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Source: Journal of Ethnobiology, 35(2) : 314-336

Published By: Society of Ethnobiology

URL: https://doi.org/10.2993/etbi-35-02-314-336.1

Journal of Ethnobiology 35(2): 314–336 2015

VULNERABILITY AND RESILIENCE OF SIDAMA ENSET AND MAIZE FARMS IN SOUTHWESTERN ETHIOPIA

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*Enset (*Ensete ventricosum*) is the traditional staple food of Sidama people who live in Rift Valley lowlands to highlands in southwest Ethiopia. Enset is drought resistant, but it matures slowly, requires substantial manure inputs from cattle, and intensive processing. Maize, introduced to Sidamaland in the mid-twentieth century, is common in midlands and lowlands. Maize matures rapidly and provides more kcal/kg than enset, but it is prone to failure in dry years and requires chemical fertilizer, which is subject to global market price fluctuations. We compare cultural ecology, productivity, failure, and resilience of enset and maize in 410 farms across four Sidama ecological zones. The risks and benefits of enset and maize are complexly associated with variable local environments. Enset offers drought-resistant produce that, with sufficient manure inputs, is adequate for subsistence in the wet highlands, but its performance is more variable elsewhere. Fertilized, maize yields larger harvests than enset, but vulnerability to rainfall and global processes create special challenges. Maize and enset appear to be in different adaptive cycle phases: maize grows quickly and maize farms rebounded from crop loss within four years. Only half of enset farms recovered within six years after crop failure, complicating farming decisions in an environment with tremendous localized variation. In general, the Sidama zone shows a pattern of regional diversity with local specialization for maize only, enset only, or mixed maize and enset cultivation. In some areas maize has become a preferred crop and food for younger people.*

Keywords: *enset, Sidama people, crop failures, Ethiopia, crop diversity*

Introduction

Enset (*Ensete ventricosum* [Welw.] Cheesman) is the source of *waasa*, the staple food of Sidama people of southwestern Ethiopia. Indigenous to East Africa, and widely distributed in sub-Saharan Africa, enset is hardly known as a food plant outside of Ethiopia where it is an important, drought-resistant crop that feeds millions of people, mostly those living in Southern Nations, Nationalities and Peoples Regional State (SNNPRS)(Brandt et al. 1997). A relative of the banana, enset bears no edible fruit; rather, people mash the pseudostem and root into a pulp, which they ferment for at least two months, and then eat it as a flat bread or as a mash mixed with milk or butter (similar to *ugali* or thick grits). Though drought resistant (Brandt et al. 1997; Mohammed et al. 2013; Shigeta 1990), enset has a very long maturation period with a minimum of four years to produce sufficient edible starch and up to ten years to produce the inedible fruit. Earlier ethnographers noted the cultural centrality of enset: William Shack (1966)

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dubbed the Gurage, north of Sidama Zone, ''people of the enset culture.'' Enset has been at the base of Sidama livelihood for as long as anyone can remember.

Maize (*Zea mays* subsp. *mays* L.), in contrast, is a newcomer to Ethiopia. It was first documented in 1623, and maize agriculture only recently ''expanded and matured'' in southwest Ethiopia, from 1950 to 1975 (McCann 2001:265). Despite enset's traditional position, several features contribute to maize's spread: maize only needs one plowing before planting (other cereals require up to four plowings), available varieties require relatively little weeding, and it provides a high yield in a short time. However, farmers relying on maize ''gambled that the rains would come on time'' (McCann 2001:265).

Our interest is the comparative vulnerability and resilience of enset and maize farming in Sidama Zone of SNNPRS, Ethiopia. Ethiopian food security requires that we understand the productivity and vulnerabilities of traditional and introduced crops on the ground as produced by smallholders. Agricultural experiments are an excellent source of information, but results, often for ''normal'' conditions, cannot assess ecological variation common to southwest Ethiopia. USAID (2005) reports 40 different climatic ''livelihood zones'' in SNNPRS, with six different zones in Sidamaland. Comparing productivity and vulnerability of traditional (enset) versus introduced (maize) crops across ecological zones provides useful information for guiding cultural transmission and acceptability of new agricultural technologies and crop varieties. We conceptualize farming practices as key components of alternative social-ecological configurations (sensu Walker et al. 2002) embedded in Sidama culture.

Social-ecological thinking imagines system evolution involving multiple ''basins of attraction'' (Folke et al. 2010; Walker et al. 2004). ''Stability landscapes'' include multiple possible ''regimes'' or ''configurations'' with properties including stability, transformability, resilience, latitude, etc. A social-ecological regime or configuration is a collection of variables that respond systematically to perturbations. In response to perturbations, social-ecological systems (SES) exhibit adaptive cycles with periods of expansion, reorganization, and transformation that respond to internal (local) and external (global) shocks (Folke 2006). The expansive ''r'' phase of the cycle may be followed by a conservative, stable ''K'' phase (Folke 2006; Walker et al. 2004). We compare the productivity, vulnerability to crop loss, and time to recovery of maize and enset in four social-ecological contexts: the Sidama ''homeland'' in the wet highlands; semi-arid midlands, the site of recent drought relief efforts; the dry lowlands; and a peri-urban, lakeshore community near the regional capital. We examine the relationship between enset and cattle as fundamental to the enset ''configuration.'' Finally we examine the ''engineering resilience'' (Pimm 1991) of maize and enset in relation to the stark differences in their growth, production, processing, and reproduction.

Enset agriculture and Sidama cultural models indicate that enset is a crucial drought-resistant crop with significant cultural value. Here we show that Sidama enset and maize farming exhibit complex relationships with ecological conditions, land constraints, livestock ownership, fertilizer and manure input, and rainfall associated with elevation. In general, enset farms appear to be in the conservative ''K'' phase of the adaptive cycle, while maize farms are in the expansive ''r'' phase. In some cases, enset performs poorly compared to maize in

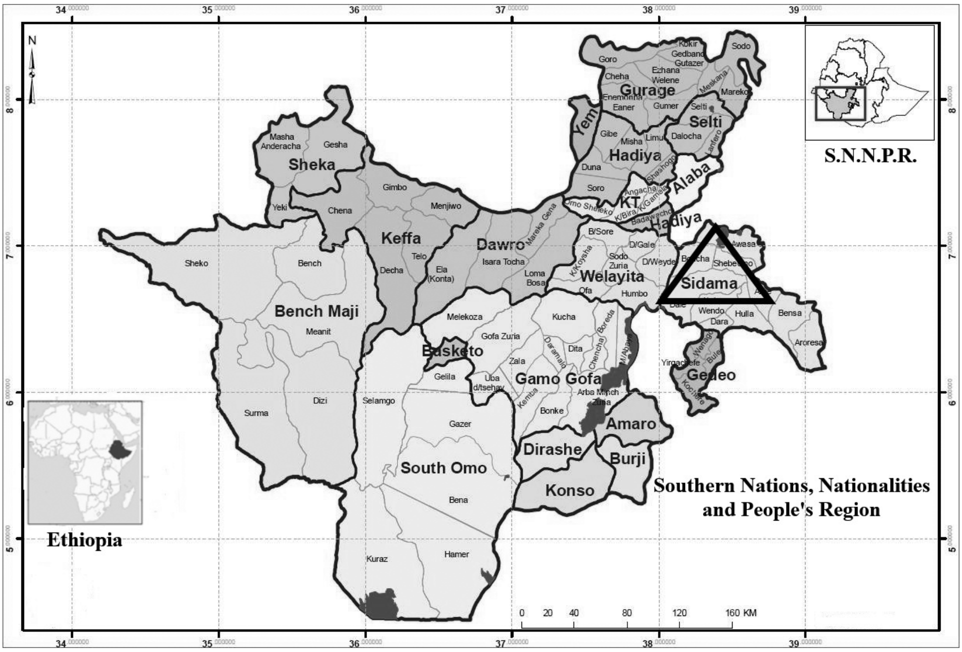

Figure 1. SNNPRS and study area.

terms of risk of crop loss. Common notions of enset as a drought-resistant crop warrant recasting in a more nuanced empirical framework.

Sidama People

Sidama are a Cushitic-speaking people inhabiting areas between the Rift Valley lakes of Hawassa and Abaya (Hamer 1987) (Figure 1). Most Sidama reside in the SNNPRS, the most rural of nine states in the Federal Democratic Republic of Ethiopia (Figure 1). SNNPRS contains 18 zones and special districts with boundaries demarcated along ethnic lines; hence, most Sidama live in Sidama Zone (Aalen 2011; CSAE 2013). Census figures estimate three million Sidama, the fifth largest ethnic group in Ethiopia (CSAE 2013) among more than 80 distinct ethnicities (Levine 2000). Additional cultural information on Sidamaland can be found in Hamer (1987), Quinlan et al. (2014) and Quinlan et al. (n.d.).

The rural Sidama are mostly subsistence agropastoralists (Asfaw and Ågren 2007; CSAE 2013; Hamer 1987). Staple crops are enset and maize, and less commonly wheat (*Triticum aestivum* L.) and barley (*Hordeum vulgare* L.). Enset, which is the main and preferred food, provides more calories *per unit of area* than do most cereals (e.g., maize) and is drought resistant; these are important characteristics given increases in population density and the frequency of droughts (Asfaw and Ågren 2007). Cash crops include coffee (*Coffea arabica* L.) and *ch'at* (*khat*, *Catha edulis* Forssk. *ex* Endl.), a perennial bush chewed as a stimulant. Crops vary across elevation, rainfall, and soil differences. Cattle play an important role in Sidama subsistence and risk-coping strategies (Caudell et al. 2015; Hamer 1987). Sidama raise zebu cattle, *Bos indicus* Linnaeus, primarily for dairy and fertilizer. Beef consumption is rare and is limited to ceremonies (e.g., marriage, funeral) or the natural death of the animal.

Sidama people recognize a symbiotic relationship between cattle and enset. Enset provides fodder for cattle, especially in times of drought when other grasses and grains are not available, and, in turn, cattle provide fertilizer for the enset. Sidama also keep smallstock and chickens (*Gallus gallus domesticus* Linnaeus) for consumption and sale (Asfaw and Ågren 2007). In general, Sidama favor using the profits from the sale of crops and wage-labor to purchase livestock and for livestock care (Yilma 2001).

Enset (*E. ventricosum*)

Maize is firmly established in much of Africa, and smallholder cultivation is well documented (McCann 2001). Enset is less familiar. Ethiopian farmers fall in two broad categories: ''plow cultures'' of cereal grains—primarily teff, but also maize, wheat, barley, sorghum, and millet—and ''hoe cultures'' growing enset and root crops—taro, sweet potatoes, and yams (Murdock 1959; Steward 1967; Westphal and Westphal-Stevels 1975). Among hoe cultures, enset is the most important food by far (Murdock 1959). The ''enset complex'' (Shack 1963:72) feeds a dense rural population across southwest Ethiopia (e.g., Bezuneh 1971; Bezuneh and Feleke 1966; Brandt et al. 1997; Rahmato 1995; Shack 1963) of ten to 15 million people (Brandt et al. 1997; Shank and Ertiro 1996). In all but the highest altitudes, where enset thrives best (Pijls et al. 1995), people grow it along with other roots or cereals (Brandt et al. 1997).

Sidama generally grow enset at elevations between 1200-3100 meters. Enset tolerates cool temperatures but not freezing, which causes frost damage. Above 3000 meters growth is stunted. Areas below 1500 meters are often too dry for enset (Brandt et al. 1997). Historically, the Sidama area had seasonal bimodal rainfall—an eight- to nine-month rainy season from March to November with a midland annual rainfall between 1300 and 2000 mm (Yilma 2001).

The pasture grass in the highlands is primarily *Andropogon abyssinicus* R.Br. *ex* Fresen., which highlanders say is good for cattle (Smeds 1955). The dense rural population in the Sidama Zone limits grazing land. Hence, enset is important livestock fodder (Asfaw and Ågren 2007; Brandt et al. 1997). Livestock eat parts of the enset plants that humans do not eat (leaves and outer stems), which contain the most protein (Yilma 2001). Enset and cattle dominate Sidama subsistence models, with an important place in Sidama cultural values (Hamer 1987).

Sidama call an enset garden *weesete gate* or *gate*. *Gate* range from .25 to 1.5 hectares (Tesfaye 2008). Gardens contain plants of various ages and sizes as enset takes years to mature. The Sidama language has about ten terms referring to enset age-stages (Quinlan et al. 2014; Tesfaye 2008). Large plants are transplanted closest to the house. Sidama people propagate enset by vegetative cloning, speeding up the naturally very long maturation process. Enset is never propagated by seed as far as we know.

A Sidama dwelling, or *mine*, is a combination house and barn at the edge of the enset garden. It is divided into a salon with a hearth, bedroom(s), and stalls for cattle and goats, all separated by bamboo walls or interior fences (see Figure 2). Sidama build *mine* on a slight slope with the animal stalls on the

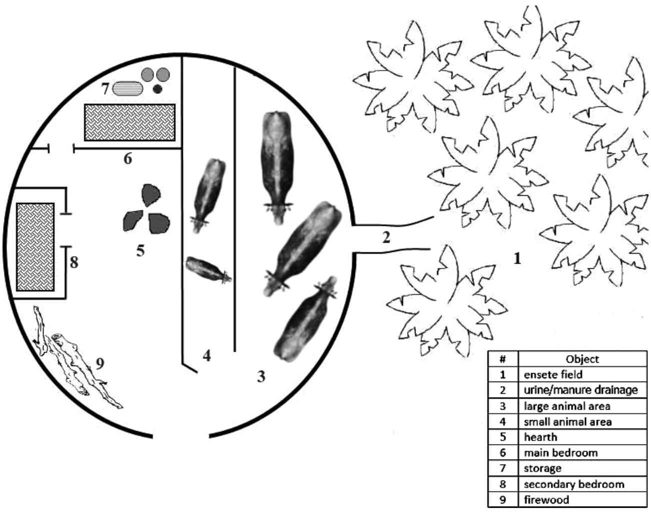

Figure 2. Model Sidama house with livestock and enset garden or *weesete gate*.

downhill side of the house. Floors have small trenches excavated into them, channeling urine outside into the *gate* (Figure 2). Women and children gather manure from the *mine,* yard, and pasture to spread on their gardens.

Sidama harvest enset before or while the plant is flowering. The time from planting to flowering depends on the breed, soil nutrients, and rain. Flowering time ranges from four to ten years. Processing, fermentation, and storage can take as much as three additional years (Quinlan et al. 2014).

Methods

Collaborative Ethnographic Science

Principles of collaborative ethnography (Lassiter 2005) guided our efforts. Lassiter's (2005) collaborative approach developed for public anthropology provides ethical and methodological principles useful for ethnobiology. Our aim was to level power differentials between Sidama people and researchers by facilitating the development of colleagues from southwestern Ethiopia. Sidama and Koore anthropologists (Dira, Sooge, and Assoma) are senior personnel, Hawassa University faculty, and coauthors of this report. Assoma and Dira are also PhD candidates in anthropology at Washington State University. Data from this study have been freely disseminated to researchers at Hawassa University through an integrated data analysis workshop.

There are empirical benefits to this collaboration. The team has advanced skills including field methods, statistical analysis, and native language proficiency. Accuracy of representations is enhanced through a dialectical process among researchers fluent in modes of anthropology and social science. Collaboration makes claims of ''time in the field''—a hallmark of quality ethnography—meaningless: half of the senior personnel are native to Sidama and nearby ''enset culture.''

Washington State University Human Subjects Research Compliance Office, Sidama Zone Administration, and District (*Woreda)* Authorities in Arbegona, Boricha, Lokka Abaya and Hawassa Zuria approved this research. Participants were given a thorough description of the project activities and data use. Verbal informed consent was obtained and all participants were paid 50 Ethiopian birr (~ $3.00 US).

Data Collection

Qualitative data were collected using open-ended ethnographic interviews with key informants and focus groups in four districts of the Sidama Zone. We conducted interviews with individuals and/or groups concerning personal and environmental histories, agricultural practices, inheritance, ethnic and interpersonal conflict, social support, family health, gender relations, intra-community cooperation, etc. All interviews were conducted in Sidama by native speakers. Interviews were translated into English for the benefit of non-Sidama speaking project personnel (Quinlan et al. n.d.).

Quantitative data were collected by oral self-report questionnaires concerning household demography, health, and production. The instrument included over 200 items yielding a range of data for comparison with other East African social and economic studies. The interviewers were five Sidama research assistants, four of whom had university degrees, and three of whom had prior survey research experience. The research assistants received the instrument in English and Amharic, then the research assistants and authors developed appropriate Sidama translations together. The authors field-tested the Sidama language instrument. Then, the assistants received one week of training in instrument administration. During the first week of data collection, assistants worked in teams of two supervised by senior personnel to ensure uniformity in instrument administration. These surveys took 30 to 90 minutes to complete.

We created a judgment sample of four Sidama districts (*woreda*) representing a range of ecological and economic variation in the Sidama Zone (detailed below). Each Sidama assistant was randomly assigned a different *kebele* (neighborhood), within which they obtained a convenience sample. The assistants recruited participants as they encountered adults while walking main neighborhood footpaths. We set a target sample size of 100 for each district. When we reached that target we moved on to the next *woreda*. This sampling method was chosen to facilitate rapid pilot data collection. Random sampling would have dramatically increased research time and expense. We were unable to reach the target sample in Lokka Abaya. Heightened ethnic tension between Sidama and neighboring Wolayta people posed an unacceptable risk for the research team, and we terminated data collection after interviewing 72 Lokka Abaya farmers. Given five data collectors and randomly assigned neighborhoods, we do not believe our sampling method introduced systematic bias. We do not claim that our analyses represent precise population estimates; however, these data are suitable for examining effects on production, risk, and resilience in the Sidama Zone. These analyses offer a foundation and guide for future research.

Analysis

Dependent variables include (1) self-reported yields (kg) produced from enset and maize farms; (2) estimated energy (kcal produced per person per day), calculated from the total reported production in kg divided by 365 days and the number of household residents, then multiplied by 2110.37 for enset and 3749.91 for maize following estimates in Tsegaye and Struik (2001:90); (3) major recent crop failure (1=lost 50% or more of a crop in last seven years, 0=did not lose 50% or more of a crop in last seven years); and (4) self-reported time to recovery from crop failure in years for which participants were asked to indicate whether the household was worse off, better off, or the same as before the crop failed.

Independent variables include the following: (1) *woreda* (district) indicators (Arbegona, Boricha, Lokka Abaya or Hawassa Zuria); (2) self-reported hectares planted; (3) fertilizer expense for the last year; (4) number of cattle owned (other livestock were recorded but cattle are of primary importance); and (5) primary and secondary crop indicators (maize only, enset only, enset primary and maize secondary, and maize primary and enset secondary).

Our analysis strategy includes descriptive statistics to characterize farming in different districts of Sidama Zone, followed by multivariate analyses using General Linear and Linearized Models (GLM). For Ordinary Least Squares (OLS) regression the dependent variables were log transformed to normalize residuals, as required by assumptions of OLS regression. Residuals for raw dependent variables were not normal; however, log transformation approximated a normal distribution. Diagnostics were conducted for multicolinearity, outliers, heteroscedasticity, non-linearity, etc. All analyses conformed to model assumptions. In one analysis, dependent variables had extreme outliers so values were Winsorized by recoding the highest value (i.e., the outlier) to the next highest value (discussed below). Interaction effects entered the analysis for variables suggested by Sidama cultural models of enset and maize agriculture. Alpha was set at 0.05. Non-significant interaction effects were removed from the models. There were insufficient sample sizes for some categorical variables; hence, some categories were combined. Recommended n/k (sample size/independent variables) was greater than 10. For analyses of production, households that produced no crops, a small fraction of the sample, were excluded from the analysis. For several models we predicted production estimates for log-transformed variables using the following back-transformation: $Y = e^{\beta_0 + \sum \beta_n x_n + \frac{\sigma^2}{2}}$ Here β_0 is the constant, $\sum \beta_n x_n$ is the summed products of variable values and regression coefficients, and $\frac{\sigma^2}{2}$ is half of the model Mean Squared Error.

Sidama Study Sites

We selected four districts for study: Arbegona in the Sidama highlands, Boricha straddling the midlands and lowlands, Lokka Abaya in the lowlands, and Hawassa Zuria in the peri-urban zone of Hawassa City, the capital of SNNPRS. These site descriptions are based on available records and interviews regarding local history and livelihood conducted by Sooge, Dira, Assoma and Quinlan between 2011 and 2014.

Arbegona *woreda* (home to the Harbee and Harbagona clans) is located 74 kilometers from Hawassa in the highland east of the Sidama Zone on the Oromia state border. In the 2007 national census, Arbegona's population was 144,300 with about 95% living in rural areas, and a population density of 405.1 people per km^2 (CSAE 2013). The majority of the population practices mixed subsistence agriculture. Coffee and chat, major cash crops in Sidama, are rare in Arbegona. Arbegona receives substantial rainfall (up to 2500 mm in long rainy seasons from June to September). At approximately 2600 m above sea level, Arbegona is wet and cool. The highland climate has buffered Arbegona from the drought experienced elsewhere in the Sidama Zone in recent history. However, Arbegona was at the center of an armed conflict through much of the 1980s as the Sidama Liberation Movement rebelled against the Derg Regime (Quinlan et al. n.d.). Many consider Arbegona and other highland areas to be archetypical landscapes of the Sidama Zone.

Boricha (homeland of the Yanase Clan) is a densely populated *woreda* in the center of the Sidama Zone, 39 kilometers south of Hawassa. The 2007 population of Boricha was 250,260 with a density of 382 people per km^2 (CSAE 2013). Elevation ranges between 560 and 1700 m above sea level with bimodal rainfall, from 56 mm (March–May) to 180 mm (June-October). Annual temperature varies from 20–33 °C (Boricha Woreda Rural Development Coordination Office 2005). Sugarcane (*Saccharum*), chat, and coffee are major cash crops in the area. Boricha has a recent history of periodic drought leading to famine in years 1998–99, 2001, 2003 and 2008. Multiple key informants report that before the mid-1970s, rains were reliable and sufficient from year to year in the area. However, the long and most important rains (March to May) have been delayed or absent periodically (Quinlan et al. n.d.). Local people used to get water from natural springs and traditional ponds until the 1999 drought, which caused water from all sources to dry up. In some villages there are standpipes and wells; however, most people in rural areas buy drinking water from a distance supplied by donkey carts. Boricha was the site of relief efforts, including food and agricultural aid, in recent years.

Lokka Abaya is a lowland *woreda* at the western border of the Sidama Zone located at about 50 kilometers southwest of Hawassa. The Lokka Abaya district population was 99,233 in 2007 (CSAE 2013). The topography is flat with a gentle downhill gradient from east to west towards the Bilate River. The altitude ranges from 560-1700 m above sea level. This is a low rainfall area with an erratic pattern during the two rainy seasons: The *belg* (February to April), and the *kiremt* rains (July to early October). The temperature ranges from 26–33 °C (USAID 2005). The soil type is mainly gray sandy loam and it is susceptible to erosion. The district's recent drought history is similar to Boricha's. In addition, Sidama people of Lokka Abaya experience periodic conflict with neighboring Wolayta people (Aalen 2011). People in Lokka Abaya also pay for water delivery.

Hawassa Zuria *woreda* is along the shores of Lake Hawassa; it is within less than an hour bus commute to Hawassa City. The administrative center, Dore Bafeno, is 18 kilometers from Hawassa. The population was 124,472 in 2007 (CSAE 2013). The average elevation is 1700 m above sea level with a mean annual rainfall ranging from 900 to 1400 mm. March to September is the rainy season. Mean annual temperature varies from 23 to 27 °C (EOSA 2007). Soil is sandy and

Table 1. Proportion of enset and maize as primary crops in Sidama Zone.

	Arbegona	Boricha	L. Abaya	H. Zuria
Total N	114	105	72	122
N maize only	2	13	6	73
Proportion maize only	**0.02**	**0.12**	**0.08**	**0.60**
N enset only	77	44	21	15
Proportion enset only	**0.68**	**0.42**	**0.29**	**0.12**
N maize-enset[a]	0	5	9	11
Proportion maize-enset	**0**	**0.05**	**0.13**	**0.09**
N enset-maize[b]	34	42	36	22
Proportion enset-maize	**0.30**	**0.40**	**0.50**	**0.18**
Total %	100%	99%	100%	99%

[a] Maize-enset = maize primary crop with enset secondary
[b] Enset-maize = enset primary crop and maize secondary

prone to water and wind erosion. There is no river in the district. Drinking water is in short supply and many residents pay for water delivery.

Results

Sidama Farm Production

Across four *woreda*, 71% of Sidama households indicated that enset was their primary crop. Twenty-seven percent indicated that maize was primary, with the remainder growing coffee, chat, carrot or cabbage. Seven households (1.7% of the sample) with crops other than enset or maize primary were excluded. Secondary crops were diverse: 33% indicated that maize was their secondary crop, less than 8% indicated that enset was their secondary crop, and 44% did not indicate a second crop.

The proportion of enset and maize grades from predominantly enset cultivation in Arbegona to predominantly maize in Hawassa Zuria (Table 1). Arbegona and Hawassa Zuria appear to specialize in one crop. Enset as the primary crop with maize secondary is common in all four districts. Maize primary with enset secondary is uncommon. Boricha and Lokka Abaya have the most diversity in farms; however, enset is the primary crop in a plurality of households.

Sidama stress that land shortage and associated food insecurity is a serious concern, even in the highlands. Traditional land tenure requires that a man divide his land equally among his sons. In the 1970s the communist Derg regime instituted land reforms whereby an individual could only possess ten ha. Larger holdings were redistributed. Technically, all land belongs to the state, and the accumulation of land has been minimal. Since redistribution, the pattern of inheritance resulted in small landholdings. As one Boricha man reported: ''Now plots are too small. We don't have enough for ourselves. We even fight with the birds to protect our crops.'' Another informant in Arbegona said that Sidama need four to five hectares for crops and grazing to make a comfortable living, yet mean landholding in Arbegona is 2.6 hectares (the most) compared with 1.7 hectares in Hawassa Zuria (the least) (see Figure 3). Land shortage is a cause for interpersonal and interethnic conflict. When asked if there are conflicts over land,

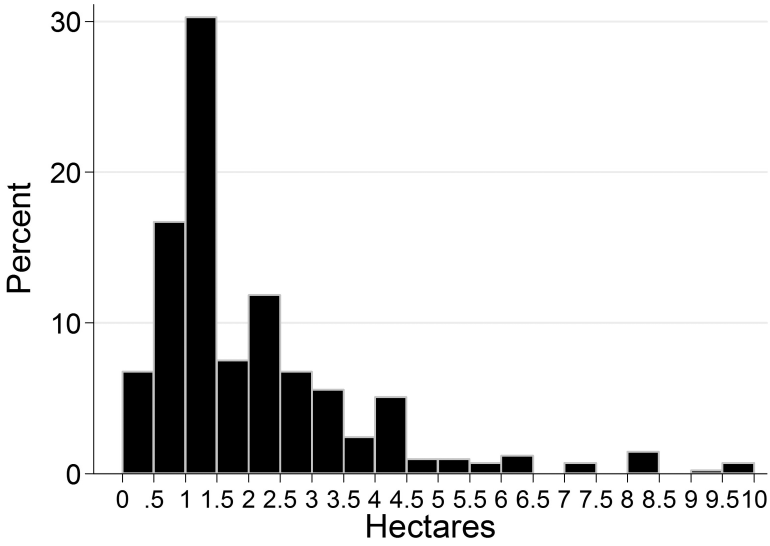

Figure 3. Average crop and grazing landholdings in Sidama Zone. Hectares include land for crops and grazing.

a woman in Boricha responded, ''Many! Even brothers from the same mother argue over land…if it is just a small argument, then the father will settle the argument. If there is harm…if there is bleeding or violence, then the law will settle the matter.'' Armed conflict over land between neighboring Oromo to the east and Wolayta to the west is not uncommon (Aalen 2011). Hence, choice of crops, land management, and productivity are key concerns for Sidama people.

Hectares planted varied from .98 in peri-urban Hawassa Zuria to 1.64 hectares in highland Arbegona (Table 2). Boricha *woreda* showed the most variation in planted area with a coefficient of variation (CV) more than three times that of Hawassa Zuria, the second most variable district. The self-reported data did not permit precise estimates of hectares planted for each crop, but the predominance of enset and maize in the Sidama Zone is economically salient. More precise land use and production estimates would be useful.

The productivity of Sidama farms depends on location and crop (Table 3). The most productive farms in Hawassa Zuria yield over 1100 kg/ha combining maize with secondary enset. These mixed farms, however, show huge variation in production and they are scarce: less than 9% of farms sampled. The least productive farms are also in Hawassa Zuria where enset only produces 117 kg/ha.

Table 2. Area of crops planted by *woreda*, in hectares.

District	Mean	SD[a]	CV[b]
Arbegona	1.64	1.00	0.61
Boricha	1.36	3.59	2.64
Lokka Abaya	1.07	0.61	0.57
Hawassa Zuria	0.98	0.75	0.77

[a] Standard deviation
[b] Coefficient of variation

Table 3. Productivity of enset and maize across the Sidama Zone.

	Arbegona	Boricha	Lokka Abaya	Hwa Zuria
Maize only				
kg/ha	168	279	499	884
SD[a]	26	376	482	726
N	2	13	6	73
Proportion	0.02	0.12	0.08	0.60
Enset only				
kg/ha	460	220	183	117
SD	884	143	170	66
N	77	44	21	15
Proportion	0.68	0.42	0.29	0.12
Maize-enset				
kg/ha		2275	533	1195
SD		2440	625	1364
N	0	5	9	11
Proportion	0.00	0.05	0.13	0.09
Enset-maize				
kg/ha	476	487	466	872
SD	474	435	731	709
N	34	42	36	22
Proportion	0.30	0.40	0.50	0.18

[a] Standard deviation

Fertilizer and manure are important for crop production. Enset relies on manure from cattle to enhance productivity. Hence, cattle ownership and enset production are intimately intertwined. Milk and butter are key ingredients for *raisame*, a thick *waasa* porridge and staple food. Cattle ownership varies (Table 4). Farmers in Arbegona own the most cattle (mean = 3.4), farmers in Boricha own the least (mean=1.6). When crops fail, farmers sell livestock to purchase food; hence, periodic drought in Boricha may explain the low number of cattle per household.

According to key informants, maize productivity can be increased by 100% by using chemical fertilizer—50 kg of chemical fertilizer (one bag) can double the output of a half hectare of maize. Sidama informants indicated that the chemical fertilizer price was a constraint on maize productivity. Fertilizer was approximately 60 birr for 50 kg in 2000, but increased to 800 birr by 2012. Price hikes put chemical fertilizer out of reach. Variation in maize productivity and fertilizer exacerbated famine in Boricha in 2003. Sidama described a bumper 2001 maize crop that caused a severe price decline, resulting in maize being less attractive in

Table 4. Cattle owned and fertilizer expense among Sidama farms.

	Cattle			Fertilizer expense		
District	**Mean**	**SD[a]**	**CV[b]**	**Mean**	**SD**	**CV**
Arbegona	3.4	3.7	1.1	79.5	197.6	2.5
Boricha	1.6	1.5	1.0	141.0	262.1	1.9
Lokka Abaya	1.8	1.4	0.8	409.7	363.9	0.9
Hawassa Zuria	2.2	3.2	1.5	382.4	334.0	0.9

[a] Standard deviation
[b] Coefficient of variation

Table 5. OLS regression of productivity of Sidama farms in log kg of harvested crops.

	Model 1	**Adj R^2=.02[a]**	**Model 2**	**Adj R^2=.14**	**Model 3**	**Adj R^2=.20**	**Model 4**	**Adj R^2=.22**
Log kg crops produced[b]	B	p	B	p	B	p	B	p
Hectares of crops	0.056	0.129	0.022	0.526	0.019	0.562	0.161	0.013
Enset only	-0.408	0.018	-0.215	0.214	-0.010	0.958	-0.161	0.443
Maize-enset	0.156	0.589	-0.208	0.450	0.067	0.807	0.126	0.645
Enset-maize	0.046	0.791	0.019	0.907	0.308	0.094	0.309	0.097
Fertilizer expense in Birr			0.001	0.000	0.001	0.000	0.001	0.001
Winsorized cattle			0.208	0.000	0.153	0.000	0.115	0.006
Boricha					-0.623	0.000	-0.499	0.005
Lokka Abaya					-0.752	0.000	-0.615	0.002
Hwa Zuria					-0.025	0.901	0.044	0.825
Boricha X hectares planted							-0.372	0.001
Hwa Zuria X hectares planted							-0.341	0.053
Enset only X fertilizer							-0.001	0.044
Constant	5.715	0.000	5.069	0.000	5.262	0.000	5.086	0.000

Note: Farmers who lost their entire crop or who did not plant enset or maize in the most recent year are excluded.
[a] Adj R^2= R-squared adjusted for the number of variables
[b] B=unstandardized regression coefficient adjusted for covariates; p=significance for B

following years. Price increases in nitrogenous fertilizers associated with oil price increases (Wright 2011) following the Multi-National Force Iraq War, coupled with declines in maize prices, set the scene for food insecurity to follow. By 2012 the average expense for chemical fertilizer in our sample's most maize-dependent district (Hawassa Zuria) was 382 birr (Table 4), not enough to fertilize a quarter hectare of maize.

We used OLS regression analysis to model productivity of Sidama crop configurations (Table 5). We are especially concerned with effects of cattle (as a proxy for manure input) and chemical fertilizer expense on production. Enset yielded the least per year compared with maize farms (Model 1; Table 5). This is a counterintuitive result given previous agricultural studies showing high enset output per meter-squared (Pijls et al. 1995; Tsegaye and Struik 2001). A farmer can grow many enset plants on a small plot, but slow maturation means only a portion of enset grown is harvested in a year. In comparison, an entire maize crop is harvested per season. One hectare of maize produced about 120 kg more per year than did one hectare of enset averaged across districts (Model 1; Table 5). Chemical fertilizer and manure inputs fully mediate this production difference (Model 2; Table 5). Differences in production were not statistically significant after controlling for soil nutrient inputs. Manure from a single cow increases production by about 40 kg per hectare, while 100 birr of fertilizer increases production by about 17 kg per hectare. This corroborates our qualitative analysis: 800 birr of fertilizer, the cost of 50 kg, increased production by 76% for .5 ha of maize.

There are significant productivity differences geographically (Model 3; Table 5). Boricha and Lokka Abaya produced significantly less than Arbegona or

Table 6. OLS regression for log kg produced in four districts.

Woreda	Arbegona	N=98	Boricha	N=89	L. Abaya	N=72	H. Zuria	N=115
log kg crops produced[a]	**B**	**p**	**B**	**p**	**B**	**p**	**B**	**p**
Hectares of crops	0.217	0.199	-0.005	0.892	0.168	0.399	0.123	0.231
Enset only			0.626	0.122	-0.021	0.954	-0.711	0.005
Enset-maize			0.956	0.022	0.324	0.245	0.370	0.057
Maize-enset			1.899	0.021			0.412	0.106
Fertilizer expense in birr	0.000	0.672	0.002	0.002	0.001	0.099	0.001	0.000
Winsorized cattle	0.279	0.012	-0.053	0.574	0.182	0.042	0.022	0.638
Constant	4.716	0.000	4.303	0.000	4.471	0.000	5.358	0.000
	Adj R^2 =.12[b]		Adj R^2 =.20		Adj R^2 =.14		Adj R^2=.37	

Note: Farmers who lost their entire crop or who did not plant enset or maize in the most recent year are excluded.
[a] B=unstandardized regression coefficient adjusted for covariates; p=significance for B
[b] Adj R^2= R-squared adjusted for the number of variables

Hawassa Zuria; this is noteworthy because Arbegona farmers specialize in enset while Hawassa Zuria farmers specialize in maize. Farms in Boricha were less productive per hectare and enset production did not improve with chemical fertilizer inputs (Model 4; Table 5). Results for Boricha may reflect erosion and soil depletion—targeted intervention areas for NGOs in Boricha. ''Hectares planted'' was only a significant predictor in Model 4, suggesting two conclusions: (1) production per hectare is variable across the districts, and (2) there is little variation in farm size. Many Sidama farms have been subdivided to minimal size over generations of partitioning for inheritance among sons.

Cattle are associated with improved enset production. In Arbegona, there was no significant difference between farms growing only enset and those that also grew maize as a secondary crop; hence, they were not distinguished in the model. There were too few maize farms in Arbegona to indicate in analyses. In Arbegona the number of cattle was the only significant predictor of enset production—cattle increased productivity (Table 6). This result corroborates the Sidama ethno-agricultural model of enset management where production depends on manure inputs. The interaction between cattle and hectares planted was not a significant predictor of enset production in Arbegona; likewise, small stock and total TLU (biomass adjusted measure of mixed livestock) were not significant predictors of production.

Sidama indicated that people need about five cattle to fertilize a good enset crop. Given densely populated territory and perceived land shortage, we expected the average number of cattle in Arbegona of 3.4 is optimal for the enset complex. We treated number of cattle owned as a reference-coded variable indicating a threshold herd size for enhanced enset production. Owning one or two cows was not a significant improvement over none, though a trend toward improved production is apparent (Table 7). Three cows, however, offered a significant improvement in enset production. Each cow beyond three provided little additional benefit, suggesting the mean of 3.4 in Arbegona may be optimal given land constraints.

Table 7. OLS regression with cattle as reference-coded variable.

Arbegona N=98		
log kg crops produced[a]	**B**	**p**
Hectares of crops	0.240	0.165
Fertilizer expense in birr	0.000	0.616
Cattle (0=reference) 1	1.320	0.107
2	1.574	0.054
3	2.002	0.013
4	2.151	0.017
5+	2.146	0.011
Constant	3.721	0.000
	Adj R^2=.11[b]	

Note: Farmers who lost their entire crop or who did not plant enset or maize are excluded.
[a] B=unstandardized regression coefficient adjusted for covariates, p=significance for B
[b] Adj R^2= R-squared adjusted for the number of variables

Mixed crops of enset and maize outperformed farms with only enset or maize in Boricha (Table 6). Maize as the primary crop with enset as a secondary crop appears to be the most productive farm configuration. Residents of Boricha claim they need enset and maize to survive there. Fertilizer expense was associated with increased productivity in Boricha, but cattle owned was not. The lack of effect of cattle on production in Boricha may reflect the smaller grazing area and enset pruning to feed cattle. Excessive pruning reduces enset's productivity (Tsegaye and Struik 2001). Given pasture shortage in Boricha (.37 ha vs. 1 ha in Arbegona), enset trimmings are an important fodder that may lead to excessive pruning.

In Lokka Abaya, cattle owned was the only predictor of production and there were no differences between crop configurations, nor was there any threshold effect for cattle owned as in Arbegona.

Hawassa Zuria was the least enset dependent *woreda*. Enset by itself performed poorly in Hawassa Zuria, and fertilizer inputs were significantly associated with farm productivity.

Arbegona and Lokka Abaya showed little predictable variability with low r-square values (.12 and .14 respectively compared to .20 and .37 for Boricha and H. Zuria). If ''unpredictable variability in the outcome of an adaptively significant behavior'' (Winterhalder and Leslie 2002:61) is an important component of risk, then Arbegona and Lokka Abaya may be the most vulnerable agricultural environments in the Sidama Zone. This approach to risk, proposed for analyses of fertility, may be poorly operationalized for subsistence agriculture because it does not account for differences in probability of failure across environments.

Productivity measured in kilograms disregards nutrient values. Tsegaye and Struik's (2001) agricultural experiments on enset production indicated 883 kj/100 g of energy from enset, compared to the 1569 kj/100 g published values for maize (2110 kcal/kg of enset vs. 3750 kcal/kg of maize). We used this conversion rate to estimate kilocalories/person/day. We multiplied kg produced by kcal values for enset and maize, divided that by 365 days, and then divided that value by the number of people living in the household to estimate *per capita energy production*. The natural log of kcal/day/person normalized model residuals.

Table 8. Average kcal/day/person in four districts.

		Total	Maize	Enset	Maize-enset	Enset-maize
Arbegona	Mean	784	251	654		1127
	SD[a]	876	191	762		1054
Boricha	Mean	441	114	294	889	612
	SD	667	133	364	956	863
Lokka Abaya	Mean	616	1304	292	726	663
	SD	848	1520	387	1095	787
Hawassa Zuria	Mean (wins.)	1151 (1077)	1151	240	2529 (1719)	1082
	SD	1827 (1274)	1269	158	4914 (2316)	671

Note: values in parentheses are Winsorized (see text).
[a] SD = standard deviation

Analyses are not weighted for age and sex of household members, but rather estimate energy per person.

The average Sidama farm produces about 785 kcal/day/person from enset and maize (Table 8). Maize primary and enset secondary farms in Hawassa Zuria have the greatest energy production, but there is huge variation (CV=1.94). This CV is due largely to one farm that produced more than 17,000 kcal/day/person. (We Winsorized this value to the next highest value of 8219 kcal/day/person to reduce its influence on the models.) Maize-only farms in Hawassa Zuria and enset primary and maize secondary farms Arbegona and Hawassa Zuria yield roughly equivalent energy per capita. Farms growing only enset produced significantly less kcal/person than maize farms. Mixed farms were not significantly different from maize-only farms (Model 1; Table 9). Nutrient inputs significantly increased kcal production (Model 2; Table 9). Controlling for geography, Lokka Abaya and Boricha produced significantly less kcal/person/day than did Arbegona; there was no difference between Arbegona and Hawassa Zuria (Model 3; Table 9). This suggests that the predominant crops for Arbegona and Hawassa Zuria are a good fit for the local environments. Interaction effects indicated differences in kcal/ha in Boricha, where farms appear to be significantly less productive per hectare than in other *woreda*s (Model 4; Table 9). The effect of cattle was mediated by interaction effects. In the final model (Table 9), enset-only farms produced significantly less energy than maize-only farms, and mixed maize-primary/enset-secondary farms produced significantly more energy per capita.

After back transformation, Model 4 (Table 9) gives predicted energy production. The maximum predicted value is approximately 1623 kcal/person/day for farms of one hectare with maize as the primary crop in Hawassa Zuria with roughly 380 birr worth of fertilizer and manure from 2.2 cows. The least productive farms in Boricha, growing 1.3 hectares of enset-only, produced about 334 kcal/person/day with 1.6 cows and 140 birr worth of fertilizer (the means for Boricha). This estimate may reflect the near-famine conditions recurring in Boricha. Energy intake values do not include food from other sources such as food aid, gifts, purchased foods, etc. Indeed, 45% of our Boricha sample reported receiving food aid in the last year. Average enset-only and mixed enset-maize farms in Arbegona with 3.4 cows and 79 birr of fertilizer produced about 690 and 1250 kcal/day/person, respectively. Our energy

Table 9. Multiple linear regression showing log kcal/day/person for enset and maize.

N=393	Model 1		Model 2		Model 3		Model 4	
Log kcal/day/person[a]	B	p	B	p	B	p	B	p
Hectares of crops	0.053	0.196	0.021	0.601	0.015	0.705	0.196	0.010
Enset only	-1.030	0.000	-0.776	0.000	-0.487	0.033	-0.570	0.013
Maize-enset	-0.203	0.517	-0.512	0.096	-0.171	0.576	-0.121	0.689
Enset-maize	-0.302	0.113	-0.274	0.137	0.096	0.650	0.026	0.902
Fertilizer expense in birr			0.001	0.000	0.001	0.000	0.001	0.000
Winsorized cattle			0.076	0.001	0.045	0.056	0.020	0.423
Boricha					-0.722	0.000	-0.660	0.001
Lokka Abaya					-0.815	0.000	-0.723	0.001
Hwa Zuria					-0.001	0.997	0.090	0.683
Boricha X hectares planted							-0.301	0.005
Constant	6.450	0.000	5.967	0.000	6.079	0.000	5.906	0.000
Adj. R^2 [b]	0.08		0.15		0.21		0.22	

Note: Production of calories was winsorized for one farm with very high production with nearly twice the next highest level of calorie production. Farmers who lost their entire crop or who did not plant enset or maize in the most recent year are excluded.

[a] B=unstandardized regression coefficient adjusted for covariates; p=significance for B

[b] Adj R^2= R-squared adjusted for the number of variables

estimates compare to 880 kcal/day/person from enset (1100 kcal total) from a study of the Gurage people 200 km north of Sidama (Pijls et al. 1995).

Crop Failure and Resilience

Analysis of productivity suggests crops respond to different highland, lowland, and peri-urban environments with different nutrient inputs. We examined the probability of recent crop loss for farm configurations in different environments. We asked whether the household lost 50% or more of crops in one season in the last five years. If they reported a loss, they were asked when the loss occurred. Thirty-nine percent of our Sidama sample reported a recent crop loss. Lokka Abaya and Hawassa Zuria were the riskiest environments, with 57% reporting a loss in Lokka Abaya and 51% in Hawassa Zuria, followed closely by Boricha at 48% (Table 10). Arbegona had a low risk of crop failure at only 3%. In all *woredas* except Hawassa Zuria, enset only is the least risky farm configuration with five-year loss at 24%. In Hawassa Zuria farming only enset is high risk with 80% of enset farmers reporting crop loss (Table 10).

Farming in Hawassa Zuria is risky, but potential for high productivity is substantial. Farming in Arbegona offers high yields and low risk. We return to risks and returns in the discussion section.

Finally, we examined ''engineering resilience'' of farm configurations. Engineering resilience is time from crop loss to full recovery or the time it takes a variable ''displaced from equilibrium'' to return to it (Pimm 1991). Given the cross-sectional nature of our data, we cannot measure return to pre-shock conditions precisely. We used a self-reported measure of household well-being as a proxy. Participants reporting crop loss were asked to indicate whether the household was worse off, better off, or the same now as before the crop loss. Farmers reporting the same or better subjective household conditions were coded

Table 10. Proportion of farms reporting a loss of 50% or more of crops in the recent past.

	Maize	Enset	Maize-enset	Enset-maize	Total
Farms in Arbegona	2	77	0	34	113
Proportion lost half or more crops	0.00	0.01		0.06	0.03
Farms in Boricha	13	44	5	42	104
Proportion lost half or more crops	0.54	0.36	0.60	0.57	0.48
Farms in Lokka Abaya	6	21	9	36	72
Proportion lost half or more crops	0.50	0.38	1.00	0.47	0.51
Farms in Hawassa Zuria	73	15	11	22	121
Proportion lost half or more crops	0.49	0.80	0.36	0.81	0.57

''recovered.'' We used hazard analyses and Kaplan-Meier failure functions to model resilience of farm configurations. A Hazard Ratio (HR) is interpreted similarly to an odds ratio in logistic regression: HR $>$ 1 indicates a greater ''instantaneous likelihood'' of an event. Here the event is recovery from crop loss, and the HR models the likelihood of recovery per year. We used maize farms in Boricha as the reference category. Farms in Hawassa Zuria were more resilient and 296% (HR=3.96) more likely to have recovered from crop loss (Model 1; Table 11) compared with maize only in Boricha. The Kaplan-Meier plot shows that about 85% of farms in Hawassa Zuria recovered in four years compared to 26% in Boricha. Only 50% of Boricha farms recovered after six years (Figure 4). Boricha and Lokka Abaya were not significantly different. Geographic differences, however, were mediated by farm configuration: enset farms were significantly less likely to recover than were maize farms independent of district (HR = 0.16 and 0.14 for enset and enset-maize farms, respectively). The Kaplan-Meier Plot shows nearly 100% of maize farms recovered in four years, whereas only about 50% of enset farms recovered in six years (Figure 5). About 60% of maize farmers reported recovering in three years or less. No doubt, these differences reflect the long life cycle and processing time for enset compared with maize. There appear to be potentially complex trade-offs in productivity, risk, and resilience for Sidama farmers. Under the right circumstances, enset is as productive as maize and less prone to crop loss, but enset has a much longer recovery time.

Changing Values

Qualitative interviews in Boricha (conducted by SJD and AS) show how enset and maize have become complementary staples in some areas. Yet farmers

Table 11. Hazard ratios for return to pre-shock household condition.

	Model 1		Model 2	
n=119	**HR[a]**	**p[b]**	**HR**	**p**
L. Abaya	1.573	0.596	0.989	0.991
H. Zuria	3.960	0.009	1.422	0.598
Enset only			0.156	0.021
Enset				
Maize			0.135	0.006

Note: Maize farm in Boricha is the reference category. Farms in Arbegona were excluded from this analysis as there were too few reporting recent crop loss to include them as a separate category.

[a] HR=hazard ratio

[b] p=significance

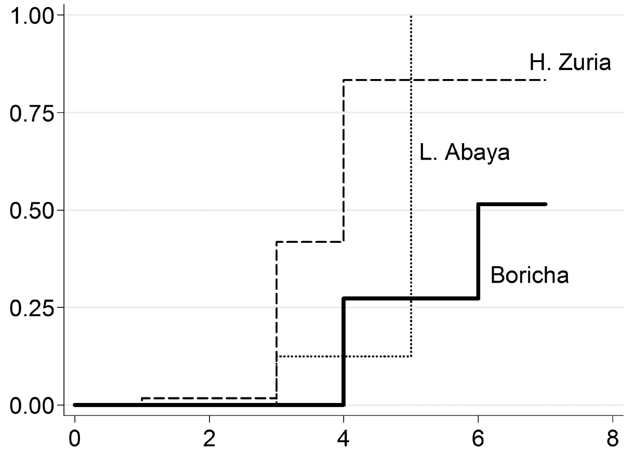

Figure 4. Kaplan-Meier plot of resilience by Sidama District. The horizontal axis indicates years, and the vertical axis indicates the proportion of the sample recovered. Boricha is the solid line and reference category for hazards analysis in Table 12. Dotted line indicates Lokka Abaya, and the dashed line indicates Hawassa Zuria.

growing both enset and maize typically claim enset is their primary crop, even when they produce more maize. More than 20% of Sidama farmers reporting enset as their most important crop harvest more maize than enset. Controlling for recent crop loss reduces probability of a mismatch between perception and production at about 10% (analysis not shown).

According to older Sidama, enset is the life of Sidama people: by-products from enset are important for rope for tethering animals and for house construction. Many people still use dried enset leaves and fiber for mattresses. Enset leaves serve as wrap and plates for food. Dry remains of harvested plants

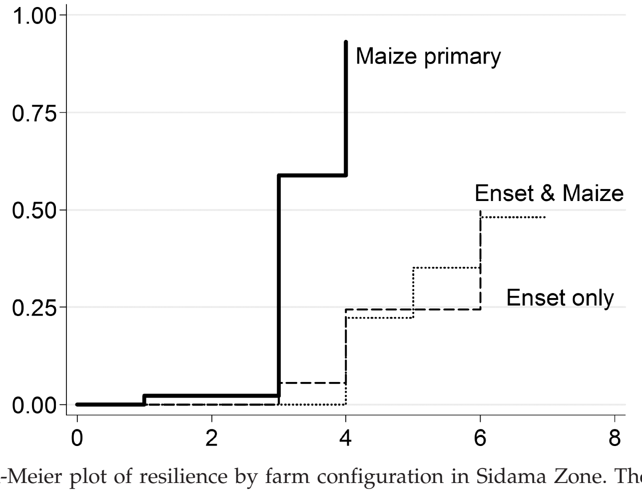

Figure 5. Kaplan-Meier plot of resilience by farm configuration in Sidama Zone. The horizontal axis indicates years, and the vertical axis indicates the proportion of the sample recovered. Maize farms are indicated by the dashed line, which is the reference category for Model 2, Table 12. Dashed and dotted lines indicate enset and mixed enset-maize farms, respectively.

are used for cooking fuel during the dry season. Sidama claim that enset maintains soil nutrients much better than other crops. Enset is a sign of household beauty, and a symbol of respect for the family.

Every Boricha informant in 2014, 34 adults (20 male) and 30 adolescents (15 male), reported that enset is crucial for survival during droughts. Sidama can store enset much longer than any other crops they grow, and people agree that *wasa* quality increases with age. *Wasa* can keep for three years, and the growing plant stores energy that Sidama can either use when needed or leave to mature. Sidama consider women who save *wasa* for a long time to be wise, and their families will survive difficult times better than one who saves other crops.

Despite the recognized enset advantages, most Boricha farmers report that enset takes only a third of their farmland; maize and cash crops occupy the remainder. People give different reasons for diversification. Some say other crops provide more cash for expenses for school, medicine, clothing, taxes, and emergencies. Maize can be planted and harvested within a year. Other Sidama mentioned a need for diet diversity: adults in Boricha said that *wasa* alone does not provide enough energy, and maize provides fuel for hard work.

All Boricha adolescents report that they prefer to eat maize over *wasa*. Adults report that adolescent sons consider farming enset a backward practice; they prefer cash crops. Some adults report that adolescents do not know how to grow enset. Lately, some Boricha parents eschew Sidama traditional land inheritance rules by giving a small plot to their unmarried sons for chat production.

These factors contribute to the decline of enset farming in Boricha. However, some people indicated a recent trend towards expanding enset cultivation in the wake of recurring drought and crop failures. Sidama people typically do not sell enset products, but that may be changing.

Efforts at marketing enset products is afoot in the region (Assoma n.d.). Neighboring Koore farmers bring surplus enset by-products (*bull'a*) to local markets for sale to middlemen who distribute it. This trade created new value-chain networks for enset. Urban Ethiopians are gaining appreciation of enset as a variant of national cuisine (Geda 2009).

Discussion and Conclusion

Ethiopians sometimes claim that enset farmers do not experience famine, even during the worst Ethiopian famines (Brandt et al. 1997). Lay people and researchers attribute this reduced vulnerability to the heartiness of the enset plant, which can withstand dry periods of several months (Brandt et al. 1997; Karlsson et al. 2013; Mohammed et al. 2013; Rahmato 1995; Shack 1971; Shigeta 1990). Perhaps the highlands, where enset grows best, are not as drought-prone as other areas. While drought is rarely a concern to highland enset farmers, it is a primary concern for mid- and lowlanders.

The benefits of enset appear highly dependent on local conditions. Highland Arbegona appears to behave as expected of the model enset environment: crop loss is infrequent, production is high, and the statistical relationship between cattle and enset production conforms to the Sidama cultural model of enset-cattle-human interdependence. In Hawassa Zuria, however, enset farms produce little, have a high risk of crop loss (80%, Table 10), and a long recovery time compared with maize farms. Yet 30% of farms in Hawassa Zuria grow enset as the primary crop. Enset farms may persist in Hawassa Zuria, because of the high cultural value placed on enset farming and *waasa* as a traditional food. Hawassa Zuria farmers, furthermore, may persist in dedicating substantial portions of their farming to enset because they believe it to be drought resistant, following local cultural models. As the archaeological record indicates with maize adoption in eastern North America (Gremillion 1996; Hart 1999), and as Winterhalder and Goland (1997) predict for agricultural change, a significant lag appears between cultural models, farming practices, and climate change, leaving some Sidama farmers at risk. Sidama say the annual rainfall has changed substantially in 40 years, especially at lower elevations. Prior to the mid-1970s rain was reliable and sufficient. In terms of social-ecological systems theory, we may be witnessing shift in a ''basin of attraction'' or ''regime'' (Walker et al. 2004) from enset farming to maize farming as a central feature of Sidama livelihood in Hawassa Zuria.

Diversity may promote resilience in social-ecological systems (Elmqvist et al. 2003). Biodiversity is a key for sustainable food security (FAO 2008; Kuhnlein 2014). We show that crop diversity may improve resilience at a regional geographic scale—across the entire Sidama Zone. However, within districts, the evidence is equivocal for the importance of diversity in staples. The best-producing farms in our analysis were in Arbegona (specializing in enset) and Hawassa Zuria (specializing in maize). In one district out of four, Boricha, mixed enset and maize farms out-performed single crops *in production, but not in risk of crop loss*. There may be substantial benefits to ''bet hedging'' by growing multiple crops; however, *diversity may not contribute more to resilience than a good fit between the local environment and a single crop*.

Ethnobiology focuses on traditional subsistence practices as the foundation of adaptive adjustment (Braje and Rick 2013; Lepofsky and Feeney 2013; Nolan and Pieroni 2014), but ecological change may render millennia-old management systems unstable, providing a role for ethnobiology as new traditions emerge (Lepofsky 2009). In sum, the diverse Sidama landscape does not lend itself to ''ideal cultural models'' of agriculture. Rather, smallholders strategically assess the mix of crops, soil, water, and space. With climate change in full swing in Ethiopia, guided culture change for adaptation is likely to be an important component of food security.

Acknowledgments

Washington State University Initiative for Global Innovation Studies provided funding thanks to Dr. Paul Whitney. We are deeply thankful to the Sidama for their kindness and patience. Special thanks to Misters Muleka, Sisay, Israel, Temesgen and Solomon for their professional help and friendship. Thanks to Mr. Mulye Girma, Sidama Zone, and *woreda* officials for their invaluable assistance. Thanks to Drs. Thomas Rotolo and Jon Yoder for help in design and project development. Many thanks to Drs. Walelign Tedesse Robele, and President Yosef of Hawassa University for encouraging and facilitating our collaborative efforts. Any shortcomings in this study are the authors' alone.

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