: Graduated sanctions: Under this principle, the severity of sanctions depends on the character or frequency of violations of community rules. This deters repeat violations while maintaining community cohesion by avoiding disproportionate sanctions for minor rule violations (Cox et al 2010). Scholars debate whether sanctions are necessary in communities with strong social capital, and some have argued that they cannot be a replacement for it (Cleaver 2000). However, CWP committee members interviewed for this study said that sanctions are a useful tool. The CWPs investigated for this study generally impose moderate penalties (such as loss of water) for minor rule violations (such as failure to pay monthly fees or to contribute labor). Of the 5 CWPs, 4 had clearly articulated penalties associated with illegal pumping or tampering with the pipe system. Repeat violations, or more serious violations such as illegal pumping or pipe tampering, can lead to financial penalties or loss of CWP membership.

Principle 6: Conflict-resolution mechanisms: The upper Ewaso Ng'iro River subcatchment has been strongly affected by conflicts between users, both between downstream and upstream users and among smallholders in the same areas. Study participants reported that participation in the CWPs prevented conflict between users regarding water access, and participants from 4 of the 5 CWPs reported that they had previously received

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complaints from users about water access. Communities are also able to turn to the WRUA and the Water Resource Management Authority (WRMA) to resolve intercommunity disputes.

This is consistent with the findings of other studies that the implementation of the WRUA system in 2002 has been an effective solution to many of these conflicts (Liniger et al 2005; Baldwin et al 2015). A fundamental feature of the WRUA is its basis in democratic representation and deliberation. It has also provided the more disadvantaged users (those living downstream) a forum in which to express their concerns. The WRUA has also increased transparency and information on water availability and use.

Principle 7: Recognition of the right to organization: Recognition by external government agencies of a community's right to self-organize allows the community to establish rules that are appropriate for local conditions. Conversely, where external government agencies do not recognize a community's right to self-organize and instead impose externally generated rules, those rules may not correspond with local conditions and may lead to undesired governance outcomes (Cox et al 2010). The WRUA architecture is based on the principle of involving the communities in the governance system and recognizing their right to manage the resource. This happens through a bottom-up representation system that begins with the election of the CWP representatives. The CWPs are constitutive components of the WRUAs, recognized by the WRMA and by the Ministry of Water and Irrigation, and their role is emphasized in the national legislation.

Principle 8: Nested governance: According to Ostrom (1990), governance activities that are organized in "multiple layers of nested enterprises" are more likely to be associated with successful outcomes. The Likii WRUA shows clear characteristics of nested governance, with decision-making taking place at multiple levels. Decisions at the CWP level are made by a management committee democratically elected by community members. The chairs of the management committees constitute the WRUA management committee, and the WRUA receives instructions from WRMA and the Ministry of Water and Irrigation. The general relationship between the different decision levels is not strictly hierarchical, but it works through feedback and mutual influence.

Demographic pressure and water management implications

The chairs of several CWPs stated that membership had greatly increased in the past 5 years. The secretary of one CWP stated that "the increase in population has led to more people irrigating." This CWP has capped membership so that no new individuals can join, in order to allow existing members to maintain their livelihood practices (including irrigation) even as the population of surrounding areas increases. The secretary of another CWP stated that the project's management committee had recently decided to cap its membership because there was not enough water. He attributed this partly to the growth of the project's membership from 279 members in ~2008 to 366 in 2013. Another CWP's caretaker stated that it has only been within the past 5 years that the water project has been forced to implement a rotation schedule during dry periods, because of an increase in membership (fueled by an increase in population in the surrounding area). One CWP chairman stated that the management committee has intentionally kept membership numbers low so that water does not become too scarce.

Household water flow differences

In parallel with the institutional analysis, we measured household water flow rates for 6 months across the 5 water projects. In terms of average household flow rate for each CWP as a whole, the projects fell roughly into 2 groups. There were only slight differences between CWPs 1, 2, and 3, but there was a strong difference between this group and the other 2 CWPs, which had much lower average rates (Table 4).

Between households within a single CWP, flow rate differences varied, in some cases substantially. This shows a fundamental challenge of community water governance. CWP bylaws mandate equitable allocation of water to all member households. However, substantial differences existed for each CWP between the highest and lowest household flow rates. In CWPs 1, 3, and 4, the maximum flow was about twice the minimum flow; in CWPs 2 and 5, the maximum was almost 3 times the minimum (Table 5).

We also mapped the CWP pipe networks along with average household flow measurements to show the spatial distribution of household-level flow rates (Figures 3, 4). These maps suggest that some potential explanations for differences in flow rate can likely be ruled out, including the specific position on the lines and distance from the CWP intake.

Discussion and conclusions

Kenya's 2002 water reform established institutions that adopt many widely accepted governance best practices, such as involving local stakeholders, encouraging active participation, building capacity, devolving centralized powers to local actors, and allocating water equitably. The governance system in the upper Ewaso Ng'iro River basin of Mount Kenya has been described as an example of this positive institutional transformation (Baldwin et al 2015). The research presented in this paper explored the institutional and biophysical dynamics of water governance at the CWP level through the lens of Ostrom's (1990) 8 design principles of natural-resource management.

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TABLE 4 Average household flow rates (L/min): differences *between* CWPs.

Water project	Households measured	Measurement period	Average flow rate	% days without water[a]
1	10	12 July 2013–31 January 2014	11.76	5.9
2	19	9 July 2013–28 January 2014	11.10	4.1
3	10	9 July 2013–29 January 2014	12.48	6.3
4	10	8 July 2013–27 January 2014	5.90	26.6
5	18	11 July 2013–30 January 2014	8.96	9.6

[a] Lack of water was only counted if the household should have received it—for example, if project pipes were broken, but not if water was cut off for nonpayment of dues.

We found a degree of institutional homogeneity among the 5 CWPs studied. However, this is not necessarily good news. An important debate on Ostrom's design principles for common-pool resources management is whether they can be considered a blueprint for sustainable governance (Cox et al 2010). The lack of diversity among the different CWPs might indicate that decentralization and the move to more participatory water governance could have replaced one institutionally locked-in system with another. There is consensus that the current water governance system has produced positive management outcomes, increased dialogue and participation, and decreased conflicts (Liniger et al 2005; Baldwin et al 2015), but the concern is that the current system is not adaptive to changing conditions such as the double threat of hydroclimatic change and population growth.

There are 2 main trends in the CWPs of the Likii WRUA: (1) a certain degree of institutional homogeneity and (2) a high level of inter- and intra-CWP differences in water flow. The origin of these differences is beyond the scope of this paper, but it is important to recognize what they imply and what they signal. The first implication of these results is the discrepancy between the CWPs' consistency with Ostrom's design principles and their low level of adaptation to change. From interview and questionnaire responses by executive members of the CWP management committee, it is possible to understand the standardized nature of the procedures, functions, and decisions of these committees. In particular, the role of information, such as the information on household water flows that we report here, is overshadowed by routine management tasks such as collection of fees, monitoring, maintenance, and meetings. Moreover, formal management procedures reveal only 1 side of the story. There is a critical component of decision-making in the CWPs that happens in the management committee and is more influenced by the interaction of individual preferences and group social–psychological dynamics than by formal rules (Dell'Angelo et al 2015). Combining institutional analysis with the social psychology of group dynamics is a particularly important

TABLE 5 Average household flow rates (L/min): differences *within* CWPs.

Water project	Scope of measurement	Maximum flow	Minimum flow
1	10 households, 29 measurement days	15.50	6.98
2	19 households, 27 measurement days	17.16	6.14
3	10 households, 30 measurement days	16.30	8.60
4	10 households, 29 measurement days	7.80	3.73
5	18 households, 29 measurement days	15.03	5.51

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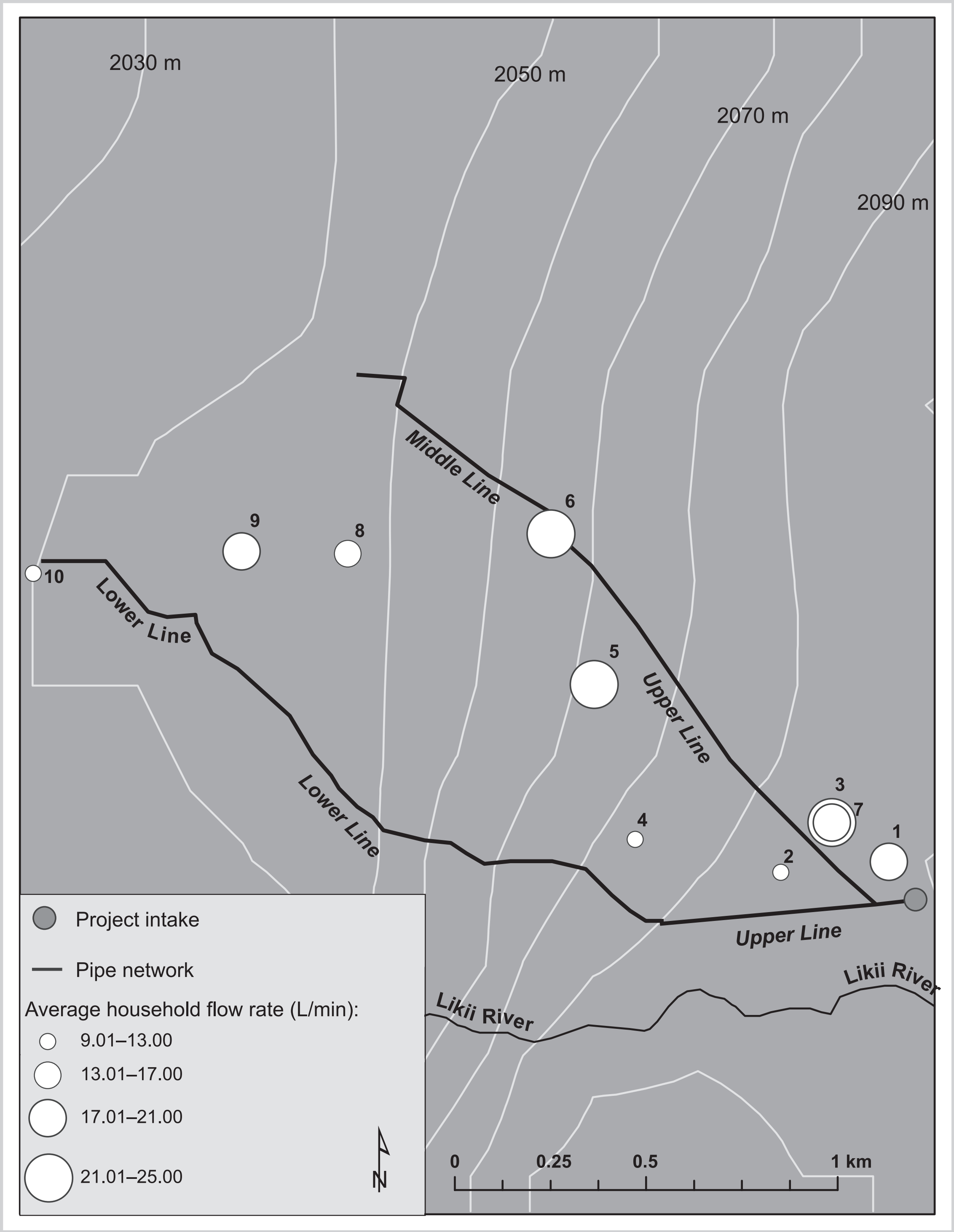
FIGURE 3 Pipe network and sampled households, CWP 1. (Map by Paul McCord)



direction for future research on community-based natural resources governance.

The second implication is that lack of information combined with inequalities in water flow has been historically associated with conflicts and tensions (Liniger et al 2005). This paper, which focuses on the CWPs, shows only 1 of the many dimensions of water inequality that characterize the upper Ewaso Ng'iro River basin. Even

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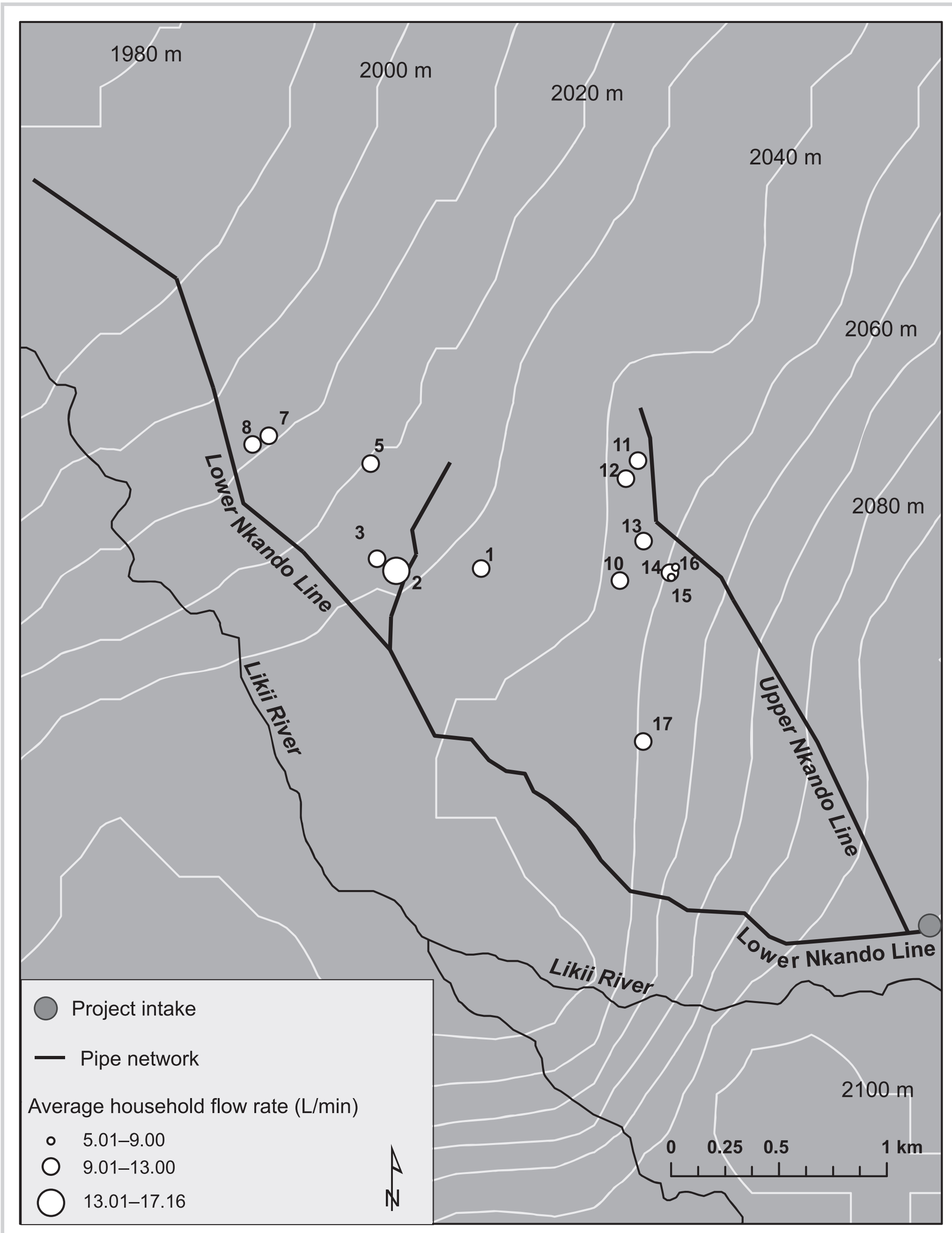
FIGURE 4 Pipe network and sampled households, CWP 2. (Map by Paul McCord)



more striking inequalities exist between CWP members, who can afford to pay for membership and water access, and nonmember households, which are often trapped in a vicious cycle of lack of economic assets leading to lack of the water necessary to develop economic assets. Similar water inequalities occur between downstream and upstream users and between different categories of users (eg commercial farms, smallholder farmers, and pastoralists). Moreover, CWP-level consistency with Ostrom's design principles does not imply the same for the (higher) WRUA level of governance. Investigation of the institutional dynamics of the WRUA is also necessary to assess overall river basin governance.

Inter- and intra-CWP water differences point to the existence of several dynamics that can threaten the sustainability of a socioecological system and its

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governance structures. Even systems with positive features such those identified by Ostrom's 8 design principles may not be able to keep up with changes in socioecological conditions. Adaptive governance is challenging, and the speed and scope of change requires an intense and constant involvement of stakeholders and redefinition of institutional strategies. The future of Mount Kenya's water governance will largely depend on how the different actors are able to collaborate and share information and on how responsive to socioenvironmental change the institutional adaptations are.

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