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Research

The role of capital in drought adaptation among rural communities in Eswatini

Karen M. Bailey [1], *Robert A. McCleery* [2] *and Grenville Barnes* [3]

ABSTRACT. People are increasingly affected by climate change. In response, some people adapt, but others may not. The aim of our research was to understand what factors influence successful adaptation to climate change in context. We surveyed rural small-scale farmers in Eswatini who had recently experienced a severe drought, and collected data on adaptive capacity, measured as household access to five types of capital: natural (access to and use of natural resources), social (integration within local social networks), financial (income and wealth), physical (access to assets and infrastructure), and human (education and employment). Our goals were to identify which type of capital was most important in driving adaptation and to identify the specific ways in which capital supported adaptation. We found that social capital and natural capital increased successful drought adaptation more than other types of capital. Primarily, social and natural capital increased access to other resources and opportunities that enabled adaptation. Our research highlights the complex pathways along which capital operates to support adaptation, and furthers our understanding of in-situ adaptation experiences.

Key Words: *climate change; drought; Eswatini; farming; natural capital; social capital*

INTRODUCTION

Background and context

Our planet is changing rapidly. Climate change is more punctuated and severe than at any time in recorded history (Foley et al. 2005, Steffen et al. 2005). Climate change affects the lives of people across the globe, who often respond by adapting their livelihoods (Osbahr et al. 2010). Although adaptation is a common response to changing climates, not everyone adapts successfully, leading to a range of potential negative consequences (Adger et al. 2005, Vincent 2007, Jones and Boyd 2011, Evans et al. 2016). Understanding how responses to climate change vary is critical to minimizing its potential negative impacts.

Climate adaptation and adaptive capacity

Across contexts, successful adaptation to climate change is often influenced by the availability and quality of capital (Scoones 1998, Bebbington 1999, Pretty and Ward 2001). Capital is often classified into five broad types: physical, financial, social, natural, and human. Physical capital refers to access to and quality of local infrastructure and physical assets (de Sherbinin et al. 2008; Vincent and Cull, *unpublished manuscript:* http://kulima.com/wordpress/wp-content/uploads/2010/12/PEGNet-conference-2010-_Vincent-and-Cull_-climate-and-development-panel-160810.pdf). Physical capital is positively associated with food security and agricultural adaptation (Mbukwa 2014). Financial capital includes income, financial assets, and access to money (Abel et al. 2006, de Sherbinin et al. 2008). Households with greater financial capital are often less risk averse and have greater access to information and opportunities, enabling adaptation (Franzel 1999, Deressa et al. 2009). Social capital refers to integration into broad social groups, networks, and organizations, and access to resources via these groups (Putnam et al. 1993, Bebbington 1997). Social capital supports adaptation via collective action, resource networks, and establishment of support systems during times of stress (Adger 2003, Deressa et al. 2009). Natural capital encompasses access to and quality of natural resources and the services they provide, such as farmland, water, and forests (Costanza et al. 1997, Nawrotzki et al. 2012). High quality natural capital supports resilience in the face of environmental stressors and is often associated with more social, financial, and human capital (McDowell and Hess 2012, Nawrotzki et al. 2012). Finally, human capital is the skills, knowledge, experience, health, and education an individual has (Scoones 1998, Nawrotzki et al. 2012). Human capital supports the competence and capabilities necessary for adaptation and minimizes barriers to many adaptation options (Paavola 2008, Cassidy and Barnes 2012). The five types of capital provide the resources, opportunities, and skills necessary to adapt to changing conditions. They are so strongly linked to adaptation that they are often used as a measure of adaptive capacity, i.e., the ability to adapt (Yohe and Tol 2002, Hinkel 2011, Bryan et al. 2015).

All five types of capital are important for successful adaptation, but under certain circumstances, one type of capital may be more important than the others in determining adaptation success (Bebbington 1997, Katz 2000, Adger 2003, Nhuan et al. 2016). One type of capital may increase access to other types of capital or play a disproportionate role in adaptation success. Social capital is often associated with more diversified livelihoods, which are better able to withstand stresses and allow greater access to other types of capital (Cassidy and Barnes 2012). Further, adaptations created through the use of social capital are often more feasible and successful than adaptations driven by other types of capital (Tibesigwa et al. 2014). Along with social capital, natural capital also heavily influences adaptation. Declines in both quality and quantity of natural resources (soil erosion, water pollution, forest fragmentation, access to land, etc.) limit adaptation options and increase negative impacts associated with climatic variability (McDowell and Hess 2012). Human capital influences livelihood diversification, access to natural capital, access to social networks, and total financial capital (Gunderson and Holling 2002; A. Masae, *unpublished manuscript*). The role that each type of capital plays in adaptation is highly context

[1]Environmental Studies Program, University of Colorado Boulder, [2]Department of Wildlife Ecology and Conservation, University of Florida, [3]School of Forest Resources and Conservation, University of Florida

dependent (Adger et al. 2005, Smit and Wandel 2006). Accordingly, it is necessary to investigate relationships among types of capital and the strength of each type in different contexts to improve our understanding of climate adaptation (Kiem and Austin 2013). Despite the large body of research on climate change adaptation, there is still a need to identify limits to adaptation and the role of capital to facilitate effective adaptation strategies (Esteve et al. 2018).

Here, we examine adaptive capacity and household adaptation to climate stress in situ. We measure adaptation at the household level because decisions made at this scale are measurable and directly influence local resource use, human health, and survival (Ellis 1998, Pelling 2003). Our goal was to evaluate relationships between the different types of capital and identify which types of capital most strongly influence climate adaptation. We investigated these relationships in communities in eastern rural Eswatini, an area that experienced a severe drought between 2015 and 2016. We hypothesized that social and natural capital would most strongly influence adaptation because social capital influences access to resources and opportunities related to adaptation, and natural capital affects the sensitivity to environmental change (Katz 2000, Sseguya 2009, Paul et al. 2016).

METHODS

Study design

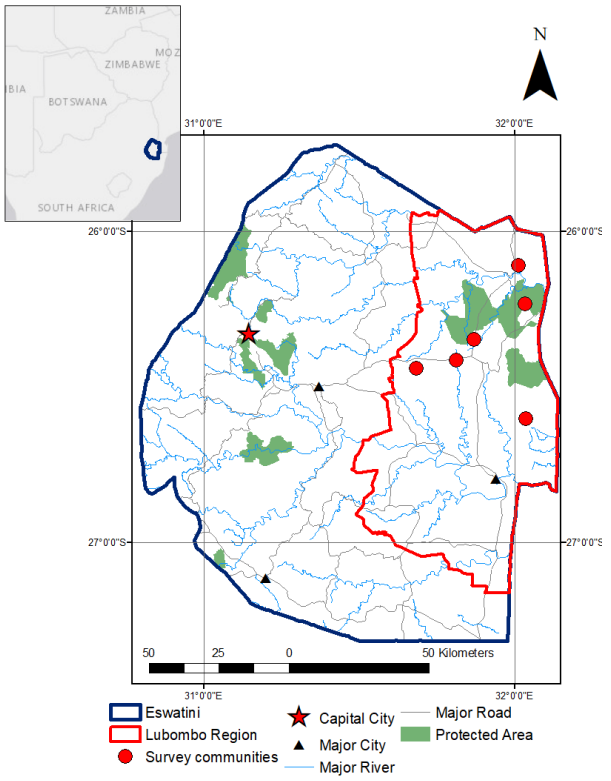
Drought has disrupted livelihoods in Eswatini for centuries and is expected to worsen as climate change continues (Mabuza et al. 2009, Moore and Daday 2010, Oseni and Masarirambi 2011). We conducted this research from 2015 to 2016, when Eswatini experienced one of the most extreme droughts in recent memory (Mabuza 2016). Based on initial information from focus groups, we created a household survey to collect data on household demographics, measures of the five types of capital, and adaptation. We translated the survey and focus group instruments from English to SiSwati and then back-translated them to English to ensure that they were understandable and locally appropriate. We conducted surveys and focus groups in SiSwati with a translator present who was fluent in English and SiSwati.

Study area

Eswatini is a small subtropical country with a population of approximately 1.4 million and an area of 17,565 km² (Goudie and Price Williams 1983; Central Intelligence Agency World Factbook: https://www.cia.gov/library/publications/the-world-factbook/geos/wz.html). It varies in altitude from 160 to 1860 m above sea level, has a mean annual rainfall between 500 and 1500 mm, and ranges in average temperature from 16 to 22°C (Goudie and Price Williams 1983). Eswatini has a wet and a dry season and is characterized by thunderstorms in the summer and decreased precipitation in the winter. Swazi homesteads are traditionally made up of a group of buildings (devoted to sleeping, cooking, storage, etc.) and land dedicated to farming (Russell 1983). Approximately 70–80% of the population is either directly engaged in or associated with homestead-based farming (Boudreau 2010). Communal grazing land is traditionally used for cattle. This dependence on crops and cattle is embedded in the social, cultural, and economic landscapes of Eswatini and is perceived as critical to the country's success and development (Forster and Nsibande 2000).

We conducted our research in the Lubombo district of eastern Eswatini (Fig. 1). This district comprises a mosaic of intensive agriculture, protected areas, subsistence cropland, grazing land, and human settlements. Sugarcane plantations are the main commercial agriculture, whereas maize is the primary subsistence crop (Department of Water Affairs and Forestry, Republic of South Africa 2002). The Lubombo district contains two main geographic regions: the Lowveld and Lubombo Mountains. The Lowveld receives the least rain in Eswatini, at 500–600 mm/yr, and has a combination of basaltic clay soils in the more eastern regions and sandstone shale soils in the west (Cleverly 1979, Rached et al. 1996, Manyatsi et al. 2015). The Lubombo Mountains range in altitude from 250–600 m, receive 600–900 mm/yr of rainfall, and have varied soils (Cleverly 1979, Rached et al. 1996, Manyatsi et al. 2015). We conducted research in six communities: three in the Lowveld (Mpaka, Matsetsa, and Lonhlupekho) and three in the Lubombo Mountains (Shewula, Mhlumeni, and Luketseni; Fig. 1). We selected these communities by working with local informants to reflect the variation in infrastructure, agro-ecology, and population size in the region. Within each of the communities, we conducted surveys in 50 homesteads. We first digitized the boundaries of each of the six communities based on information from local informants. We then generated 50 random geographic points and selected the homestead nearest to each point to be surveyed.

Fig. 1. Map of Eswatini showing the Lubombo region and locations of the communities surveyed. Inset: Map showing the location of Eswatini in relation to its neighbouring countries in Africa.



Focus groups
We conducted focus groups to understand the history and current challenges faced by each community (Appendix 1, section A1.1). We conducted at least two focus groups per community, with an average of seven participants (5–20) in each group. These groups included community members who had knowledge of past community events and were selected with the help of local informants. All focus group members were between 20 and 80 years old. We separated male and female participants into different groups. We asked open-ended questions to prompt broad discussion. Focus groups typically lasted for 1–2 h.

In the first section of the focus group, we asked participants about major changes in the community. Sources of major changes included infrastructure, disease, livelihood strategies, leadership, access to education, natural resources, healthcare, and jobs. We also asked about adaptation options, past experiences with drought, and major stresses and shocks experienced within the community. Further, we asked open-ended questions to gather general information on daily activities, resource collection, employment options, social interactions, and health. We also used focus groups to identify the specific set of adaptations most common in the region in response to drought.

Household surveys
Each household survey took approximately 1 h and included six thematic sections: (1) demographics and human capital; (2) natural capital, farming, and food resources; (3) financial capital: (4) physical capital: (5) social capital; and (6) adaptations. We conducted the survey with the primary household decision maker when possible. If the primary decision maker was unavailable, we conducted the survey with the oldest household member present.

Demographics and capital
First, we asked questions about household demographics and human capital (Appendix 1, section A1.2). We collected data on age, highest level of education, employment status (including self-employment), marital status, and time at the homestead for those living at the homestead. We used this information to quantify dependency ratios (ratio of children under 16 and adults over 65 to the total household population aged 16 to 65), household jobs and businesses, average education, and time in the community.

For the second section of our survey, we asked questions about natural capital, food sources, and crops (Appendix 1, section A1.2). To quantify natural capital, we asked questions about access to and use of natural resources (de Sherbinin et al. 2008, Below et al. 2012, Cassidy and Barnes 2012, Tibesigwa et al. 2014). For example, to determine the use of wild food, we asked, "What proportion of your household's diet comes from wild foods?" (We provided examples of common wild foods). Additionally, we asked, "How many kilometers do you travel to collect wild foods?" To determine farming behavior, we asked the respondent to describe the most recent farming activities, including time, crops planted, proportion of fields used, and yield. We also asked the respondent to compare their most recent farming activities to past farming activities. We also asked about ownership of livestock. We asked about the number and type of livestock owned and if any had been sold or died recently.

In the third section, we asked question pertaining to financial capital (Appendix 1, section A1.2). Recognizing the variety of livelihood strategies available, we asked questions accounting for multiple sources of income. We asked about total income from salaried employment, small businesses, and exchange of goods and services. Additionally, we asked for descriptions of small business activities, costs of materials, and how often sales or exchanges are made, on average. Further, because people are often hesitant to report total income (Moore et al. 2000, United Nations Department of Economic and Social Affairs 2005, Meyer et al. 2015), we asked questions that could serve as a proxy for relative income. We asked, "On average, how much money does your household spend on groceries each month?" and "On average, how much money does your household spend on school fees each year?" There are a range of costs associated with schooling beyond the seventh grade in Eswatini. Additionally, some schools charge more than others, and many households are unable to afford to send their children to school at all, although most acknowledge the value of advanced education. Thus, school fees serve as an additional proxy for household wealth for those families with children. Based on our preliminary surveys, this information was well known to heads of households and was correlated with income.

The fourth section of our survey was used to ascertain physical capital, including relative access to physical resources and infrastructure. We asked respondents to describe the location, means of travel, and most recent visit to hospitals, schools, and markets. We also asked about access to water and electricity. Specifically, we asked: "What is your household's main source of drinking water?", "How far do you travel to this water source?", and, "How many months out of the year is this water source available?" We asked if the household had access to electricity and about any costs associated with electricity and water access. Last, we asked about ownership of physical assets (Below et al. 2012, Jain et al. 2015), including vehicles (cars, tractors, etc.), farming tools (hoe plow), and electronics (refrigerator, stove, television, computer, tablet, cell phone; Appendix 1, section A1.2).

The fifth section of our survey asked participants about their social capital. We collected data on participation in community groups, attendance at community meetings, hiring or working for neighbors, and trade or exchange with neighbors. We also asked if anyone in the homestead held a leadership position in the community. Such positions could include those in schools or churches, official community titles such as chief or *induna* (local leader), working with community police, or serving on a leadership council, etc.

Adaptation
The last section of our survey focused on exposure to drought and past adaptations. Based on preliminary research, we identified nine primary adaptation strategies typically employed in response to drought conditions: planting drought- or heat-resistant crops, conservation farming to minimize soil erosion and nutrient loss, beekeeping, chicken husbandry, selling natural resources (primarily firewood), selling handicrafts, looking for off-farm employment, and participating in training or activities with aid organizations. For each adaptation, we asked if they had ever performed the adaptation strategy and if they had performed it within the past five years. We did not distinguish between households that specifically chose the behavior as an adaptation to the current drought and those who attempted it for other

reasons because climate adaptation often happens in conjunction with other factors (Adger et al. 2005). In addition, for adaptations that the respondent did not perform, we asked what the barriers were (e.g., time, labor, money, knowledge, interest, social norms, etc.; Appendix 1, section A1.2). To determine if an adaptation was successful, we asked about the outcomes of the adaptation. Specifically, we asked if the adaptation, in the respondent's opinion, led to a change in food consumption, income, or agricultural output. We categorized any adaptation that led to an increase in any of the three possibilities as successful. We also asked if, in the respondent's view, the adaptation was successful in minimizing the negative impacts of the current drought. Such a definition of adaptation is subjective to the performer and operates on a relatively short timescale. We believe that this definition of success is relevant in determining future adaptation options and perceived well-being. If a household believes that an adaptation improved conditions during this drought, they are more likely to engage in that adaptation in the future.

Statistical analysis

The initial survey included > 60 questions related to the five types of capital. We first conducted a multicollinearity analysis using Pearson's correlation coefficient to identify highly correlated survey variables, which we removed from the analysis. To create a more parsimonious model and avoid overfitting of the data, we conducted nonlinear principal components analysis (PCA) on the variables from the remaining questions for each capital in the package GIFI (de Leeuw et al. 2009). Nonlinear PCA accommodates nonparametric data, including ordinal and binomial data such as those collected in our research (Linting et al. 2007). From the nonlinear PCA, we obtained two sets of variables that we could include in our models. The first set was a principal component for each of the five types of capital. The second set included PCA loadings for the individual survey variables that accounted for the most variation in the data for each type of capital (hereafter "capital indicators").

We created several response variables to assess the relationship between adaptation and different types of capital using generalized linear models. We fitted models to the total number of adaptations attempted by a household during the past five years (this includes households that did not attempt any adaptations), a binary measure of adaptation success, and the ratio of successful adaptations to attempted adaptations (this excludes households that did not attempt any adaptations). Additionally, we fit models to binary response variables (attempted, 0 or 1) for each of the adaptations (e.g., conservation farming, alternative crops, selling chickens) that were attempted by at least 15% of the survey population.

For each of the three response variables, we created two sets of competing models (models 1–3). The first set included a global model with all five types of capital (using the PCA metrics), competing capital models, and a null model (model subset a). The second set of competing models included a global model with all capital indicators, competing capital indicator models, and a null model (model subset b). We selected the best models using the Aikaike Information Criterion (AIC). We ranked all models according to AICc values and took their model-averaged coefficients (Burnham and Anderson 2002). We considered models with ΔAICc values ≤ 2 as candidates for the best model. We completed our analysis using the packages MASS and MuMIn in RStudio with the R platform (Venables and Ripley 2002, Barton 2015, RStudio Team 2015, R Core Team 2016).

RESULTS

Focus groups

The 13 community focus groups identified drought as the biggest change affecting their communities. Respondents reported that drought affected food availability, food quality, jobs, interpersonal relationships, infrastructure, development, and a host of other aspects of their lives. The most commonly cited type of response to drought was changing farming strategies, which included farming different types of crops, conservation farming, farming a smaller proportion of available land, or temporarily stopping farming activities.

Capital

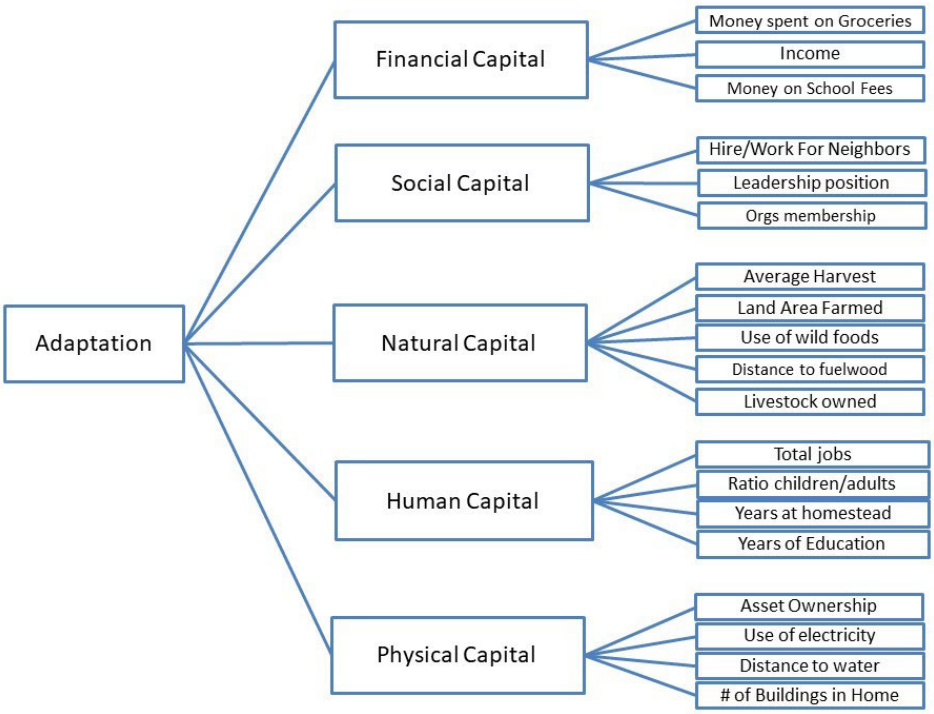
We completed a total of 307 household surveys. In terms of human capital, the average household size was 6.7 (standard deviation [SD] = 3.5), and the average proportion of household members with jobs was 0.31 (SD = 0.32). For natural capital, most households travel 3–5 km to collect fuelwood, 56% of households did not plant crops during the previous wet season, and 30% of households eat wild food collected from nearby natural resources (although this accounts for < 10% of the total diet for all households). Additionally, there was an average of 1.4 cows, 8.3 chickens, and 2.6 goats per household. In terms of financial capital, 57% of households earn < 1000 Emalangeni (USD $74.50) per month, and households spend an average of 674 Emalangeni (USD $50) on groceries each month. In terms of physical capital, there is an average of 3.7 (SD = 2.4) buildings per household, 64% of households have electricity, and 45% of households get water from a tap within the homestead, whereas 25% of households get water from a borehole, well, or dam. In addition, 50% of households own a refrigerator, 90% own a cell phone, and 19% own a vehicle. In terms of social capital, 42% of households work for or hire their neighbors, 37% of households are involved in a community organization, and 22% of households have a family member with a leadership position in the community.

We included 19 capital indicators in the final PCA and indices (Fig. 2). PCA variable loadings represent the variation in the data explained by each variable (Abdi and Williams 2010). The indicators with the largest principal component loadings for each capital were amount of land available to farm (natural capital), participating in a community organization (social capital), average money spent on groceries (financial capital), ratio of adults to dependents (human capital), and number of buildings in the homestead (physical capital).

Trends in adaptation

Of the households surveyed, 78% attempted one or more adaptations. Of those that attempted to adapt, 57% reported at least one successful adaptation (Table 1). The most common adaptations attempted were planting alternative crops that were understood to be heat or drought resistant. Fifty-two percent of households planted alternative crops, and it was reported as successful 15% of the time. The second most common adaptation was implementation of conservation farming practices that are taught by government officials, aid organizations, or community

Fig. 2. Diagram of the five types of capital hypothesized to influence adaptation and their indicator measures.



members. Thirty percent of households attempted conservation farming, and it was reported as successful 10% of the time. Other common adaptations included raising chickens to sell (23% of households), making handicrafts to sell (19% of households), collecting natural resources to sell (18.5% of households), and looking for work off-farm, typically in Swazi cities or in South Africa (24% of households; Table 1). Twenty-two percent of households did not attempt any adaptation, and 55% of households attempted more than one adaptation.

Table 1. List of adaptations, the proportion of households attempting the adaptation, and the proportion that reported that they were successful. The data summarize 240 households in the Lowveld of Eswatini that attempted to adapt.

Adaptation	Attempted (% households)	Successful (% households)
Alternate crops	52	15
Conservation farming	30	10
Raising chickens	23	17
Selling handicrafts	19	21
Selling natural resources	19	20
Working off-farm	24	9

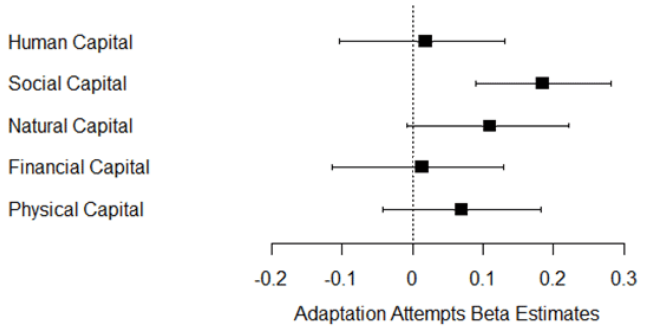
Adaptation and capital

The top competing models for total adaptations attempted per household included variables for social, natural, financial, and human capital (Table 2, model 1a; see also Appendix 2). The model-averaged beta estimates indicate that social capital ($\beta = 0.19 \pm 0.048$) was most strongly correlated with attempted adaptations (Fig. 3). Working for or hiring neighbors ($\beta = 0.16 \pm 0.09$), participating in a community organization ($\beta = 0.33 \pm 0.1$), number of chickens ($\beta = 0.02 \pm 0.01$) and goats ($\beta = 0.02 \pm 0.01$) owned, area farmed ($\beta = -0.05 \pm 0.03$), and distance to savanna were in the top competing capital indicator models (Table 2, model 1b).

Table 2. Akaike Information Criterion (AIC) and degrees of freedom (df) for the top competing regression models of household adaptation attempts (1a, 1b), adaptation success ratio (2a, 2b), and whether a household had any successful adaptations (3a, 3b) as a function of type of capital and capital indicators. See Appendix 2 for all competing models.

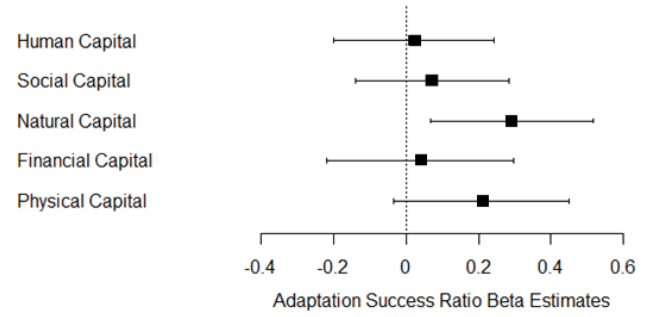
Model	Model variables	df	AIC
1a	Social + Financial	3	653.5
1b	Chickens + Community organization membership + Distance to savanna + Hire/work for neighbors	5	648.8
2a	Financial + Natural + Physical	4	339.8
2b	Buildings + Income + Average harvest + Hire/work for neighbors	5	334.8
3a	Social + Natural	3	245
3b	Community organization membership + Goats	3	245.6

Fig. 3. Plot showing the model-averaged beta estimates for each type of capital for adaptations attempted by a household.



The top competing models for the ratio of successful adaptations to attempted adaptations included variables for natural, social, financial, and physical capital (Table 2, model 2a; see also Appendix 2). The model-averaged beta estimates indicate that natural capital ($\beta = 0.32 \pm 0.22$) was most strongly correlated with adaptation success ratio (Fig. 4). The number of buildings in the homestead ($\beta = -0.12 \pm 0.05$), working for or hiring neighbors ($\beta = 0.39 \pm 0.18$), the average homestead harvest ($\beta = 0.13 \pm 0.07$), and household income ($\beta = -0.2 \pm 0.1$) were included in the top competing models (Table 2, model 2b).

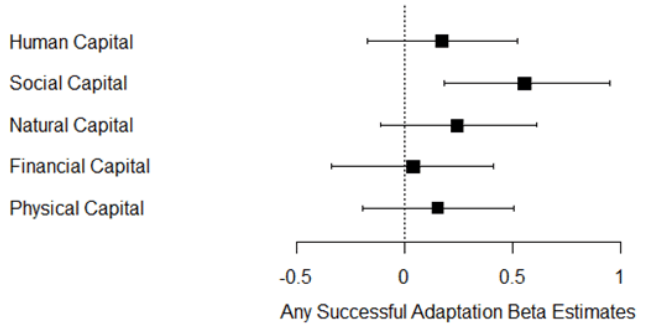
Fig. 4. Plot showing the model-averaged beta estimates for each type of capital for the adaptation success ratio.



The top competing models for successful adaptation included social, natural, physical, and financial capital (Table 2, model 3a; see also Appendix 2). The model-averaged beta estimates indicated that social capital ($\beta = 0.59 \pm 0.4$) was most strongly correlated with a successful adaptation (Fig. 5). Participation in a community organization ($\beta = 1.22 \pm 0.35$), working for or hiring neighbors ($\beta = 0.34 \pm 0.29$), owning goats ($\beta = 0.08 \pm 0.04$) or chickens ($\beta = 0.04 \pm 0.03$), and distance to savanna ($\beta = 0.11 \pm 0.14$) were in the competing models (Table 2, model 3b).

While overall adaptation behavior was strongly correlated with social and natural capital, individual adaptations varied more with individual survey variables. The decision to engage in conservation farming was positively correlated with social and natural capital, and specifically, with working for or hiring neighbors, land available to farm, and distance to savanna patches available for wood collection (Table 3). The decision to plant alternate crops, however, was most strongly correlated with participation in a community organization, cow ownership, and distance to water (Table 3). A household's decision to sell chickens was positively correlated with social and natural capital, specifically, working for neighbors and consuming wild foods (Table 3). The decision to sell natural resources (primarily firewood) was negatively correlated with household electricity and education, and positively correlated with working for and hiring neighbors (Table 3). Finally, the decision to sell handicrafts was positively correlated with social and natural capital variables, including participation in a community organization, consuming wild foods, and ownership of goats (Table 3).

Fig. 5. Plot showing the model-averaged beta estimates for each type of capital for the probability of having any successful adaptation.



DISCUSSION

As climate change continues to threaten environmentally dependent livelihoods in the developing world, there is a need to identify the resources and strategies that allow livelihoods to persist across contexts. To contribute to that effort, we studied adaptation to drought-related stress among rural farmers in Eswatini. We found that social capital and natural capital were the most important types of capital in predicting successful adaptation to drought. Our data highlight the critical link between social and natural capital and adaptation observed elsewhere (Bebbington 1997, Woolcock 1998, Nawrotzki et al. 2012, Tibesigwa et al. 2014) and furthers the understanding of pathways through which capital operates to support livelihoods.

Social capital and community networks operate in diverse ways to serve as critical resources for adaptation to drought across contexts. For instance, the decision to engage in an adaptation is often driven by encouragement and information gained via trusted information sources and contacts within social networks (Lo 2013, Udmale et al. 2014). In contrast, younger, more socially isolated households may be less likely to adapt effectively and more likely to experience greater stress and loss as a result of drought (Austin et al. 2018, Neef et al. 2018). Examining the role of social capital in a household and community context in Eswatini enables us to understand better how place influences the role of social capital and adaptation (Pelling and High 2005). In our study area, households reported increased knowledge of adaptation options and support for adaptation via social

Table 3. Results of logistic regressions for attempts of each adaptation. The table shows model-averaged beta estimates and their significance for all variables in the top competing model for each adaptation. We show results from models that included each type of capital and for individual capital variables, grouped according to capital.

Type of capital	Survey variable	Conservation farming	Planting alternate crops	Selling chickens	Selling natural resources	Selling handicrafts
Social capital		0.605*	0.232	0.358*	--	--
Natural capital		0.356*	--	0.287*	--	0.363*
Physical capital		--	--	0.667	0.553*	--
Financial capital		--	--	--	--	0.388*
Human capital		--	--	--	--	--
Social capital	Hire/work for neighbors	0.702*	0.446	0.650*	0.942*	--
	Community organization membership	--	--	0.670	--	0.965*
	Leadership	0.540	--	--	--	--
Natural capital	Farmland	0.134	--	--	--	0.183
	Distance to wood	0.292*	--	0.282	--	0.612*
	Wild food	--	0.595	0.862*	--	0.957*
	Goats	0.059	--	--	--	0.132*
	Chickens	--	0.065*	--	−0.051	--
	Cows	--	−0.120*	--	--	--
Physical capital	Distance to water	--	0.233	−0.206	--	--
	Buildings	--	--	−0.131	--	--
	Electricity				−0.661	--
Human capital	Average education				−0.131*	--
Financial capital	Income					−0.267

*$P \leq 0.05$ based on the Wald test

networks, particularly involvement with community organizations. Gains in social capital are also positively associated with increases in other forms of capital and greater access to resources that support climate adaptation (Narayan and Pritchett 1999, Guiso et al. 2004). We found that households participating in community-led organizations reported increased human capital via training in farming strategies, small business management, and trade skills. Similarly, households participating in community organizations and those that worked for neighbors reported increased financial security and access to short-term financial resources and information on adaptation strategies, and increased access to otherwise inaccessible physical capital such as tractors. In Eswatini, as elsewhere, social capital operates along multiple pathways to enable households to obtain additional capital and resources, allowing them to engage in more adaptation during drought.

Natural capital also affects adaptation in multiple complex pathways. First, households that are heavily dependent on natural resources are more likely to be affected by climate shocks and stresses such as drought than those that are decoupled from the environment (Osbahr et al. 2008, Nawrotzki et al. 2012, Blignaut et al. 2014, Guerry et al. 2015). In Eswatini, many households reported a lack of alternative livelihood strategies and strong cultural connections to natural resources, increasing their vulnerability to drought. Second, natural capital also supports adaptation by providing critical resources that are often readily available and do not require extensive knowledge or training to exploit (Osbahr et al. 2008, Belay et al. 2017). Respondents in our study reported that local natural capital, with which they were familiar, supported adaptations, including shifting to drought- or heat-resistant crops, making and selling crafts, and collecting and selling firewood, fruit, and thatch grass. Finally, natural capital, depending on the context, can also serve as a form of social and financial capital (Kerven 1992, Turner 2009). Specifically, livestock and communal rangelands serve important cultural and economic functions across southern Africa (Cousins 1999, Carter and May 1999). Respondents in the communities we surveyed reported liquidating livestock, using livestock as collateral, and strengthening social connections through livestock during the drought, enabling increased adaptation success.

While social and natural capital were the best predictors of overall adaptation, we also found evidence that a diverse pool of capital enables diverse adaptation and a greater likelihood of success. Adaptation strategies such as planting drought-resistant crops, for example, require access to physical (plow), natural (land, seeds), and social or human capital (education on alternative crops). To sell firewood, a household must have access to savannas or forests to collect firewood (natural capital), a network of households to buy firewood (social capital), and demand driven by a lack of affordable access to electricity (limitations on physical capital). Households with greater capital diversity, i.e., a more even spread across the five types of capital, were more likely to have successful adaptations. Diverse capital also supports diverse adaptations and livelihood strategies, which are especially valuable when environmental stresses are extreme (Berman et al. 2015, Huynh and Stringer 2018).

It is worth noting that these data were collected during the drought. Perceptions of the success of an adaptation may have changed following the end of the drought. Adaptations operate across broad spatial and temporal scales. Adaptations that benefit

the adopter now may have negative effects in the future (Paavola 2008, Barnett and O'Neill 2010). Similarly, adaptations that benefit one household or community may have negative effects on other households or communities (Adger et al. 2005, Holler 2014). This is a limitation of our study, and there is a need for longitudinal research assessing perceptions of adaptation effectiveness in Eswatini and elsewhere.

CONCLUSION

Our findings suggest that maintenance and growth of social and natural capital are important ways to improve the ability of households to respond to drought and other changes. Evidence of this trend has been observed elsewhere, where the establishment of local community organizations and programs led to increased economic activity and increased resilience to natural disasters (Westerman et al. 2012). Our work provides further evidence of the complex ways in which social capital operates and additional evidence for relevant indicators of social capital at household and community levels (Pelling and High 2005). As our data suggest, social capital enables adaptation largely because it creates opportunities for tangible exchange of goods, services, information, and trust, which allow for successful adaptation. Broad networks of resources exchange across spatial, temporal, and structural scales have enabled transformational adaptation, which increased resilience to climate change (Dowd et al. 2014). The importance of social capital is now being incorporated into community-based disaster preparedness strategies to strengthen community relationships and leverage assets to improve community-level responses to natural disasters (Luna 2001). As our research demonstrates, social capital is critical to adaptation in our changing world and needs to be at the forefront of development and climate adaptation policy. Communities, governments, and organizations should establish and foster programs that allow households to connect in meaningful ways, to ensure they have access to the resources and opportunities necessary for long-term adaptation and resilience.

Responses to this article can be read online at:
http://www.ecologyandsociety.org/issues/responses.php/10981

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Appendix A1

Focus group guidelines and household survey for communities and households in the lowveld of Swaziland.

A1.1 Focus Group Guidelines

Focus group questions

Purpose:

The purpose of this focus group is to better understand what changes have happened in Lubombo communities over the last decade and how people respond to those changes. We are specifically interested in things that impact day to day livelihood activities and quality of life and wellbeing.

Major community events (Event Matrix)

Please discuss any major events that have affected daily activities in the community over the last 20-30 years. This can include change in leadership, drought, flood, sugarcane, migration, roads, electricity, water, urbanization, schools, clinics, and disease, anything that has impacted daily life in the community.

Livelihood strategies (Spidergram)

Let's create a picture by drawing areas where you collect resources and other things needed for day to day life. For each area, we want to identify livelihood strategies. These are activities that the family uses to obtain income or food. Please include areas where you farm, collect firewood or plants, sell products, or have jobs that provide wages. (Create a diagram of livelihood activities and general location of activities or resources needed).

We're providing you with 100 counters that represent a homestead's livelihood activities. Think about an average month. Please distribute the counters in proportion to the contribution that each activity makes to a homestead. For example, if your homestead spends 50% of the time farming and 50% of your time working in a town, place 50 counters on the homestead and 50 in the village where they work. Each homestead may be different but we want to get a general understanding of most homesteads in the community.

Drought and Impacts

Next, we want to talk about drought. When has drought impacted your community? Are the impacts of drought getting worse or better? What has drought impacted directly, for example, farming, firewood, sales, and cattle? Did you lose income? Were people out of work? Did you have less food? Did your family members lose weight or get sick? Did cattle die or were their other changes in the environment that impacted you?

Responses to major events

Now consider the picture we made of resources and activities and where you get your resources. How did the distribution of resources change following each event? For instance, after a drought, did farming increase or decrease in importance to your homestead? Did you get more resources from a different area, like food aid or food gifts? (Go through and ask them to move counters if they changed strategies. Have them discuss other changes they made to their daily activities).

Limitations to responses

There are some times when your livelihoods and resource use did not change after a major event in the community. We want to understand why. Please think about things that may have prevented you from altering your daily activities and discuss them. This may include a lack of money or information, lack of access to machines or markets, or maybe you simply didn't want to change. Perhaps it was inappropriate for you to change anything. Please think of anything that may have led to your decision to change your livelihoods or not.

Community factors

Please look at the map and try to outline where your community starts and ends. Do you think your community is different than other communities in any way? Are there more or less resources? Is there the same amount of development or aid? Are there more or less people or are the populations changing differently. (Prompt to compare to communities in the Lowveld or others on the ridge)

Other Topics and Conclusion

Again, our goal is to understand what changes have happened in your lives, how people respond or don't respond to those changes, and how it all impacts your wellbeing. Is there anything that you think is important that we haven't discussed today?

Thank you for participating in this focus group!

A1.2 Household Survey

Enumerator Name	**Translator name**
Date of Survey	**Community Name**
Time survey start	**Time Survey End**
Sex of Interviewee(s)	**Household head (Y/N)**
Household Code	

Section A-Homestead data

A.1 Date of Settlement at homestead

| _____ |

A.2 What is the main type of roof?

1. Thatched Grass
2. Corrugated Iron
3. Other (specify)

| _____ |

A.3 What is the main type of floor?

1. Mud
2. Cement/stone
3. Other (Specify) |_____|

A.4 What is the main type of floor?

1. Mud
2. Cement/stone
3. Other (Specify) |_____|

A.5 What is the main type of wall?

1. Mud and sticks
2. Mud and stones
3. Cement, cinderblock
4. Other (specify) |_____|

A.6 Do you have electricity at the homestead?

1. No |_____|
2. Yes

A.7 What fuel is used to cook with?

1. Dung
2. Wood
3. Coal/charcoal
4. LPG
5. Kerosene
6. Electricity |_____|

A.7 How many children <16 years old live at the homestead? |_____|

A.8 Answer the following for all family members 16 and older

HH ID	ID Code	Sex	Age	Marital status	Literate (yes/no)	Years of Education	Months/years at homestead	Principal Occupation	Secondary Occupation
	01								
	02								
	03								

B.1 What is the primary livelihood activity?

1. Own farm activity
2. Salaried employment
3. Agriculture employment

4. Small business
5. Natural resource collection
6. Craft manufacture
7. Other (Specify)

B.2 What is the secondary livelihood activity?
(Use codes from above

B.3 What is the tertiary livelihood activity?
(Use codes from above)

B.4 Does the primary livelihood activity account for more than 50 percent of your household's livelihood?

1. No
2. Yes

B.5 Who is the main breadwinner in the household?
(Use individual ID Code)

B.6 For household members who work off-farm, how far do they travel for work, on average?

1. <1km
2. 1-5km
3. 5-10km
4. 10-15km
5. 15-20km
6. 20-30km
7. >30km

Location of off-farm work

B.7 What is the primary food source?

1. Own farm harvest
2. Purchased food
3. Traded food
4. Food gifts
5. Food aid
6. Other (specify)

B.8 What is the secondary food source?
(Use codes from question B.7)

B.9 What are the primary crops that you cultivate at home (20% or more of total planted crops)?

B.9 In a good year, how many bags does your household harvest?

1. **<5 bags**
2. **5-10 bags**
3. **10-15 bags**
4. **15-20 bags**
5. **20-30 bags**
6. **30-40 bags**
7. **>40 bags**

Section C-Financial Capital

C.1 Does your household own any of the following? (1 if No, 2 if yes)

Radio/Cassette player?

|_____|

Bicycle?

|_____|

Motorcycle/scooter?

|_____|

Refrigerator?

|_____|

Tractor?

|_____|

Plow?

|_____|

Television?

|_____|

Telephone/cell phone?

|_____|

C.2 What is your average total monthly household income?

1. <E200
2. E200-E500
3. E500-E1,000
4. E1,000-E2,000
5. E2,000-E3,000
6. E3,000-E5,000
7. >5,000

|_____|

C.3 When was the last time someone in your household received money for work (a paycheck), government money, money for services, or payment for product sales?

1. Within the last 3 days
2. Within the last week
3. Within the last 2 weeks
4. Within the last month
5. Within the last 2 months
6. More than 2 months ago

|_____|

Section D-Natural Capital

D.1 Have you planted anything this season?

1. No
2. Yes

|_____|

D.2 If no, do you plan to plant this season?

1. No
2. Yes

|_____|

D.3 If yes, what proportion of your farmland are you currently using for farming?

1. <10%
2. 10-30%
3. 30-50%
4. 50-70%
5. 70-90%
6. >90%

|_____|

D.4 What percentage of your farmland did you farm last year?

1. <10%
2. 10-30%
3. 30-50%
4. 50-70%
5. 70-90%
6. >90%

|_____|

D.5 Does your household collect wild food?

1. No
2. Yes

|_____|

D.6 What proportion of your diet comes from wild foods?

1. <10%
2. 10-30%
3. 30-50%
4. >50%

|_____|

D.7 How far do you travel to collect wild foods?

1. <1km
2. 1-3km
3. 3-5km
4. >5km

|_____|

D.8 How far do you travel to collect fuel wood?

1. <1km
2. 1-3km
3. 3-5km
4. >5km

|_____|

D.9 Please look at the map and outline the following:

Where your farmland is located
Where you travel to collect firewood
Where you travel to collect wild foods

Section E-Physical Capital

E.1	**How far (Km) do you travel to reach the [FACILITY]:** 1. <1km 2. 1-5km 3. 5-10km 4. 10-20km 5. 20-30km 6. 30-50km 7. >50km	**How do you travel to get to [FACILITY]?** 1. Walk 2. Drive 3. Bus/public transport 4. Bicycle	**How long does it take you to reach [FACILITY]?** **Hours** **Minutes**
Primary School			
Middle School			
Secondary School			
Clinic			
Market			

E.2 **How many do you own of each of the following?**

1. Chicken
   |_____|
2. Turkey
   |_____|
3. Goat
   |_____|
4. Sheep
   |_____|
5. Cow
   |_____|
6. Donkey
   |_____|
7. Pig
   |_____|
8. Other livestock (specify)
   |_____|

E.3 **What is the main source for your drinking water?**

1. Tap
2. Well
3. Borehole
4. Running water (river, stream)
5. Lake
6. Other (specify)

|_____|

E.4 How far is this drinking source from the homestead?

1. Within homestead
2. <0.5 km
3. 0.5-1km
4. 1-3km
5. >3km

|_____|

E.5 How many months of the year is this water source available?

1. 0-3 months
2. 3-6 months
3. 6-9 months
4. 12 months

|_____|

E.6 What is the distance to the water sources used for livestock (cattle)?

1. Within homestead
2. <0.5 km
3. 0.5-1km
4. 1-3km
5. >3km

|_____|

Section F-Social Capital

F.1 Are you or any member of your household a member of a community organization?

1. No
2. Yes

|_____|

F.2 How many times in the last month did you attend:

Church

|_____|

Community Meeting

|_____|

Organizational meeting

|_____|

F.3 Do you or any household member have any leadership positions in the community?

1. No
2. Yes

|_____|

F.4 If so, how long have they held the leadership position

|_____|

F.5 How many times in the last month have you received gifts from friends or community member?

|_____|

F.6 Does your household trade goods with your neighbors?

1. No
2. Yes

|_____|

F.7 If, so, how often do you trade, on average?

1. Daily
2. Weekly
3. Every 2-3 weeks
4. Monthly
5. Every 2-3 months
6. 1-2 times per year
7. Other (specify)

|_____|

F.8 Does your household work for your neighbors?

1. No
2. Yes

|_____|

F.9 If, so, how often do you work for your neighbors, on average?

1. Daily
2. Weekly
3. Every 2-3 weeks
4. Monthly
5. Every 2-3 months
6. 1-2 times per year
7. Other (specify)

|_____|

F.10 Do you hire your neighbors?

1. No
2. Yes

|_____|

F.11 If, so, how often do you hire your neighbors, on average?

1. Daily
2. Weekly
3. Every 2-3 weeks
4. Monthly
5. Every 2-3 months
6. 1-2 times per year
7. Other (specify)

|_____|

F.12 Where do you get information about farming and weather?

1. Neighbors
2. Community Meetings
3. Government extensions
4. UniSwa
5. Radio/TV
6. Cell phone

7. Newspaper
8. RSSC
9. Aid Organization

|_____|

Section G-Health and Food Security

G.1 In the past 24 hours how many times have household women eaten?

|_____|

G.2 In the past 24 hours how many times have household men eaten?

|_____|

G.3 In the past 24 hours how many times have household children eaten?

|_____|

G.4 In the past <u>24 HOURS</u> has anyone in your household eaten the following? (1 if No, 2 if yes)

Maize
|_____|
Rice
|_____|
Sorghum
|_____|
Other grains?
|_____|
Bread
|_____|
Chicken
|_____|
Fish
|_____|
Beef
|_____|
Pork
|_____|
Other meat
|_____|
Eggs
|_____|
Beans
|_____|
Vegetables
|_____|
Milk or dairy
|_____|

Other food (specify)
|_____|

G.5 In the past 7 DAYS has anyone in your household eaten the following? (1 if No, 2 if yes)

Maize
|_____|
Rice
|_____|
Sorghum
|_____|
Other grains?
|_____|
Bread
|_____|
Chicken
|_____|
Fish
|_____|
Beef
|_____|
Pork
|_____|
Other meat
|_____|
Eggs
|_____|
Beans
|_____|
Vegetables
|_____|
Milk or dairy
|_____|
Other food (specify)
|_____|

G.6 How many household children 0-5 years old have died recently (in the past 2 years)?
|_____|

G.7 (If 0, Skip to next question) By what cause(s)?
_____

G.8 How many household adults have died recently (in the past 2 years)?
|_____|

G.9 In the past 30 days, how many household members have visited a hospital or clinic?
|_____|

Section H- Drought & Adaptation

H. How do you know when there is a drought? (What cues, evidence, and trends do you

1 use)?

_____

H. 2 Thinking back over the last 30 years (or when you first moved to the community) how have the impacts of drought changed compared to the past?

1. Fewer negative impacts of drought
2. No change in impacts of drought
3. More negative impacts of drought

|_____|

H. 4 In the past 5 years, have you and your household experienced drought?

1. No
2. Yes

|_____|

H. 5 Excluding the last 6 months, has your household done any of the following over the past 5 years in response to drought? (1 if no, 2 if yes)

Planting Alternative crops
|_____|
Conservation farming
|_____|
Bee Keeping
|_____|
Raising Indigenous Chickens
|_____|
Collecting natural resources to sell
|_____|
Handicrafts
|_____|
Sending family to work in cities
|_____|
Sending family to work in Sugarcane
|_____|
Participated in training provided by aid organizations
|_____|
Other (specify)
_____
_____

H. 6 What were the results of each adaptation (prompt if necessary, increase in production, increased income, increased food consumption, etc.).

Planting Alternative crops
_____
_____
Conservation farming
_____
_____
Bee Keeping

_____

_____

Raising Indigenous Chickens

_____

_____

Collecting natural resources to sell

_____

_____

Handicrafts

_____

_____

Sending family to work in cities

_____

_____

Sending family to work in Sugarcane

_____

_____

Participated in training provided by aid organizations

_____

_____

Other (specify)

_____

_____

H. 7 In response to drought this year, in the last 6 months, has your household done any of the following? (1 if no, 2 if yes)

Planting Alternative crops
|_____|
Conservation farming
|_____|
Bee Keeping
|_____|
Raising Indigenous Chickens
|_____|
Collecting natural resources to sell
|_____|
Handicrafts
|_____|
Sending family to work in cities
|_____|
Sending family to work in Sugarcane
|_____|
Participated in training provided by aid organizations
|_____|
Other (specify)

_____

Section I-Barriers and Impacts of Adaptation

For the next section, organize questions based on adaptation behavior. Ask first about adaptations that were done and second about those that weren't.

If adaptation was done in the last 6 months ask

I. 1 What did [the adaptation] involve, describe what you and your household changed?

_____

I. 2 How much money did your household spend to do [the adaptation]?

1. No money spent
2. < E100
3. E100-200
4. E200-500
5. E500-1000
6. >E1000

|_____|

I. 3 Did [the adaptation] require more time spent working or more people? If so, how much

_____

I. 4 How has [the adaptation] impacted the following

1. Increased/Improved
2. Decreased/Decline
3. No change

Total amount of agricultural production
|_____|
Total number of meals eaten by the household
|_____|
Amount of food eaten per meal by the household
|_____|
Total Household Income
|_____|

I. 5 Did [the adaptation] have any other impacts to you or your household?

_____

If the adaptation WASN'T done, ask the following questions

I. Which of the following BEST explains why you didn't do [the adaptation]?

6

1. **Don't know enough about it**
2. **Don't have the money**
3. **Don't have the time**
4. **Don't have the resources (land, plow, household members, etc., specify)**
5. **It won't help my household deal with drought**
6. **No one else is doing the adaptation**
7. **It is not an option for my household for some other reason (specify)**

_____

_____

I. Which of the following are additional reasons why you didn't do [the adaptation]?

7

1. **Don't know enough about it**
2. **Don't have the money**
3. **Don't have the time**
4. **Don't have the resources (land, plow, household members, etc., specify)**
5. **It won't help my household deal with drought**
6. **No one else is doing the adaptation**
7. **It is not an option for my household for some other reason (specify)**

_____

_____

I. Are there other things you would like to be able to do in response to drought that you

8 can’t? Specify

_____

_____

Appendix A2.

Top competing models (ΔAIC <2) for adaptation attempts, adaptation success ratio, and whether a household had any successful adaptations as a function of capital and capital indicators.

Table A2.1 Akaike information Criteria (AIC), change in AIC (ΔAIC) and degrees of freedom (df) from the top competing regression models of household adaptation attempts as a function of types of household capital.

Model	Model Variables (Capital)	df	AIC	ΔAIC
1	Social + Financial	3	653.5	0.00
2	Social + Financial + Natural	4	653.9	0.40
3	Social + Financial + Human	4	654.4	0.90
4	Social	2	654.7	1.20
5	Social + Financial + Natural + Human	5	654.9	1.40

Table A2.2 Akaike information Criteria (AIC), change in AIC (ΔAIC) and degrees of freedom (df) from the top competing regression models of household adaptation attempts as a function of individual indicators of household capital.

Model	Model Variables	df	AIC	ΔAIC
1	Chickens + Community Org + Distance to savanna + Work/Hire	5	648.8	0.00
2	Chickens + Community Org + Distance to savanna + Work/Hire + Goats + Area farmed	7	650.6	1.80
3	Chickens + Community Org + Distance to savanna + Work/Hire + Goats + Distance to water	7	650.7	1.85

Table A2.3 Akaike information Criteria (AIC), change in AIC (ΔAIC) and degrees of freedom (df) from the top competing regression models of household adaptation success ratio as a function of types of household capital.

Model	Model Variables	DF	AIC	ΔAIC
1	Financial + Natural + Physical	4	339.8	0
2	Natural + Physical	3	340.1	0.32
3	Financial + Physical	3	340.2	0.45
4	Physical	2	340.7	0.87
5	Financial + Physical + Social	4	340.7	0.92
6	Financial + Natural + Physical + Social	5	341	1.25
7	Physical + Social	3	341.3	1.46

Table A2.4 Akaike information Criteria (AIC), change in AIC (ΔAIC) and degrees of freedom (df) from the top competing regression models of household adaptation success ratio as a function of individual indicators of household capital.

Model	Model Variables	df	AIC	ΔAIC

1	Buildings + Income + Average Harvest+ Work/Hire	5	334.8	0
2	Buildings + Income + Work/Hire	4	336.2	1.4
3	Buildings + Work/Hire	3	336.8	1.93

Table A2.5 Akaike information Criteria (AIC), change in AIC (ΔAIC) and degrees of freedom (df) from the top competing regression models of whether a household had any successful adaptations as a function of types of household capital.

Model	Model	df	AIC	ΔAIC
1	Social + Natural	3	245	0
2	Social + Natural + Physical	4	245.06	0.06
3	Social	2	245.24	0.24
4	Social + Physical	3	245.95	0.95
5	Social + Natural + Physical + Financial	5	246.03	1.03
6	Social + Natural + Financial	4	246.19	1.19
7	Social + Financial	3	246.33	1.33

Table A2.6 Akaike information Criteria (AIC), change in AIC (ΔAIC) and degrees of freedom (df) from the top competing regression models of whether a household had any successful adaptations as a function of individual metrics of household capital.

Model	Model Variables	df	AIC	ΔAIC
1	Community Org + Goats	3	245.6	0
2	Community Org + Goats + Chickens	4	246.3	0.72
3	Community Org + Goats + Chickens + Work/Hire	5	246.6	0.98
4	Community Org + Work/Hire	3	246.8	1.20
5	Community Org + Goats + Chickens + Work/Hire + Distance to savanna	6	247.4	1.80