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Moving the Conversation on Climate Change and Inequality to the Local:

Socio-ecological Vulnerability in Agricultural Tanzania

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Abstract

Climate change is expected to shift seasonality in Tanzania, while smallholder farmers' livelihoods and the economy rely upon the success of rainfed agriculture. However, we should not *a priori* assume doomsday climate vulnerability scenarios of drought and devastation in the rural global South nor, on the other hand, that farmers will optimally employ local knowledge for effective adaptation. Drawing from qualitative fieldwork in two Tanzanian communities, I question these grand narratives of devastation and local adaptive capacity and introduce an approach that brings inequality to the center. Poorer nations are most vulnerable to climate change, but they are not homogenous and neither are the smallholder farmers living within them. I present evidence on the crucial context-specific dimensions of socio-ecological vulnerability for these smallholder farmers —1) water resources and access to them; 2) agricultural knowledge, including farmers' own knowledge and their interactions with sources like government-run agricultural extension and NGOs; and 3) existing drought-coping strategies—and the heterogeneity among farmers across these dimensions. Ultimately, this case demonstrates how climate change can reproduce existing inequalities within nations by drawing upon how farmers currently respond to drought as evidence. I present the difficult and somewhat bleak contexts within which the farmers are coping, but also illustrate the agency that farmers exhibit in response to these conditions and the adaptive capacity they possess. Finally, I call for more sub-national research on climate and inequality by sociologists and draw connections among within-nation inequality, climate change, and agricultural development initiatives.

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INTRODUCTION

Agriculture is fundamental to Tanzania's economy, constituting half the nation's GDP compared with the global average of less than 6 percent. Smallholder farmers represent 70 percent of the Tanzanian workforce, and agriculture, despite sometimes being risky and uncertain, is also a backbone of livelihoods, stability, and resilience (De Haen and Stamoulis 2004; Challinor et al. 2007). At the same time, Tanzanian agriculture is beginning to see the shifts in growing seasons, temperature, precipitation, and yields expected with climate change (Lobell et al. 2008, 2011). Given that a small (but growing) portion of the farmland in the country is irrigated, agricultural livelihoods are heavily reliant upon increasingly variable precipitation patterns. Although seasonality and drought have always shaped farmers' livelihoods, climate change means greater deviations from familiarity. During my time in the field, farmers in central Tanzania were anticipating the delayed annual rainy season, and the short rainy season that should have occurred in northern Tanzania was unrecognizable.

Agricultural productivity models link climate change, particularly increases in both temperature and rainfall variability, to reductions in the yields of staple crops and a shortening of the growing season. An increase of 1°C in temperature is predicted to reduce maize yields in Tanzania by 17 percent (Ahmed et al. 2011), while growing season temperatures are likely to exceed the most extreme heat in Tanzanian farmers' past experience by the end of this century (Battisti and Naylor 2009). Climate projections for East Africa also suggest a decline in rainfall during the dry season, leading to more frequent and severe droughts. The most recent Intergovernmental Panel on Climate Change (IPCC) report suggests that Tanzanian farmers can expect rainy seasons to both shorten and lengthen, depending upon geography (Field et al. 2014). This raises the additional possibility of unpredictable starts to the growing season, which typically begins with the rain.

Sociologists and economists posit that Tanzania is one of twenty countries with the highest cumulative number of people already affected by climate change (Roberts and Parks 2007) and among the countries with the largest portion of the population at risk for entering poverty because of climate variability (Ahmed, Diffenbaugh, and Hertel 2009). The grave implications for agricultural productivity and livelihoods suggested by natural and social science research call for further work on farmers' vulnerability to climate change and on how climate change may influence rural farming communities. However, we should not assume *a priori* either doomsday climate vulnerability scenarios of drought and devastation in the rural global South or, on the other hand, that farmers will optimally employ local knowledge for effective adaptation.

Drawing from qualitative fieldwork with smallholder farmers in two Tanzanian communities, I question the grand narratives of devastating adaptation limits and local resilience and adaptive capacity by introducing an approach that brings local inequalities and subnational analysis to the center. Poorer nations are more vulnerable, but they are not homogeneous, and neither are the smallholder farmers living within them. I demonstrate the crucial context-specific dimensions of climate vulnerability for these smallholder farmers—(1) water resources and access to them; (2) agricultural knowledge, including farmers' own knowledge and their interactions with sources like government-run agricultural extension and international nongovernmental organizations (NGOs); and (3) existing drought-coping strategies—and the heterogeneity among farmers across these dimensions.

My primary focus is the existing inequalities among smallholder farmers and how these may shift with climate change. As Mohai, Pellow, and Roberts (2009) write, "Climate change reflects and increases social inequality in a series of ways, including who suffers most its consequences, who caused the problem, who is expected to act, and who has the resources to do so." Previous sociological work on climate has focused primarily on structural inequalities in the global political economy, with nation-states as the actors negotiating on a global stage. Climate injustice and inequality are typically conceived as relationships among nation-states or blocks of nation-states organized around notions like core/periphery and global South/global North (Adger et al. 2006; Mohai et al. 2009; Parks and Roberts 2010; Beck 2010a). Following Ulrich Beck's (2010b) call to rethink our units of analysis and "remap social inequalities in an age of climate change," I contribute much-needed subnational research on climate change and inequality. However, I question Beck's (2010a; 2010b) assertion that climate change will disrupt existing inequalities by examining how they are reinforced during drought at the local level.

I focus on how farmers actively cope with drought (or do not), while at the same time presenting the contextual socio-ecological constraints within which this occurs. My attention to national and global institutions such as government agricultural extension and international NGOs also importantly extends this work beyond the local, as farmers' drought-coping strategies are connected to processes operating on broader scales (Eakin 2005; Adger, Eakin, and Winkels 2009b). The social and the individual levels iteratively construct limits to adaptation, a sociological perspective that goes beyond the climate adaptation literature's approach that we need to understand both individual and institutional actors and constraints (Adger et al. 2009a).

By drawing from vulnerability and adaptation, environment, and development literatures, I place somewhat disparate areas of sociology and environmental social science in more direct communication to address the pressing issues of climate vulnerability and adaptation, inequality, and their interconnections in the rural global South. I begin with targeted overviews of vulnerability and adaptation literature to ground the analysis, followed by an introduction to the two farming communities and a description of my qualitative methods. For the remainder, I illustrate the dimensions of vulnerability that are relevant for smallholder Tanzanian farmers, show how these vary within communities and relate to inequality, and discuss temporal and spatial scales of vulnerability. Ultimately, I argue that sociologists should be more devoted to subnational investigations of climate and inequality by demonstrating how climate change may reproduce or worsen existing socio-ecological inequalities in Tanzanian communities.

THEORY AND BACKGROUND

Vulnerability Theory

Vulnerability can be defined as both the risk of a climate hazard and the ability of those affected to adapt. This risk-hazard approach unites climate change's influence on the weather system, the sensitivity of that system, a region's exposure to the climate hazard, the consequences for affected individuals, and human capacity to adapt (Burton, Kates, and White 1993; Cutter 1996; Watson, Zinyowera, and Moss 1996; Turner et al. 2003; Brooks 2003). However, climate modeling cannot yet precisely predict the frequency and magnitude of future climate hazards regionally within Tanzania, and not enough climate change and adaptation has been observed so far to document the adaptive strategies that smallholder farmers will pursue. Rather than feeling the paralysis of uncertainty, I assume that households' present capacity to cope with and respond to drought will be indicative of their abilities to adapt to the greater frequency and severity of droughts expected in the future. Though farmers may change their responses to drought as the common experience of weather variability shifts to a sense of climate change and greater unpredictability (Hastrup 2009), the best current approach for understanding future adaptation and consequences is learning what farmers do to cope with drought in the present and how drought affects communities now. Thus my analysis centers on variation in farmers' *adaptive capacities*, or their abilities to anticipate, cope with, resist, and recover from drought (Blaikie et al. 1994; Kelly and Adger 2000; Cutter, Boruff, and Shirley 2003; Eakin 2005). Instead of focusing primarily on the hazards of climate change, we should be at least as concerned about the underlying inequalities it exposes and has the potential to worsen.

This political economy perspective on vulnerability draws from Kelly and Adger (2000), who see vulnerability as the present ability or inability of individuals and social groups to respond to external stresses. Known as *social vulnerability*, this framework is sensitive to the dynamic state of social, economic, and institutional structures that limit adaptive capacity, and it centers upon who exactly is vulnerable and why. Those with better access to social, cultural, and financial capital—such as knowledge, income, and social networks to mobilize resources from outside the household—are less susceptible to livelihood disruptions than more marginalized individuals, as are those who are more politically and administratively integrated (Lewis 1999; Kelly and Adger 2000; Cutter et al. 2003; Eakin and Luers 2006).

However, when the focus shifts away from the climate hazard and toward adaptive capacity and the political economy of vulnerability, the environment tends to be back-grounded and the social structure and social production of vulnerability tend to be over-emphasized (Eakin and Luers 2006; Oliver-Smith 2009). I underscore that households' access to social and *natural* resources is relevant for understanding vulnerability by integrating nature into underlying social vulnerabilities. Dimensions of vulnerability in this smallholder agriculture context are a co-constitution of the social and natural, including soil resilience; the rules, relationships, and institutions that govern water access; and human knowledge of natural and agricultural systems. Vulnerability is a product of complex interactions between society and ecosystems, and thus social vulnerability is treated as socio-ecological vulnerability in this paper (Freudenburg, Frickel, and Gramling 1995; Cutter et al. 2003; Adger 2006; Adger et al. 2009b; Hastrup 2009; Field et al. 2014). The attention on inequality and social mediation of natural resources unavoidably favors social structure, but I also demonstrate the intimate connections between the biophysical world and the reproduction of inequality.

Furthermore, centering my analysis on how socio-ecological vulnerability relates to inequality directs it away from climate reductionism, ensuring that climate change is not the only point of interest in a consideration of farmers' vulnerabilities (Hulme 2011). Focusing work about the shifting conditions for global South farming livelihoods entirely on the hazards of climate change would lead to a simplistic account that would overlook the roles of social change, local stratification, farmers' agency, historical relations, and Tanzania's place in the global agricultural system. A climatic single-stressor explanation misses important realities of vulnerability and reinforces the hegemony of the model-based, predictive natural sciences over humanistic accounts of environmental and social change (Eakin and Luers 2006; Leichenko and O'Brien 2008; Nuttall 2009; Adger et al. 2009a, 2009b; Hulme 2011). Also, key sociological concepts like inequality and power are not distinct from climate change vulnerability (Beck 2010a).

The qualitative approach to climate vulnerability taken here is meant to complement existing work that relies on standard quantitative indicators such as agricultural prices, income per capita, income risks, and measures of poverty (Adger 1999, 2006; Ahmed et al. 2009, 2011). A drought-year shift in GDP per capita, for example, does not necessarily translate directly to the livelihoods, and thus the vulnerabilities, of all smallholder farmers (Eakin 2005). Dercon and Krishnan (2000) also found that the proportion of farming households vulnerable to shocks in Ethiopia was not accurately represented in poverty statistics. Vulnerability has a normative component, and peoples' ideas about future losses and damages or important vulnerability dimensions can align or differ within households, communities, and nations (Field et al. 2014). For these reasons, the uncertainties surrounding climate change and vulnerability are sometimes not easily quantified, making narratives another useful approach to such research (Dessai and Hulme 2004). Expanding the picture of socio-ecological vulnerability beyond indicators provides important context and detail toward building a better understanding of climate vulnerability in one particular socio-ecological system—smallholder farming communities in Tanzania—that can be cautiously applied more broadly. Although some aspects of vulnerability and adaptation are context specific, similarities do exist between causes and consequences of vulnerability across places (Turner et al. 2003; Eakin 2005; Adger et al. 2009b; Beck 2010b).

In this paper, I focus on three distinct yet interconnected dimensions of vulnerability: (1) access to water resources and current drought-related crop losses; (2) agricultural knowledge; and (3) existing drought-coping strategies. That discussion is preceded by a section that outlines the two communities' farming systems and touches on traditional indicators of social vulnerability such as agricultural incomes and nonfarm work opportunities that should not be left out of the picture. By demonstrating that farmers change their practices to varying extents during drought, I contribute a nuanced criticism of the production-function relationship between climate and agriculture—the notion that climate change impacts on farming can be predicted by how climate is expected to affect crop output (Dell, Jones, and Olken 2014). To do this, I move farmers' behaviors, knowledge, and constraints to the center of the vulnerability analysis, along with inequalities. Throughout the paper, I also consider the four crucial areas for improvement in vulnerability research that Eakin and Luers outline (2006): (1) addressing multiple interacting stressors, (2) capturing socioeconomic and biophysical uncertainty, (3) accounting for cross-scalar influences and outcomes, and (4) emphasizing equity and social justice.

Climate Adaptation in the Global South

Climate change adaptation has received growing attention in scholarly and public debates during the past decade. Adger et al. (2009a) summarize this conversation as consisting of two strands. The first is concerned with how adaptation to climate change can be facilitated and enhanced through policies and institutional change, and the second with whether limits to adaptation exist and what underlies these limits. Earlier, Smit et al. (2000) positioned these two approaches into somewhat different categories—first, studies focused on adaptation as a potential policy and prescription, and second, those interested in what adaptations are expected or likely in different systems. In my analysis of smallholder farmers' vulnerabilities to climate change, I speak more directly to the second discussion, which considers constraints on peoples' adaptive capacities with consequences that are ethically and politically unacceptable, including adaptations that are expected or already happening (Adger et al. 2009a).

The literature's focus on adaptation limits lends itself toward the conception of thresholds. Consequently, adaptation limits are seen as absolute and objective biophysical, economic, and technological measures like insurmountable economic costs for Tanzania as a nation and smallholder farming communities, or irreversible changes to sensitive physical systems such as seasonal rainfall patterns. Economistic approaches that estimate the effects of exogenous biophysical factors like drought on agricultural productivity are part of this endeavor (Dell et al. 2014). Adger et al. (2009a) begin to critique this literature by suggesting that limits are actually endogenous, or contingently emerging in place at social and individual levels, rather than externally imposed.

From these ideas of adaptation, a public and scholarly discourse around limits has emerged that outlines two possible trajectories. Either Tanzanian smallholder farmers are facing insufferable ecological, economic, and technological limits to adaptation, or local and scientific knowledge can be employed for effective adaptation if the necessary individual and political acts come to fruition. Both approaches also tend to separate the institutional and social levels from individual and household adaptation actions. For example, Smit et al. (2000) write in response to the question of who or what adapts, "It can be people, social and economic sectors and activities, managed or unmanaged natural or ecological systems, or practices, processes, and structures of systems." The sociological imagination coloring my analysis mediates these conversations from the adaptation literature in two ways. First, I look at the agency of individual farming households in the context of broader constraints; and second, I center farmers' vulnerabilities, or limits to their adaptive capacities, on social inequality in order to demonstrate that limits to adaptation vary within the same rural community and that inequality itself is a social limit to adaptation.

CASES AND METHODS

Study Sites

Given that diverse biophysical environments vary in their vulnerability and resilience to climate change (Turner et al. 2003), I selected two sites with the aim of carrying out a vulnerability analysis that would span two of Tanzania's agro-ecological zones: the semiarid tropics in the north and the subhumid tropics in the eastern central region (figure 1). I collected data from one village in each region, and the particular villages were chosen on the grounds of convenience and connections with resident translators. The first community is located in the steppe region of northern Tanzania, where mean annual precipitation is only about 400 mm. Rainfall is bimodal, with short rains occurring from September to December and long rains from March until May. The second community, located in a more mountainous part of central Tanzania, has a higher mean annual precipitation of around 900 mm. The rain is unimodal, lasting from fall to spring. The biophysical differences between the two sites allow patterns in socio-ecological vulnerability for rain-fed farmers to emerge that cannot be attributed simply to environment or geography, thus highlighting the importance of the social.

The two sites differ on characteristics other than climate. The northern village is positioned on a direct, paved road 60 miles from a major city and in close proximity to a national park that draws a steady stream of tourists. Ecotourism and cultural tourism provide nonfarm sources of income for some northern village residents, though few farmers in the sample draw any additional income from the industry directly. Northern farmers sell in urban markets and local markets, though some also farm for subsistence only. The central village's location in the highlands is more remote, about 100 miles by unpaved mountain roads from the closest city, and working-age adults are farmers almost without exception. Its isolation also presents a barrier to connecting with agricultural markets outside the community and to bringing in agricultural inputs. Some farmers walk, bike, or catch a ride up to 35 miles each week to access a market where they can receive a better price for their crops, though overall central farmers regularly depend upon local markets and lower prices.

In terms of integration into agribusiness, northern farmers use commercial hybrid maize seed unless the maize is for home consumption. In contrast, almost all farmers in the central village save local maize seed to use each year, although an NGO began introducing hybrid seeds in 2010. Two different international NGOs are actively involved with agriculture initiatives, one in each community. Alarmingly, none of the current NGO initiatives in either village specifically target climate vulnerability or adaptation, but their interventions unavoidably interact with the dimensions of vulnerability evaluated in this paper. Table 1 presents a summary of the communities' social and ecological characteristics, showing that the northern village farmers are more socioeconomically stratified and the central village farmers more similar.

Data Collection and Descriptive Statistics

I carried out structured open-ended interviews in 2011 with 54 northern farmers and 30 central farmers. Though the farmers were selected through convenience sampling, they represent a wide range of individual and household characteristics (table 2). The semistructured interviews targeted data on yields, agricultural inputs, and demographics, while also allowing the farmers to talk freely about their experiences with drought, flooding, irrigation, agricultural extension, NGOs, and environmental change. Notably, we did not discuss global climate change directly or use the term in the interviews with farmers. This aligns with the approach of ethnographers Elizabeth Marino and Peter Schweitzer, who suggest that the best method for understanding local conceptions of environmental change is to avoid talking about climate change, which may have varying meanings or no meaning for informants (Marino and Schweitzer 2009).

To supplement the farmers' perspectives, I had additional interviews with the three seed sellers in the northern village, all accessible government and agricultural officers, a plant breeder at a Tanzanian university of agriculture, two East Africa–based scientists working for international agricultural research organizations, and a representative from the international NGO working on agriculture in the northern village. These individuals were also selected on the basis of convenience, as access relied on establishing connections in person. Conversations with farmers, seed sellers, and the central village executive officer were conducted through two English-Kiswahili translators who resided in the communities, while the interviews with the Northern village's agricultural officers, the scientists, and the NGO representatives were done in English. My interview translator-partner in each site was a familiar member of the community, which helped tremendously with access and data collection.

RESULTS AND DISCUSSION

Farming Systems and the Vulnerability Context

The northern village has four distinct farming systems. One group consists of farmers with land on the village's one irrigation system that was "modernized" by an East Asian NGO in 2009 (figure 2a). They follow a rice-beans-maize rotation throughout the year, and rice, the most valuable cash crop, receives the majority of irrigation water. The second group includes those situated along earthen irrigation channels, where the water flow is diverted by rocks and organic material and is regulated by a locally elected official (figure 2b). These farmers grow nearly every type of crop supported by the region, including bananas, rice, maize, and vegetables. The third group consists of farmers on dryland plots without any irrigation access who find other ways to get water to their plots, such as pumping groundwater or constructing hand-dug channels to divert water from one of the irrigation schemes. This type of "unregulated" water access allows farmers to cultivate rice on the small parcels of land that receive water along with crops with lower water needs (maize, sunflowers, and millet) on the remainder of their dryland plots. Fourth are the farmers occupying dryland plots who are solely dependent upon rainfall and do not irrigate by any means. These rain-fed plots produce mostly maize and millet, occasionally complemented with sunflowers or vegetables.

In contrast, the central village does not have any irrigation infrastructure. All farmers rely entirely upon rainfall, and farming systems are similar across the community. The typical rain-fed central village farmer grows three or four different crops from among maize, rice, cassava, sorghum, and sesame, dispersed on plots throughout the village's hills. Sesame and sorghum, rather than rice, are the cash crops in the region. Despite the differences among farmers in the two communities, all are smallholders with farm sizes averaging about two hectares across both communities. Notably, none of the farmers have formal crop insurance to protect their livelihoods.

The variation in water access and farming systems across the northern village is associated with tremendous within-community inequalities in agricultural productivity and income. Mean agricultural income ranges from just 280,000 Tanzanian shillings (TSh; ~$190 USD based on 2011 conversion) for dryland farmers to around 2,225,000 TSh (~$1,510 USD) for farmers on the “modern” irrigation system. These incomes are based on crop yields in years that farmers labeled as good and thus do not take drought into account. Despite that, a wide gap separates the relative wealth of the irrigation farmers in the northern village from the challenging circumstances dryland farmers face even in favorable seasons. In a farmer-defined good year, those on the “modern” irrigation system harvest an average of 28 bags per hectare of rice (a bag is equivalent to 55 kg), while farmers growing rice on earthen channel irrigation schemes or with some form of unregulated water access produce 14 bags per hectare annually, and dryland farmers do not grow lucrative rice at all. The cereal they do grow is maize, and on average they produce just 4 bags/hectare.

Furthermore, a portion of the northern village’s dryland farmers are solely subsistence farmers, and even the dryland farmers who are integrated into markets farm primarily for consumption rather than to make a profit, as one farmer illustrated by saying, “Farming is not a business for us.” Meanwhile, the central village’s dryland farmers earn 718,000 TSh (~ $490 USD) for their crops annually, which falls close to Tanzania’s gross national income per capita in 2011 of $530 USD (World Bank 2015). The typical central village farmer keeps about half of what he or she grows for consumption and sells the other half. Nonsubsistence northern village farmers keep enough maize for home consumption (two to four bags depending upon family size and harvest results) and sell the remainder of their yields—though this remainder varies dramatically across the farming systems.

Overall, farm income in the central village is more consistently monetized and evenly spread across households, while greater disparities from high incomes to subsistence livelihoods exist in the northern village. This socioeconomic stratification across farming systems must be incorporated into an understanding of vulnerability in the northern community and similarly heterogeneous ones, especially since the majority of farming households do not have nonagricultural income sources. Participation in nonfarm work alongside agriculture, which is positively correlated with income and wealth (Barrett, Reardon, and Webb 2001), is not common in either community. Just 12 percent of farming households in the northern village and 25 percent in the central village diversify outside of agriculture. This underscores the importance of water resources and access, agricultural knowledge, and existing drought-coping strategies as vulnerability dimensions in these agriculture-dependent communities.

Water Resources

In the northern village, rain-fed farmers emphasized the importance of water resources by identifying drought as their biggest concern for the present and the future. In a postinterview focus group, six dryland farmers expressed grave fears about the continuation or worsening of the current rainfall trends they had observed. About 80 percent of farmers in the northern village have experienced lower yields because of drought in the past ten years, and on average farmers reported that their productivity was halved during a drought year. However, farmers' vulnerabilities along the socio-ecological dimension of water resources and access vary substantially.

In this section, I concentrate on the two extremes of the water resource spectrum: the dryland and "modern" irrigation farmers. As expected, dryland farmers suffer the greatest losses during drought, while "modern" irrigation farmers have the most effective buffer from the consequences of drought. The disparity is shocking, however, with dryland farmers losing over 70 percent of typical annual yield during drought, whereas average drought-year yields for "modern" irrigation farmers are just 25 percent below normal (figure 3). Touching upon the reach of drought in addition to its severity, all dryland farmers experience lower yields in drought years, while about 30 percent of the "modern" irrigation farmers reported no crop losses from drought. Dryland farmers are also the most likely to have seen a season with no harvest at all in their farming careers.

The northern village as a whole loses about 50 percent of its agricultural production potential during dry years. Reducing the range of farmer experiences to a 50 percent loss does not accurately represent vulnerabilities in the community, but it succinctly responds to the general importance of adaptation. Though drought is endogenous to production—farmers may choose to plant less in drought years, in addition to drought causing patchy and stunted growth of planted crops—these severe losses are meaningful scenarios. If drought events become more extreme and frequent, as predicted, the extrapolation is that the majority of farmers in arid communities like this one will often have substantially smaller harvests. Though this is not unexpected, it provides valuable local corroboration for large-scale model predictions.

Water resources were substantiated as a key socio-ecological determinant of farmer vulnerability in the Northern village through conversations with both farmers and agricultural officials. One farmer who had been on the same dryland plot for 30 years said, "Every year is a bad year because of low rainfall." He hoped that one of the nearby irrigation channels would soon reach his family's plot, improving the inequity in water access. The local agricultural supervisor named water scarcity and climate change as his chief concerns for the farming community in the future, highlighting a growing dependency on irrigation and water as a scarce resource in sub-Saharan Africa. The Ministry of Agriculture confirms the prominence of securing water resources through its discourse and laws, including the National Irrigation Act of 2013. which aims for 25 percent of food production from irrigated land (United Republic of Tanzania 2013).

Yet irrigation is a technology conditioned by both social relations and natural features. The northern village NGO targeted a small group of farmers for the 2009 irrigation rehabilitation on the basis of criteria including farmers' motivation to "modernize" and a socioeconomic assessment. During the selection process, farmers in each scheme were interviewed about their willingness to change irrigation methods and pay for water. Other important factors were access to roads and reliable markets, as well as fewer anticipated conflicts among water users based on historical events. This evaluation led the NGO to select the most productive and secure farmers for the new irrigation technology, conceivably and understandably, though not justly, to better ensure the success of the project. A scientist based at an international crop research center in the region supported this observation, saying, “Research and project implementation sites are often chosen based on market access, proximity to research institutions, availability of long-term data, and the interest of collaborative organizations and leaders at the site.” He recognized the predicament for those without these resources, who are likely to be more vulnerable and in greater need of support.

A focus group of northern dryland farmers said they were willing to do anything required to build an irrigation system in their area, including contributing a percentage of the costs and labor. However, the farmers said government extension and the NGO had not given them the opportunity and that “the problem is on their side, not ours.” New technologies can increase inequality in smallholder agriculture areas, and if irrigation improvements exclude lower-income or subsistence farmers, inequalities and varying vulnerabilities are likely to persist (Barrett, Carter, and Timmer 2010; Burney and Naylor 2012). Even if additional farmers in the northern community begin to irrigate in the future, they may continue to be disadvantaged if a *technology treadmill* occurs, meaning that the economic benefits of the new technology always remain disproportionately with those that adopted it first while profits were highest (Barrett et al. 2010).

This irrigation project is part of the NGO’s umbrella program to increase production of rice, a crop that requires substantial water and soil moisture, in sub-Saharan Africa. Their mission, as summarized by a representative in the northern village, “is to provide technical support and expertise toward this goal.” “Modernized” irrigation begins to seem like a technical solution to a problem—no or low rice productivity in an exceptionally arid region—that was envisaged by the NGO in order to provide assistance that aligned with its technocratic logic (Ferguson 1990; Eakin 2000; Mitchell 2002). This irrigation case provides an example of how development initiatives can align with and exacerbate existing inequalities and, importantly in the context of climate change, how such initiatives can influence vulnerabilities and future inequalities.

Meanwhile, the central village is situated in a region with a more favorable, though still variable, climate for productive dryland agriculture. Despite higher baseline precipitation, the average loss of maize, rice, sorghum, and sesame productivity during a drought year in the central village is 69 percent, with each crop similarly susceptible (figure 3). This supports Paavola’s (2008) findings that maize yields declined by up to 75 percent during dry years in the same region of Tanzania and aligns the central farmers closely with the northern dryland farmers in terms of drought-year losses. Along this water dimension of vulnerability, the northern village has greater within-community stratification and the central village is quite homogeneous by comparison, though losses are substantial when aggregated to the community level in both places. If farmers’ current capacities to anticipate, cope with, resist, and recover from drought are indicative of their adaptive capacities for future climate change, the drought-year losses provide evidence that Tanzanian smallholder farmers will be less productive and to varying degrees. This lends attention to two additional vulnerability dimensions and how they differ among farmers: (1) agricultural knowledge; and (2) existing drought-coping strategies.

Agricultural Knowledge: Extension, NGOs, and Diffusion

In the northern village, farmers with more reliable water resources also have better access to critical sociocultural and institutional resources, including agricultural extension services and NGO-run farming classes. A government-run agricultural extension office with the mission statement "to guide farmers so that they can produce enough crops of high quality to sell and sustain themselves" is situated in the center of the northern village within short walking distance to the farms on the "modern" irrigation system. The more distant locations of all the dryland and some of the earthen channel irrigation farms undermine access to the agricultural office and the transfer of information. Dryland farmers routinely stated that agricultural officers rarely or never visited their farms—over years of tenure on the same plot— although the institutionalized rule at the agricultural extension office is that every farmer in the village receives a routine bimonthly extension visit. Also, farmers are required to pay the fuel costs for extension to respond to any specific problems on a farm, and dryland farmers are a greater distance from the offices and less able to pay the higher costs. A farmer who owns both dry and irrigated land disclosed that "nobody gives advice for dryland farmers but they do for the irrigated land." For example, the agricultural office advises farmers to select their cropping patterns each season on the basis of the amount of available water, yet this information is not appropriate for the farmers outside the reach of the irrigation systems.

In addition to its responsibility of providing agricultural knowledge, the office supplies farmers with vouchers to buy subsidized fertilizer from the local agricultural shops. Although the office provides this subsidy, the dryland farmers in particular rarely benefit. Most dryland farmers expressed either no knowledge of this assistance or an inability to afford even the reduced-cost fertilizer. Also, some dryland farmers were hesitant to apply fertilizer because without sufficient soil moisture and the correct application procedure fertilizer is not absorbed and can cause burn damage to crops. Farmers in the central village do not have any agricultural extension resources. None of the farmers I spoke with had ever interacted with the one extension officer assigned to the ward that incorporates the central village, as the officer lives in one of six other villages in the ward despite being responsible for all. Chronically under-resourced and inequitably distributed, extension is certainly a structural constraint on adaptive capacity across the two villages.

In the era of NGOs as agents of development, these organizations influence Tanzanian farmers' livelihoods and practices as much as or more than agricultural extension. In the northern village, the NGO held seminars to teach rice-farming practices. One "modern" irrigation farmer reported that these new techniques had helped him increase his rice yield from 25 bags per hectare to between 35 and 40 bags. Yet a farmer without irrigation access who sometimes pumps water to his plot said, "The advice from the NGO was not very useful for me, and it did not improve my production because water is what limits it." Also, the seminars are advertised in residential areas near the agricultural extension office. Since dryland farmers are rarely in contact with agricultural officers and live farther from the center of the village, none of them attend the classes. Dryland farmers cannot grow water-intensive rice, so the farming knowledge being disseminated is not pertinent to their cropping systems. The most common response from dryland farmers to the question of whether they received farming assistance from any individuals or organizations was that the NGO never visited them. Within the agricultural knowledge dimension of vulnerability, as within the water resources dimension, the NGO's initiatives deepen inequalities.

Moving to the central village, an international antipoverty NGO began working there in 2009. Half of the community's farmers attend the NGO's classes on new planting techniques that are run from demonstration farms in the village. The classes are announced in churches, at the village administrative office, and at the local markets—a variety of locations that most residents visit frequently. Also, as a venture to involve the community in building its own agricultural knowledge, the NGO selected and trained two farmers from the village to be facilitators who can support farmers when no NGO representatives are present. These initiatives might iteratively help reduce inequalities while reflecting the community's less stark inequalities.

The NGO is primarily encouraging farmers to discontinue burning as a method to remove crop residue and clear brush prior to planting. This common practice can increase biophysical vulnerability to drought by compromising soil moisture and nutrients, while leaving crop residue in the fields can improve the quality, organic matter, and moisture retention capacity of soils (Boddey et al. 1997). Before the NGO arrived, 90 percent of farmers in the central village burned their fields, but two years later just half still used burning as a clearing technique. The farmers' most frequent reason for maintaining the practice is that burning makes the process of preparing the field more efficient and less strenuous. This is an example of how NGO or "outside expert" knowledge may be beneficial for reducing climate vulnerability, yet the new practices can also increase the burden on farmers, particularly in this low-mechanization context.

As in the northern village, some central village farmers do not attend the NGO classes. Reasons for not participating include the time investment required, the travel distance across the village's sprawling hills to the demonstration farms, and illiteracy. However, in both villages, farmers that do not have direct personal contact with the NGO still are affected by the diffusion of knowledge across social networks of families, neighbors, and friends, and some are using new techniques that they learned from talking to or observing other farmers (Portes 1998). Social networks are known to play an important role in the diffusion of coping and adaptation strategies (Adger 2003), and my findings demonstrate why this matters particularly for climate vulnerability and inequality.

In the northern village, only the rice farmers have been likely to adopt the practices taught by the NGO or to have the social ties for diffusion, while techniques are more easily disseminated to all farmers throughout the central village. Particularly in a more diverse community like the northern village, knowledge diffusion does not necessarily traverse existing hierarchies or pertain to all types of farmers. If social ties do not make bridges across farming groups, allowing knowledge and strategies to flow throughout communities, closed pockets of agricultural knowledge form (DiMaggio and Garip 2011). Information diffusion networks and social ties are essential elements of understanding inequality and variation in vulnerabilities among households (Entwisle 2007; DiMaggio and Garip 2011). Farming knowledge is crucial for drought coping and future climate change adaptation but often is not directly available to everyone, making this a mechanism that can reproduce inequality in the context of climate change (DiMaggio and Garip 2011).

Existing Drought-coping Techniques and Future Climate Adaptation

Despite the picture of vulnerability presented thus far, farmers unquestionably have their own strategies and agricultural knowledge that they employ to cope during drought years. These strategies also diverge across farming systems, as exemplified by the northern village. However, farmers' drought-coping strategies are temporary measures to endure one bad season, whereas climate change will require these strategies to become more permanent adaptations. Therefore, I also evaluate the potential for current drought-coping strategies to become effective long-term adaptations, as it is likely that some strategies will be sustainable in the long term and others will not. I use the "modern" irrigation system in the northern village as a case to demonstrate the importance of considering time scales in analyses of vulnerability, adaptation, and inequality.

Drought-year coping strategies are highly variable among the northern village's farming systems, with the exception that all farmers adjust planting dates on the basis of when and whether the rains come. Dryland farmers and earthen channel irrigation farmers replace maize with more drought-tolerant crops, such as sweet potatoes or sunflowers, or they switch to planting quicker-maturing varieties of maize. This trait allows the maize to mature in time for harvest even if the rainy season is short, although yields are lower. In some cases, dryland farmers do not plant at all to save financial resources they anticipate losing during a drought year and instead rely on the short-term support of their networks, a social insurance including family members and religious organizations at mosques and churches. Dryland farmers may also resort to digging their own wells and using electric pumps to draw water to their plots from the ground or water channels.

The "modern" irrigation farmers have seemingly more effective drought-coping techniques, as demonstrated by their lower drought-year losses. Their common responses to drought include concentrating available irrigation water on rice while leaving beans and maize dry that season; planting a smaller fraction of their land to focus water allotments; continuing to plant on all of their land but staggering planting times to concentrate irrigation on one newly planted area at a time; adding more pesticides and fertilizer; forgoing rice entirely; or aiming for just one rice harvest during the year instead of two. These strategies reflect a combination of their better access to water, financial capital, and formal agricultural training and assistance, emphasizing reinforcement across the vulnerability dimensions as a mechanism of stratification that creates a privileged outcome for this group. This is why the previously discussed factors like access to water and knowledge matter.

When asked if anything can be done to prepare for or cope with drought, dryland farmers routinely responded that they had no strategies to maintain productivity. As one dryland farmer said, "There is nothing I can do to change during drought. The ability to make changes depends on money." Meanwhile, acquiring new coping techniques is not common, and this same individual reported, “I never get any advice on farming.” The agricultural offices and the northern village NGO are more attuned to expanding irrigation than to the farmers currently trying to manage without it. Again, northern farmers’ arrays of drought-coping strategies align with their drought-year crop losses, access to water resources, knowledge, and income inequalities.

Farmers in the northern village often seek advice on seed selection and agricultural practices from the village’s three local seed sellers, with some farmers expressing a preference for the advice of seed sellers over that of agricultural officers and the NGO. For the northern farmers, these social institutions and individuals cannot be overlooked as part of the vulnerability and adaptation picture, including coping strategies. This is illustrated by one quote from a northern village farmer: “I don’t know why I use the hybrid maize variety I do. I go to the seller and ask for seeds to use this year.” Central farmers, on the other hand, do not have access to any seed sellers in their village, highlighting a difference across communities in the actors involved in adaptation.

Farmers in the central village adjust planting with the timing of the rain just as northern farmers do. Another common strategy for central farmers is farming more cassava, a more drought-tolerant root crop, for consumption in years that seem to be dry. Similarly, farmers choose to grow sorghum instead of sesame as their cash crop in years when rainfall is late and drought is likely. This aligns with previous findings that changing crop types, crop varieties, and planting times are common responses to climatic stress (Paavola 2008; Mertz et al. 2009b).

However, central farmers’ sorghum losses during drought are not differentiable from their losses of other crops, including sesame. Previous research and programs run by international agricultural organizations suggest that sorghum is a drought- and heat-tolerant crop with less climate-variable yields and the potential to adapt well to future climate conditions (Paavola 2008). Since central village farmers lose 64 percent of their sorghum yields in drought years —despite the possible positive countereffect on yields of planting more sorghum in those years—sorghum’s reliability as a drought-year cash crop requires further investigation. Cassava drought losses are the lowest, 35 percent overall, and households rely on cassava for food during years with minimal rainfall. Since most central village farmers grow cassava every year, this assures some success and a reliable food source regardless of rainfall, although the harvest may not allow for both home consumption and market sale. Notably, rather than diversifying to more crops as a drought management strategy (Barrett et al. 2001), farmers in both communities focus on fewer and more drought-resistant options during anticipated drought years.

Next, I want to consider what the consequences might be if these drought-coping strategies become climate adaptations in the future, and the northern village’s irrigation systems provide one example. Irrigation is a drought-coping strategy in a farming community with variable rainfall, but the long-term viability of the northern village’s “modern” irrigation system, as well as the other types of water access, is highly uncertain. Can irrigation be an effective adaptation to more frequent and severe drought, especially given that understandings of future local precipitation patterns, groundwater resources, and consequently, irrigation water sources are limited? As I will discuss, the irrigation system appears to exacerbate existing inequalities and vulnerability differences in the present, though it could also eventually harm the advantaged farmers who are on the system depending upon its sustainability.

The intensive use of water through irrigation and water pumps on half of the village's farmland is depleting water resources. Farmers mentioned that during the dry season the river feeding the system recently started withering out completely downstream from the "modern" irrigation system—three times in the past five years. Describing change over time in the river, one farmer said, "The river no longer flows strongly toward my farm after it was obstructed to take water for the rice," and another provided a strong visual: "The river is just a muddy trickle this far downstream." Farmers shared that groundwater pumping had increased now that the river tended to dry up, demonstrating a common practice during ecological scarcity: the replacement of one resource for another as its supply diminishes (Catton and Dunlap 1980). Also, access to water currently relies on loose regulations—no working gauge on the "modernized" system, the possibility of bribing "the water mayor" who facilitates the earthen irrigation systems, and unmonitored pumping from the river, the ground, and the irrigation systems. This complex social system of water regulation will need to respond to less reliable water availability in the future, and it will find ways to adapt. However, since inequities are so embedded within the system now, these may persist or worsen under greater water stress.

Meanwhile, the dryland farmers are seeking consistent water resources with a sense of urgency. The village extension office aims to bring irrigation to 1,000 additional hectares of its farmland, even though adding more farms to irrigation systems that rely on poorly understood and depleting water sources could be risky for all. These water sources also support wildlife in a nearby national park, the health of which draws tourism and sources of nonfarm income to the community. Ultimately, increasing water distribution and consumption through irrigation may be counterproductive for livelihoods in this already arid region, despite farmers' severe need for more reliable water access.

Two successive questions emerge: (1) how being connected to the irrigation system influences a farmer's climate vulnerability in the present and future; and (2) how having irrigation influences vulnerability at the community level. Current drought-year losses are undoubtedly lower for farmers with irrigated plots, but does having personal irrigation access or irrigation in the community necessarily improve farmers' abilities to cope with drought or adapt to climate change? The data point to mechanisms linking irrigation access and adaptive capacity, which suggest different possible outcomes surrounding irrigation and long-term adaptation. First, the "modern" irrigation farmers may exhibit greater adaptive capacity because they are more accustomed to accepting new technologies and shifting their farming practices. They also have the financial capital to make adaptation easier, because the irrigation system has facilitated their production of more reliable and valuable crops. At the same time, water availability is a more complex, indirect function of local climate for the irrigation plots as compared with the dryland plots (Schlenker, Hanemann, and Fisher 2005). Farmers with irrigation access may be less likely to perceive low precipitation and the need for adaptation because they do not experience the precariousness of water stress as directly

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as other farmers do during drought (Gbetibouo 2008). Following this logic, they may be more vulnerable to drought if the irrigation system fails to support them, while dryland farmers are familiar with coping in a system that relies on rainfall.

At the community level, irrigation is not an ideal capacity-building or vulnerability-reducing intervention. The systems are not high-return investments, and their installations have long time lines. Uncertainties like shifting rainfall patterns will be present alongside the implementation and use of the system, making it a dubious form of sunk capital, especially given that an assessment of the water sources has not been undertaken (Mertz et al. 2009a). Also, the irrigation project has reproduced inequalities among northern farmers, and farmers outside the “modernized” system have not seen community-wide improvements as a result of the project. Dryland farmers in the northern community with irrigation and in the central community without it have similar drought-year losses and coping strategies, suggesting that the presence of irrigation does not reduce vulnerability across the community on these dimensions.

CONCLUSION

Foremost, this research emphasizes empirically that not all smallholder farmers even within one community look similar across context-specific dimensions of climate vulnerability. The two community cases underscore the possibility of vulnerability being idiosyncratic (northern) or covarying (central) across farming households (Barrett 2011), a finding that calls for continued household-level work on climate change in agricultural areas. This perspective aligns with previous work showing that depictions of vulnerability vary depending upon the spatial scale of analysis and that these scales for understanding place and livelihoods can interact in a vulnerability assessment (Cutter et al. 2003; Gray and Mueller 2012). The climate adaptation literature often considers the trade-offs between focusing on the resilience of a community, region, or nation as a whole as opposed to concentrating on reducing the vulnerability of “worst-off” individuals (Adger et al. 2009a). Sociologists have been dedicated to studying social inequality across these scales for a long time and have much to offer such discussions about climate vulnerability and adaptation.

Adaptation discourse is often constructed around ecological and physical limits, economic limits, and technological limits to adaptation (Adger et al. 2009a). Again, a sociological lens contributes to this broader climate adaptation conversation by bringing inequality to the center and considering how limits to adaptation must be understood in terms of inequalities. This introduces social limits to the notion of what constrains adaptation. To begin, my findings suggest that a diverse community with more heterogeneity in socioeconomic status, resource access, and farming systems—the northern village—is more vulnerable to drought or climate change than a community that is more homogeneous on these characteristics—the central village. This question has been examined at the level of the nation-state, and generally countries with greater inequality experience more devastation from climatic events than societies with low levels of inequality (Roberts and Parks 2007). The theory can transfer to the community level if we consider that the sharing of adaptation strategies is restricted in a diverse community like the northern village, for example. The relationship between local inequalities and vulnerability requires continued thought and investigation through theoretical and empirical efforts by sociologists and development scholars. Importantly, this analysis raises concerns about climate inequality in contexts often considered to be homogeneous like rural smallholder farming communities.

Furthermore, my findings do not align with the production-function theory from economics on the relationship between climate and agriculture, which suggests that drought impacts can be predicted through biophysical effects on agricultural output (Dell et al. 2014). Stated differently, a researcher following this approach empirically specifies the relationship between temperature, precipitation, and agricultural productivity and uses this estimate to simulate what climate change means for agriculture in a particular place. The critical response to this method in economics is that it does not capture farmer behavior (Dell et al. 2014). Here, I show that farmers employ various strategies to cope with climate variability that affect production, including changing crop types and varieties, adding new inputs, and shifting techniques. Also, the extent to which farmers employ these strategies is by no means uniform across households, and a blanket model would miss how this relates to inequality. Research on the relationship between climate change and agriculture must consider the diversity of farmer responses, including that some farmers make no adjustments to their practices during drought.

In contrast with Beck’s position (2010a. 2010b) that climate change will dissolve current inequalities and produce new ones, I argue that climate change is likely to reproduce existing inequalities at the local level in smallholder farming communities. This brings existing thoughts about global climate change and structural inequality (Parks and Roberts 2010) to the local level within a least-developed country (LDC). In the community with greater inequality and more variation across the dimensions of vulnerability, drought aligned with this variation. It reinforced inequalities and has the potential to do so as rainfall variability increases. This is seen most clearly through the differences in drought-year losses between the farmer groups. My work only begins to address potential mechanisms related to unequal outcomes in this context, such as water resources, knowledge diffusion, NGO interventions, and interaction and reinforcement among these dimensions of vulnerability. With these pathways for inequality to increase over time with climate change, local inequalities are important considerations for climate vulnerability and adaptation research and policy.

This is complex, however, since work on environmental inequality deals with the future as well as the present (Catton and Dunlap 1980). Though an intervention like irrigation improves livelihoods for a subset of farmers in the present, it also has the potential to influence farmers’ vulnerability to future climate change—to reproduce or attenuate a community’s future level of inequality. Concentrating narrowly on the present can generate misleading conclusions about vulnerability and inequality. Despite these challenges, I hope that linking climate vulnerability and local inequality encourages more sociologists and development scholars to consider climate change. This link emphasizes the connections between two of the greatest concerns for global society in the early to mid-twenty-first century—climate change and within-nation inequality—both of which are also bedfellows of development.

In reflection, the prevailing sentiment of farmers in these communities was that severe weather events and effective coping techniques were beyond their control. The farmers' not seeing agency for themselves was especially difficult to process. Was this a desperation that farmers actually felt strongly, or was this how they presented themselves to me as an outsider? Frequent reflexivity was necessary while I did this research, considering also the tremendous effect that climate change will have on farmers' livelihoods, the historical relations present in climate change vulnerability, and the polarization surrounding the issue. For example, farmers may have crafted their stories about irrigation and the severity of their water access limitations as they did because they perceived me as someone who could influence where irrigation systems might be built It could also be what they thought I was looking to hear. At the same time, this fatalism on the part of the farmers can be explored in future work, including whether farmers' positions within their communities (with more or less inequality) influence their emotions and thoughts about future climate and livelihood. Suffering is challenging to research and articulate, but the issue of climate vulnerability and local inequality includes emotional well-being.

Whether and how this analysis aligns with the two grand narratives on climate change in the global South introduced earlier—widespread, absolute, and devastating adaptation limits (vulnerability), versus effective local adaptation knowledge (resilience)—are also important to consider. First, the evidence from these two communities pushes back somewhat against the paradigm that celebrates the supremacy of local knowledge and climate adaptive capacity (Berkes 1999; Riedlinger and Berkes 2001; Houde 2007; Prober, O'Connor, and Walsh 2011). I documented the ways individuals currently cope with drought (and the absence of drought-coping strategies), and the data show that drought-year losses, which incorporate farmers' existing knowledge, are severe. Those losses suggest that local agricultural and adaptation knowledge will not support farmers' livelihoods through a changing climate in these communities. Nor, however, is local farming knowledge one homogeneous body, as seen by the variation in coping strategies across farmers.

Overemphasizing local knowledge and adaptive capacity can also create a tendency to ignore the systems of power that have led to the current state of climate vulnerability for smallholder farmers in Tanzania. Assuming local agency in adaptation can mask the need for reforming these global systems, as well as the need for help in adaptation and compensation for inequities (Roberts and Parks 2007). At the same time, local knowledge is where an understanding of ecological and agricultural processes lies, especially environmental changes like the declining health of the river near the northern village. Drawing from the partial knowledge of local farmers and outside "experts" may be the best path, despite possible conflict and hierarchy among these differently located knowledges (Haraway 1988; Harding 1991). The sociology of climate adaptation knowledge is another related area in which sociologists can make important contributions. Moreover, the agro-historical context of a region influences how effective local agricultural knowledge is for climate adaptation. For example, even though crop agriculture is the primary livelihood in the two communities today, these parts of Tanzania have a history that is far more pastoralist than agricultural, which affects the collection of local adaptive knowledge for crops like maize, rice, and cassava.

However, this perspective should not make the farmers seem incapable or diminish their agency. As Hulme (2011) writes about the climate reductionist perspective, “Humans are depicted as ‘dumb farmers’ passively awaiting their climate fate. The possibilities of human agency are relegated to footnotes.” Academic and media discourses are exhausted with stories about climate change victims in the global South. This paper does present the difficult and somewhat bleak context within which farmers are coping, but it is also a narrative about the agency that farmers exhibit in response to these conditions and the adaptive capacity they have. Despite water access constraints, northern village farmers find ways to put pressure on the system that does not incorporate them and to obtain the water they need (Anand 2011). Whether agency consists of getting water in any way possible, finding a route to a better market by bicycle, or adjusting the crops they grow, farmers find opportunities to protect or improve their livelihoods despite their positions in the world socio-ecological system.

Finally, this case illustrates that social (in)equality cannot be disconnected from environmental issues like climate change. A closer relationship between development policies and climate adaptation policies is necessary because, as this paper demonstrates, conventional agricultural development initiatives will interact with drought and climate change whether or not a project considers climate. At the same time, some scholars see climate mitigation and adaptation as the “new sustainable development” (Adger et al. 2009a). Adaptation can have various goals—to avoid complete devastation, to maintain livelihoods, or to ultimately improve well-being. The second goal and, most definitely, the third require thinking about the connections between climate change and inequality subnationally. Adaptation assistance and related development initiatives can consider the potential heterogeneity across smallholder farming systems and households in the target area, as a step toward avoiding reproducing inequalities. The understanding presented here of context-specific vulnerability dimensions, constraints to adaptation, and the coping strategies that farmers already use can contribute to this indispensable conversation, as climate change adaptation becomes a priority for farmers alongside continuing development initiatives.

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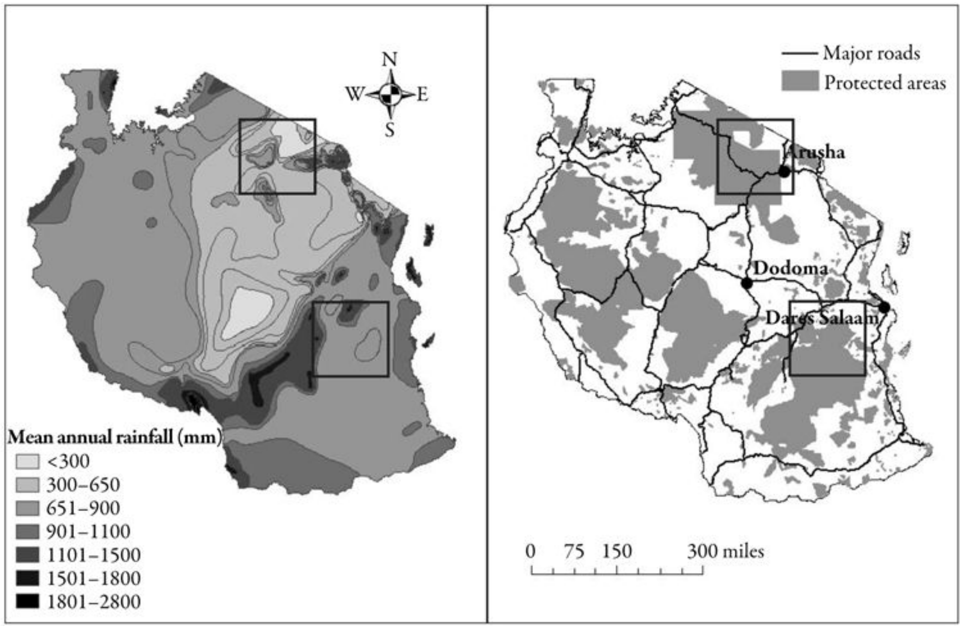

FIGURE 1.

Map of Tanzania with mean annual rainfall gradient (mm), major roads, and all types of protected areas. The northern and central villages are within the two highlighted areas. Data sources: International Livestock Research Institute, World Database on Protected Areas (United Nations Environment Programme), African Development Bank Group.

FIGURE 2.

Two types of irrigation systems in the northern village: (a) the locks and concrete of the modern irrigation system, and (b) the traditional irrigation systems with water flow directed by a diversion constructed from rocks and organic material above and an earthen channel below (Photos: A. Teller).

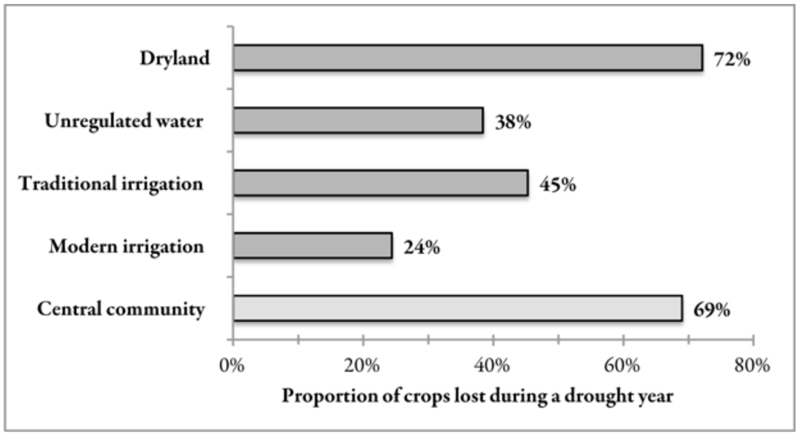

FIGURE 3.
Average crop loss in a drought year for farms with each type of water access in the northern community (*Darker bars*; Dryland N = 23; Unregulated water N = 6; Traditional irrigation N = 6; Modern irrigation N = 19) and all farms in the central community (*Lighter bar*; N = 30). Farmers reported their yields in drought-ridden years and in a "good" year, which were both left to them to define. The percent crop loss is the average productivity loss in drought years compared with a good year.

TABLE 1

Summary of Ecological and Social Characteristics of the Two Communities

Attributes	Northern Village	Central Village
Annual rainfall (1950–2010)	400 mm	900 mm
Rainfall seasonality	Bimodal—short rain in fall, long rain in spring	Unimodal—one rainy season spans fall to spring
Agro-ecological zone	Semiarid tropics	Subhumid tropics
Topography	Flat valley	Mountainous
Irrigation	50% of farmland	None
Population (in 2011)	16,000	3,000
Distance from closest major city	60 miles (paved road)	100 miles (unpaved road)
Agricultural markets	Urban, regional, and local	Local
Seeds (maize)	Mostly commercial	Mostly saved
Tourism?	Yes	No
Farm income inequality	Higher	Lower
Any fully subsistence farmers?	Yes	No

TABLE 2

Descriptive Statistics for Samples of Smallholder Farmers in Both Communities

	Mean or Percentage	Standard Deviation	Minimum	Maximum
Northern Community (N = 54)				
Age	48	16	22	83
Household size	6	3	1	12
Farmland (hectares)	2	2	0.5	8
Farming experience (years)	24	17	2	68
Any Nonfarm income	12%	–	–	–
Central Community (N = 30)				
Age	42	12	24	77
Household size	5	2	1	10
Farmland (hectares)	3	2	1	6.5
Farming experience (years)	18	9	3	40
Any Nonfarm income	25%	–	–	–