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# Assessing multi-level drivers of adaptation to climate variability and water insecurity in smallholder irrigation systems

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ABSTRACT

Smallholder agriculturalists employ a range of strategies to adapt to climate variability. These adaptive strategies include decisions to plant different seed varieties, changes to the array of cultivated crops, and shifts in planting dates. Smallholder access to irrigation water is crucial to the adoption of such strategies, and uncertainty of water availability may prove to be a stimulating force in a smallholder's decision to adjust their on-farm practices. Within smallholder irrigation systems, attributes at multiple levels influence water availability and collective action, and in the process play a role in adaptation: community-level governance institutions may influence trust in others and the ability to overcome appropriation and provisioning dilemmas, and, at the household-level, the availability of irrigation water and socioeconomic and demographic factors may influence farmer willingness to take on the risk of altering their on-farm practices. In this study we investigate smallholder adaptation in Kenya from multiple levels. Specifically, we identify the role of household- and community-level characteristics in shaping smallholder experimentation with different seed varieties. Standard ordinary least squares and logistic regressions are constructed to assess the influence of these interactions on smallholder adaptation. We further discuss the ability of smallholders to respond to poor water provisioning. Among the study's findings is evidence that smallholders are more willing to employ adaptive measures if they have a limited capacity to irrigate.



## 1. Introduction

Climatic conditions play a significant role in food security in semi-arid environments where livelihood is dependent on agriculture. Smallholders employ a range of adaptation strategies to mitigate the effects of changing climatic conditions, including seeking wage labor, diversifying livelihood practices, selling livestock, and, most relevant for this paper, changing the seed varieties that they cultivate. Given smallholders' economic vulnerability in the face of climate change, it is crucial to understand why some smallholders adopt adaptation strategies to minimize their risk and others do not. While a growing number of studies identify the drivers of smallholder adaptation strategies, most of the literature to date has focused on identifying the household attributes that explain smallholder adaptation behaviors (e.g., Hassan and Nhemachena, 2008; Bryan, Deressa, Gbetibouo, & Ringler, 2009; Deressa, Hassan, & Ringler, 2011; Kristjanson et al., 2012). In the present text, we argue that such studies have overlooked the potential importance of community-level variables, particularly attributes related to the resolution of collective action problems, i.e., problems where individual incentives differ from the incentives of the group. Our study, conducted in twenty-five community irrigation systems within a semi-arid region around Mount Kenya, approaches smallholder adaptation from multiple levels to identify

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attributes of the household and the community irrigation system that influence the likelihood of smallholders' use of adaptive strategies.

Reliable access to irrigation water has emerged as a key predictor of a households' use of adaptation strategies (Gower, Dell'Angelo, McCord, Caylor, & Evans, 2016). For example, Deressa, Hassan, Ringler, Alemu, and Yesuf (2009) found smallholders in Ethiopia's Nile Basin more willing to adapt to the effects of climate change if they had poor access to irrigation water. Likewise, in northern Ghana, farmers have responded to over-exploitation of groundwater for irrigation by adjusting their on-farm practices so as to cope with reoccurring water deficits (Laube, Schraven, & Awo, 2012). In both cases, the scarcity of water creates an incentive to adjust farming practices. However, smallholder adaptation cannot be understood by solely exploring household-level water availability, particularly where households share common irrigation systems. In semi-arid irrigation systems, trust that the collective group will coordinate their actions to ensure the functioning of irrigation infrastructure and that all smallholders will abide by water use restrictions is built on well-crafted water governance institutions capable of addressing collective action problems (Janssen, Anderies, Perez, & Yu, 2015; Lam, 1998; Ostrom, 1990). If members perceive that governance arrangements are insufficient to address these challenges, they may explore household-level adaptation strategies foreseeing the need to "go it alone" in the face of climate uncertainty (e.g., Markelova, Meinzen-Dick, Hellin, and Dohrn (2009) concerning market access). Studies such as Lam (1998) and Bardhan (2000) emphasize that effective management is key to smallholder water access; yet, to our knowledge research exploring the role of irrigation systems' institutional arrangements in shaping households' adaptive behaviors through the resolution of collective action dilemmas has been limited (some exceptions include Anderies, Janssen, Lee, & Wasserman, 2013; Janssen et al., 2015).

A substantial body of literature has been amassed to understand smallholder adaptation within settings of water scarcity and variable precipitation (e.g., Cooper et al., 2008; Deressa et al., 2009; Mertz, Mbow, Reenberg, & Diouf, 2009; Shiferaw, Okello, & Reddy, 2009; Below et al., 2012; Laube, Schraven, & Awo, 2012). Likewise, researchers have devoted much effort to understanding the role of institutional arrangements in resolving collective action challenges within irrigation systems (e.g., Ostrom, 1992; Ostrom and Gardner, 1993; Lam, 1998; Berkes, 2002; Ostrom, 2005; Huitema et al., 2009; Pahl-Wostl, Holtz, Kastens, & Knieper, 2010; Cox and Ross, 2011; Janssen et al., 2015). Surprisingly, these two lines of research have largely remained separate, and little attention has been given to the interplay between resource governance, water availability, and adaptation. For instance, studies such as Deressa et al. (2011) consider the role played by irrigation in allowing smallholders to adapt to climatic events; however, governance arrangements influencing the availability of irrigation water are largely overlooked. Conversely, studies such as Ostrom and Gardner (1993) and Lam (1998) give sufficient attention to the infrastructural and institutional drivers of smallholder water availability, and Ostrom (1990) has synthesized a set of "design principles" that are associated with reliable and sustainable water supplies. Yet, such studies rarely link governance to household-level adaptive behaviors.

The goal of this study, therefore, is to examine the degree to which institutional arrangements of irrigation systems (i.e., community-level attributes) and household-level elements, including irrigation water supply, affect smallholder adaptation. This study focuses on a semi-arid region near Mount Kenya where smallholder farmers receive water from community-based irrigation systems, known as Community Water Projects (CWPs). Consistent with previous research, we hypothesize that smallholder adaptation decisions depend on the reliability of irrigation water supplied by CWPs. In particular, we expect adaptation to occur when the supply of irrigation water to smallholders is less reliable (e.g., Deressa et al., 2009, 2011), holding constant other household attributes such as education and income level. We also hypothesize that CWP governance and attributes facilitating or inhibiting collective action matter. In particular, individual-level adaptation will be more likely when CWPs exhibit traits that have been found to inhibit collective action, such as within large CWPs or CWPs where members are less familiar with one another (Fujiie, Hayami, & Kikuchi, 2005; Ostrom, 2005). In both cases, we hypothesize that limited familiarity and trust for one another dispels confidence in the CWP's water provisioning mission and in turn leads smallholders to embrace their own endogenous adaptation strategies. Additionally, we hypothesize that smallholders residing within irrigation systems that have failed to adopt rules consistent with Ostrom's design principles – described below – will be more likely to employ adaptation strategies due to their own calculation of institutional failure in the face of climate variability.

## 2. Theory

### 2.1. Adaptation

The concept of adaptation has been analyzed in anthropology, sociology, and geography literatures, among others, for some time (e.g., Parsons, 1964; Grossman, 1977; Moran, 1991). In geography, for example, these were often studies of "man-land" or "man-environment" relations seeking to understand human adaptation made in response to changes in the physical environment (White, 1973). With the growing recognition of challenges posed by climate change, as well as the formation of scientific bodies such as the Intergovernmental Panel on Climate Change (IPCC), an uptick in climate change adaptation research has taken place represented by the publishing of thousands of climate change articles each year and the creation of new scholarly journals devoted to gaining a deeper understanding of the issue (Berrang-Ford, Ford, & Paterson, 2011; Hulme, 2010).

Along with providing a better understanding of individual-, community-, and national-level responses to changing conditions, the swell of climate change adaptation research has encouraged deeper inspections of what truly should be considered "adaptation." For instance, Perramond (2007) emphasized a need to account for the temporal dimension of adaptation. He suggested using the term "adaptation" for changes that were certain to be long-term, such as the movement of a group of sedentary farmers to an area more favorable for cultivation, while "adaptive tactics" would consist of fleeting adjustments and "adaptive strategies" would consist of those tactics that, over time, materialize into a more systematic strategy. The IPCC has offered a more widely-recognized definition for the term "adaptation", which they describe as "the process of adjustment to actual or expected climate and its effects" (Field et al., 2014: 40). While this definition does not explicitly address the issue of temporal duration (i.e., the difference between a fleeting alteration and a long-term change), it does suggest that adaptation can occur either *ex-ante* or *ex-post*. Throughout this article, our usage of "adaptation" is consistent with the somewhat broader definition provided by the IPCC.

However, adding some nuance to the IPCC definition, we follow Tschakert and Dietrich (2010) in advocating that adaptation be viewed as encompassing a learning process in which adjustments develop over time. In other words, climate adaptation is not a linear process; rather, it is intermittent and varied as individuals navigate their own incomplete information concerning climate change

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