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Drivers of farmer satisfaction with small-scale irrigation systems

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ABSTRACT

Climate change impacts the quantity and seasonality of rainfall, threatening Africans' ability to maintain satisfactory yields on rain-fed farms. On the semi-arid northwestern slopes of Mount Kenya, irrigation systems structured around Community Water Projects (CWPs) provide households with piped water, which helps mitigate drought impacts and enhances resilience to increasingly variable rainfall patterns. The vision of these irrigation systems is to equitably distribute water resources among CWP members both for household consumption and to maintain or improve agricultural yields. However, not all households receive equal quantities of water from their CWPs, and little is known about the impact of water provisioning on farmers' opinions or perceptions of CWP performance.

In this study, we relate respondents' satisfaction with their CWPs to the quantity of water delivered. Not surprisingly, farmers who received low quantities of water from their CWPs expressed above-average rates of concern regarding drought. In contrast, satisfaction with one's CWP was unrelated to the absolute quantity of water received (log liters/minute), but it was strongly associated with relative measures of water delivery: respondents who received less water than other members of the same water project experienced high rates of dissatisfaction, as did respondents who received less water than in the past. These results suggest that Kenyan farmers may feel particularly dissatisfied—and, perhaps, particularly driven to demand improved water governance—when they perceive inadequate water delivery relative to some reference group.

Because relative water quantity dictates satisfaction even after controlling for factors that can be resolved internally at the CWP level (by, for example, striving for uniformity of water flows across and within households), water project managers are limited to some degree in their ability to improve satisfaction through better governance. That said, governance actions that prevent declines in flows over time (e.g. maintaining infrastructure to reduce leaks) could ostensibly lead to meaningful improvements in member satisfaction.

1. Introduction

The impacts of climate change are being felt globally, with particularly severe consequences forecasted for Africa. As climate change continues to transform precipitation patterns, farmers who fail to adapt to the changes will face threats to their livelihoods and food security. Many of Africa's farming systems are largely or entirely rain-fed, meaning farmers are limited in their capacity to respond to unanticipated precipitation shocks. In this regard, access to piped water serves as a valuable complement to rainfall, allowing some farmers to build resilience to unseasonable dry spells, shorter or earlier growing seasons, and increasingly variable rainfall patterns (Rockström et al., 2010).

Access to piped water does not benefit all farmers equally, however. Membership in a water delivery system can be cost-prohibitive for poor farming households (Kimmage, 1991). Furthermore, for those who do belong to localized water systems, the degree to which those systems capably deliver water can be highly variable, both spatially and temporally (Gower, Dell'Angelo, McCord, Caylor, & Evans, 2016; McCord, Dell'Angelo, Gower, Caylor, & Evans, 2017). This variability in delivery outcomes—as reflected by metrics such as adequacy and dependability of water provision (Molden & Gates, 1990)—can be attributed to a complex combination of infrastructural, institutional, and biophysical conditions (Janssen, Anderies, & Ostrom, 2007; Lam, 1998; McCord et al., 2017).

A key characteristic of irrigation systems is the heterogeneity of water delivery across space, which results in distinct upstream-downstream dynamics. Spatial arrangement of water users forms the basis for

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negotiation over water rights, as downstream users rely on the willingness of upstream users to share water resources (Lam, 1998; McCord et al., 2017). Even within community-based water delivery systems, spatial arrangement has important implications. For example, households at the tail-end of water distribution lines can have higher water pressure if they lie at the base of a steep gradient, thus allowing them to receive larger volumes of water in a given period of time. Alternatively, because water lines are difficult to maintain, poorly maintained lines can develop leaks that result in lower flows for users at the ends of lines. Beyond these biophysical and infrastructural components, other spatial inequalities can exist, such as the ability of some households to directly connect to lines, whereas other households cannot.

In addition to examining water delivery as an outcome, researchers have also investigated how water delivery itself drives other outcomes, such as farming behaviors. Water delivery can influence farmers' capacity to adapt to changing environmental conditions, but this area of study is not well understood. Reliability of irrigation water, for example, has been shown in different studies to be both positively (Bryan, Deressa, Gbetibouo, & Ringler, 2009; Bryan et al., 2013) and negatively (Deressa, Hassan, Ringler, Alemu, & Yesuf, 2009) associated with farmers' likelihood of experimenting with farming strategies, such as adoption of new seed varieties.

We believe an irrigation system's water delivery will drive members' satisfaction with their system, which can, in turn, affect the system's longevity. Within the substantial literature examining the institutional factors that contribute to long-standing common-pool resource systems, much of the focus is on irrigation systems in particular (Lam, 1998; Ostrom, 1999). There are numerous examples of failed irrigation systems that fell into disrepair through a lack of resources to maintain the infrastructure or through mismanagement that contributed to inadequate maintenance (Hashimoto, Stedinger, & Loucks, 1982; Webb, 1991). System failure is a conceivable result of member dissatisfaction because displeasure with water delivery outcomes can create impediments to achieving collective action among members (Lam, 1998).

Dissatisfaction with one's water system—and associated threats to its longevity—may occur through two avenues. First, dissatisfaction may be the result of external, and potentially non-resolvable, factors, such as climate conditions. For example, if drought is a frequent problem, the quantity of water delivered may be an inadequate complement to rainfall, leading members to feel dissatisfied with their decision to invest in the development of a surface water irrigation system. Second, dissatisfaction may be the result of internal, potentially resolvable, factors, such as poor project management or maintenance. If, for example, members perceive that they receive disproportionately lower allocations of water than other members in their network, they may be dissatisfied with the management of their system, which is tasked with providing equitable delivery of water to all members. Using the analogy of water allotment as slices of a pie, we see the external factors (e.g. climate) as those that determine the size of the pie. Internal factors (e.g. management) are those that determine whether the pie's slices are of equal size and are served to members with equal regularity. Both external (e.g. population size) and internal factors (e.g. restrictions on new membership) can influence the number of slices in the pie. Although either avenue of dissatisfaction may lead members to leave the system, which could in turn cause system collapse, dissatisfaction due to internal factors comes with greater potential to resolve the problem through better management.

To what degree would we expect satisfaction and drought perceptions to relate to water delivery outcomes? In a most basic sense, absolute measures of water delivery, such as the quantity of water received or the degree to which water is delivered reliably, are likely to impact farmers' perceptions. Under this line of reasoning, farmers who receive low quantities, infrequent delivery, or unreliable delivery of piped water will be dissatisfied and concerned about drought, ostensibly because the piped water is an inadequate complement to on-farm rainfall.

Beyond the absolute quantity and reliability of water delivery, however, individuals' satisfaction levels might also be a function of relative conditions. The importance of relative conditions in dictating perceptions has long been of interest to economists and psychologists, who argue that individuals base their satisfaction levels on their positions relative to their own prior conditions (Hsee, Abelson, & Salovey, 1991) or on their conditions relative to others' (Boyce, Brown, & Moore, 2010; Duesenberry, 1949; Rablen, 2008)—especially, relative to others in their local reference groups (Norton, 2013).

When considering one's ranked position within a group, the uniformity with which water is provisioned to the members of that group might also be of importance. Societal inequality in its various forms has been linked to high rates of social problems (e.g. unhappiness, violence, and poor health [Oishi, Kesebir, & Diener, 2011; Wilkinson & Pickett, 2006, 2009]); might inequality in water provisioning act similarly, driving high levels of farmer dissatisfaction? We believe the answer to this question is “yes.” In semi-arid Africa, where precipitation events are highly spatially and temporally variable, effective governance of irrigation sources—such as rivers, lakes, and streams—may be of huge importance to farmers, determining the difference between a successful and failed harvest (The Economist, 2016).

Here, we study the drought perceptions and satisfaction levels of semi-arid smallholder farmers located in an area where, given the reliance on seasonal river discharge, effective water governance is particularly important. Using survey data, piped water flow data, and interpolated precipitation data from 24 Community Water Projects (CWPs) in the Mount Kenya region, we relate farmers' drought perceptions and CWP satisfaction to absolute and relative measures of their piped water flows. Our results offer insight into the hydrological drivers underlying Kenyan farmers' opinions and, potentially, into a CWP's ability to improve satisfaction in the face of climate uncertainty.

2. Study area, material, and methods

2.1. Study area

In the Upper Ewaso Ng'iro basin on the northwestern slopes of Mount Kenya, regional precipitation patterns are heavily influenced by topography. High-elevation (i.e. upstream) farms receive mean annual rainfall in excess of 1000 mm, whereas lower-elevation (i.e. downstream) farms receive less than half that amount each year (Fig. 1). In addition to upstream farmers' precipitation advantage, they can also experience an irrigation advantage if water delivery is more plentiful and reliable for those who withdraw water from higher up the river (Lam, 1998). Well-managed water systems can mitigate this downstream disadvantage by regulating water distribution.

In our study area, access to and delivery of water is governed by Water Resource Users Associations (WRUAs) at the catchment level and by CWPs at the community level. During dry periods when river levels are low, the WRUA implements a water rationing schedule that allows only a selection of CWPs to withdraw water on a particular day. Once water is withdrawn from a river and enters a CWP's water distribution network (a series of buried pipes), a host of institutional, infrastructural, and biophysical traits account for the amount of water received by a particular household. For example, some CWP management committees elect to restrict the number of households belonging to the irrigation system in order to hold membership within a range at which the management committee is able to meet user demand. Other CWPs may possess newer pipe infrastructure with fewer incidences of water leakage, or they may be in areas that pose fewer topographic obstacles for water distribution infrastructure, thereby resulting in superior household water delivery.

It is important to note that local farmers play a role in shaping the water management rules and policies within their CWPs (Baldwin, Washington-Ottombre, Dell'Angelo, Cole, & Evans, 2015), and a member experiencing poor water delivery can take his or her grievance