Crop Genetic Diversity, Food Security and Farm Household Well-being During Shocks

Romina Cavatassi
Jeffrey Hopkins
Leslie Lipper

I. Introduction

The relationship between crop genetic diversity, food security and farm household well-being has received extensive study from economists. Public investments in research and development of improved crop varieties under the green revolution resulted in increased agricultural production and capacity to feed the growing population, but the effects from increased research and development have not been uniform. There are still considerable areas in the world where low rates of agricultural productivity give rise to poverty and food insecurity. Bruinsma (2003) estimates that agricultural intensification will be the primary source of crop production growth globally over the next 25 years. The same report showed estimates of the potential attainable yield with existing technologies compared with actual yields for rainfed wheat production in Ethiopia and indicated the presence of a significant gap of approximately 2.8 tonnes/hectare. An important aspect of narrowing the gap involves improving the management of crop genetic resources. (Bruinsma 2003) Empirical evidence also indicates that in countries with high dependence on agriculture such as Ethiopia, giving priority to food production is a promising means of increasing nutritional levels and reducing food security.

Since the 1970's another concern has arisen as well; the erosion of crop genetic diversity through the widespread replacement of traditional, landrace varieties with improved modern varieties (National Research Council 1972; Frankel 1970 Harlan 1972; Hawkes 1983; Brush, 1995; Bellon, 1996; Perales 1996). Landrace varieties have a high rate of adaptability to human and natural selection and thus provide a potentially high source of rare alleles. These genetic resources are valuable not only to meet current and future food preferences but also as insurance against future disease threats. The FAO-sponsored International Treaty on Plant Genetic Resources and the UN-sponsored Convention on Biological Diversity are agreements put in place that recognize the important role that genetic diversity conservation plays in current and future food and agriculture production.

In this paper we use a unique dataset from eastern Ethiopia to explore the role of crop genetic resources in attaining household food security. The study area is a center of origin and domestication for sorghum, and about three quarters of the farms are growing land race varieties of sorghum rather than improved varieties; while about three quarters of farms grow improved varieties of wheat rather than land races.

This paper looks at reasons for why improved varieties are adopted and why traditional varieties persist within a region, oftentimes side by side. Special attention will be paid to the nexus of crop variety genetic stocks and farm household well-being in the presence of production shocks.. The dataset combines rich crop and physical data on plant varieties (independent field work was used to validate that plant varieties had mutually exclusive forms and structures) with rich household-level wellbeing data (including income, assets and debts from both farm and off-farm sources) druing a shock year. In the year that the data were collected (2002-2003 production season) eastern Ethiopia experienced a major drought with widespread crop failure ensuing. Use of a shock year is important, because households use a variety of methods to cope with the shock, with varying implications for resource damage and extraction. Moreover, this is one of the first uses of the Ethiopian data that was collected in 2002.

II. Public and private values of crop genetic diversity in the Ethiopian context

Crop genetic resources are the product of the interaction between human and natural selection of plants, yielding a set of domesticated crops and varieties used in agricultural production. Crop

genetic resources are embedded in seeds and they are an important determinant of the characteristics and attributes of the crop species, together with environmental and human management factors. Farmers choose crops and seeds to provide a set of attributes that meet their specific production and consumption needs. However, since seeds are simultaneously a physical input to crop production and a source of genetic code, their pattern of utilization provides both a private value to the farmer, and also a public value through contributing to the conservation and evolution of genetic resources. This dual role may give rise to conflicts between public and private interests in terms of the desirable pattern of seed use (Smale and Bellon, 1999).

In response, the genetic resources under threat of loss can and are being collected and stored in gene-banks. However, this form of ex situ conservation is static, and does not capture the dynamic process of genetic resource evolution in response to continuing human and natural selection pressures. Only in situ or on farm conservation can provide this service. The distinction between the cultivation of landraces and modern varieties is one means of measuring diversity on farm. Modern varieties are by definition genetically uniform and stable, whereas landrace cultivars are more volatile, encompassing a population of genes and alleles that is adaptable to natural and human selection pressures. The degree to which a landrace is adaptable depends on the crop biology as well as the level and distribution of diversity locally.

Maintaining the cultivation of landraces has been found to provide private values to farmers as well. Farmers choose to cultivate landraces over modern varieties for a number of reasons. The most common is that MVs do not provide the attributes that farmers desire, particularly farmers operating under marginal conditions. Even if a variety is available that farmers desire, the accessibility may be limited due to poor distribution networks, high prices relative to returns and lack of credit. All three are problems in Ethiopia (Mulatu, 2000). McGuire (2005) cites the lack of agricultural extension as a major barrier to adoption of MVs, particularly in more marginal production areas. Due to their higher adaptability, landraces often have a higher capacity to respond to changing or variable production conditions. Adaptability is valuable in highly variable environments for farmers with limited risk coping mechanisms, which can have important implications for food security

Several studies have indicated high private values of landrace varieties in Ethiopia. (Gebremehdin, McGuire, 2005; Unruh, 2001; Mulatu, 2000) Attributes such yield under stressed or marginal production conditions, as well a desirable consumption characteristics are primary drivers of the demand for landraces. Unruh (2000) discusses the importance of landrace varieties in managing risk in the Ethiopian highlands and posits that the highly risky production environment in Ethiopia necessitates frequent replanting in response to crop failure. Replanting leads to higher levels of diversity, as different varieties or crops are selected to address the problem causing the failure. Unruh argues that farmers might initially plant a modern variety in the hopes of having a good agricultural year, but as production problems arise, they would replant with landraces known to be resistant to the particular problem at hand. He also argues that the modern varieties are not very well suited to the small plot sizes of highland Ethiopian agriculture, requiring a minimum area for plowing, and the necessity of taking on debt which may require the sale of productive assets to repay will also result in low rates of modern variety adoption.

II. Food Security and Agricultural Productivity in Ethiopia

Ethiopia's economy is mainly based on small-scale agriculture, accounting for half of GDP and employing 85% of the labor force (MEDAC, 1999; Zegaye, 2001; Shiferaw and Holden, 1999). Unfortunately, the agricultural sector suffers from frequent drought, poor cultivation practices

and limited farm endowments. In eight of the past 15 years, major droughts have affected 5-14 million people. In 2000 and 2003 production seasons the number exceeded 10 million (Bramel et. al. 2004). Ethiopia is the second most populous nation in Africa and one of the poorest of the world with an estimated population of over 67 million of which 40 to 50 percent is estimated to be food-insecure. The high density of the population together with the practice of dividing holdings between offspring, leads to land fragmentation and small field sizes (frequently less than one hectare) (Unruh, 2001). The resulting increased intensification, characterized by absence of fallowing, lack of technical change and total absence of conservation practices and furthermore complicated by frequent drought, is creating a high degree of land degradation and, therefore, a decline of land and grain productivity (Shiferaw and Holden, 1997).

The major food crops grown by the small-farm sector include cereals (sorghum, maize, wheat, barley, millet, tef, and oats), pulses (faba beans, field peas, lentils, chickpeas, and haricot beans), and oil crops (flax and noug) (CSA, 1999). One of the most critical cash crops of Ethiopia is coffee with exports of some $156 million in 2002. However, historically low prices have made many farmers to switch to "chat", a mild narcotic, to supplement income (FAO-GIEWS, Zegeye, 2001). Livestock production also plays a crucial role in Ethiopia's economy, contributing to about one-third of agriculture's share of GDP. Most of the rural population is in some way involved with animal husbandry, whose role includes the provision of draft power, food, cash, transportation, fuel, and, especially in pastoral areas, social prestige. In the highlands, oxen provide draft power in crop production. In pastoral areas, livestock forms the basis of the economy. Beef represents the main meat consumed, followed by mutton and lamb, poultry and goat.

Agricultural policy in Ethiopia has undergone several changes over the past decades, moving from a semi-feudal system in the 50's and 60's, to a socialist controlled economy in the 70's and 80's;v and finally towards a market based economy in the early 1990's. Market reform represented the first encouragement of market-based activities through land reform, facilitation of off-farm activities and gradual removal of subsidies for fertilisers. However the land reform has been more on paper than in practice, as land is still publicly owned and excessively fragmented with the only difference that now households are entitled to transfer and sell their long-time possession rights on land (Unruh, 2001; Dercon, 2001). Other aspects of market reform have also had limited success. In 2001 high agricultural surpluses in high productivity areas of the country lead to plummeting grain prices and ruin for farmers in the area, while other areas of the country were experiencing food shortages and strong market demand for grain (Teketel, 2002).

The combination of low agricultural productivity, high population pressures, poor agricultural policy making, conflicts and environmental degradation have left Ethiopia a country with high rates of food insecurity and high rates of dependency on external food sources. Recent estimates (USDA, 2005) indicate that Ethiopia's annual food deficit is 4.7 million tons (the amount required to bring the poorest up to a minimum nutrition standard), making it the least food-secure country in the world. This food deficit persists despite the fact that food aid constitutes about 10 percent of total food availability in Ethiopia.

The food gap could be made up in a number of ways, by increasing domestic production, commercial imports, and/or food aid. USDA (2005) recently estimated that an exogenous 10 percent yield increase for domestic producers would reduce the food deficit by 19 percent. However, aggregate food availability even after a 10-percent yield increase would still be only 76 percent of the total food required.

Officially, increasing agricultural production is the policy the Government of Ethiopia has adopted to address the problem of food security and economic growth, through the adoption of the "Agricultural Development Led Industrialization" strategy. In practice, the Government of Ethiopia has come to rely heavily on food aid as a source of food security for the country. The impact of food aid on the long term growth capacity of the agricultural sector is controversial, but in Ethiopia's case, the sheer volume and length of time of Ethiopia's food aid imports indicates that the dependency and disincentive effects in agricultural markets are likely to be substantial. (Devereaux 2000)

Increasing the productivity in the intensive margin is the main means by which Ethiopia can increase domestic production, due to a lack of new lands to bring into agricultural production. Increased agricultural productivity is expected to result in increased food security by increasing both food supply and household incomes. A key aspect of the government's strategy is the promotion of improved technological inputs and practices in order to raise agricultural productivity. Food production in Ethiopia is expected to grow at 4.2% per year over the next ten years, while population is expected to grow at only 2.5%. Estimates are that in 2014 the food deficit will be less than half what it is today USDA (2005).

Improving the productivity of crop genetic resources and their accessibility to farmers is likely to be a key aspect of increasing agricultural productivity in Ethiopia. The question is, what kind of strategy could best achieve this? What are the implications of these strategies for not only improving food security, but also conserving the important crop genetic diversity of the country? Ethiopia provides a very interesting case to consider the most effective means of improving the crop genetic resource performance of farmers in the country. The country is richly endowed with native crop genetic diversity, has a highly heterogenous and variable production environment and little capital inputs to agriculture. On the other hand, it is also a country which has invested considerably in agricultural research and development and more recently has undertaken a major reform of the formal seed sector production and distribution sector. However several problems still exist in the formal system, both in terms of the poor fit between attributes which are being generated through the crop breeding system and farmer demands, as well as the distribution system for seeds. These issues are taken up in the following section.

III. Modern varieties and the formal seed sector

Ethiopia, with one of the largest national agricultural research systems in Africa in terms of staff and budget, has been following an agricultural-led growth strategy for years (Weijenberg et.al., 1995), with crop breeding for modern varieties a major focus of efforts. Due to the importance of sorghum in food security the government has allocated considerable resources to the breeding program (McGuire, 2005). Approximately one million hectares are sown to sorghum, making it the third most important crop grown in the country, and it is a major staple in the diet of the population - particularly the poor. A breeding program for sorghum has been in place since the 1950's with somewhere between 27 to 30 modern varieties of the crop released since then (McGuire, 2005).

In terms of formal seed sector multiplication and distribution, sorghum has received relatively little attention however (Mulatu, 2000). The Ethiopian Seed Enterprise (ESE) until recently had a monopoly on the production of modern varieties released from the agricultural research and development sector. The production and storage capacity of the institute is quite limited. The primary focus of MV seed production has been on wheat and secondly maize. Mulatu (2000) finds that for several years, ESE produced less than 1% of the total potential MV seed required in the country, using an estimation based on area sown, seeding rate and replacement rates,.

Adoption rates of MV sorghum varieties in Ethiopia are not well measured, but there seems to be agreement that they are low (McGuire, 2005 ; Mulatu, 2000). One obvious reason may be a lack of supply due to the low production levels sited above. However, ESE has reported some years of excess seed supply, even with the very small production levels of sorghum it has attained. Another issue may be pricing. Sorghum MV selling prices from ESE increased 130% over the period 1992-2000, with a major increase in the 1999-2000 production season.

Low adoption rates may also be related to the demand side. The MV sorghum cultivars do not provide the attributes farmers want. The main focus of the formal sector breeding program was the development of early maturing cultivars as a means of coping with drought. Although this characteristic is important for marginal areas, these varieties were developed with grain yield as the main performance indicator, when in fact stalk yield is equally if not more important to farmers.

Demand for sorghum seed by farmers in the Hararghe region of Ethiopia (see map) is driven by the highly heterogenous agro-ecology and very low levels of farm household income in the area. Farms in the Hararghe region, (and Ethiopia in general) are highly fragmented, with small plot sizes. The average size of landholding in the area is .25 hectare and this may be divided among several plots. The area is characterized by high agro-ecological heterogeneity, as well as high variability over time of climatic and production conditions. The high level of spatial and temporal variability means there is strong demand for diversity - no one crop or variety can meet the variety of needs of the farm household. This is especially true because of the low use of complementary inputs; very little area is irrigated and there is little use of fertilizer or pesticides. For this reason, in the absence of market reforms, they call for a shift in research priorities away from traditional cereals such as sorghum because "adoption of cultivars alone is insufficient to improve yields" (Ahmed 2000).

IV. Household food security, coping strategies and crop genetic resources

One of the primary causes of household food insecurity in Ethiopia is the presence of production risks in the form of drought and pests which result in frequent crop failures, and thus reduced agricultural production and incomes (Degesfa, 2002; Dercon, 2002 Devereaux, 2000). Using a simulation model and data from six rural Ethiopian communities, Dercon 2001 estimates that the poor rainfall together with illness shocks and population growth resulted in a 13 percent decline in per adult consumption and 23 percent increase in poverty between 1989 to 1995. He notes that a lack of capacity to insure against rainfall and illness shocks and the absence of safety nets significantly reduces agricultural growth and poverty reduction in the studied areas.

Farmers do adopt a variety of coping strategies to manage risk, both ex ante and ex post. The coping strategies farmers adopt in the face of such vulnerability is linked to their overall livelihood strategy. Some of the strategies both depend on, and impact crop genetic diversity, and the accessibility of CGRs is likely to be a determinant of the livelihood and coping strategies farmers adopt.

Within the agricultural sector, farmer livelihoods may involve either the intensification or extensification of agricultural production as a strategy for reducing food insecurity. Intensification could be done simply by applying more labor per unit area and in many cases depleting natural capital stock. Or intensification could involve the adoption of improved varieties, as well as complementary inputs. This strategy may lead to increased productivity in good production years, however it is associated with higher exposure to risks of both crop and

market failures. Replanting is clearly one of these strategies. Unruh (2000) argues that the replanting is most likely to be with a traditional variety – as these are more likely to have attributes which address the production problem.

Replanting is also a coping strategy in less intensive forms of agriculture; e.g. systems based entirely on landrace production. One strategy may be to change from one landrace variety to another. Alternatively the household may move from planting landraces of one crop to another (e.g. substitute barley for sorghum).

Households may turn to other means of coping with shocks as well. Liquidating assets is clearly one important strategy utilized (Desfeya, 2002). Falling livestock prices associated with a high volume of liquidation sales on the part of households needing income for food purchases is one of the key indicators of an impending food shortage in Ethiopia (Ahmed, personal communication). Increasing off farm sources of income is another important coping strategy adopted in Ethiopia, involving activities such as firewood collection and sales, agricultural labor exchange and temporary migration. Finally, receiving emergency assistance and gifts of food from government, NGO and local community members is a very important coping strategy used in Ethiopia. Emergency seed relief is another important part of a coping strategy; seeds may be used for replanting or in many cases for consumption as grain.

The four main coping strategies a household can adopt in response to shocks can be categorized as follows: 1) replant 2) receive relief or gifts of food and seed 3) increase off farm income and 4) liquidate assets. Households may choose[1] to pursue one of more of these. In this study, we are interested in focusing on the impact of the supply of crop genetic resources, through local diversity as well as modern varieties, on the choice of strategy. Clearly replanting is a strategy which relies upon the availability of a stock of genetic resources which meet problematic production conditions – e.g. drought or pest incidence. In the case of sorghum, replanting with sorghum after a crop failure associated with drought (as is the case in our case study) requires the presence of seeds of short season varieties – e.g. modern varieties. Alternatively, seeds for short season crops (wheat or barley) could also allow for replanting.

We are also interested in focusing on comparing the impacts of adopting these different strategies on household food security. How effective is replanting as a strategy for coping with drought? Are households better off looking for off farm sources of income or replanting in terms of maintaining food security? Responses to these questions and the driving forces of the responses can provide valuable insight into strategies to improve household food security in Ethiopia, as well as the management of crop genetic resources. The remainder of the paper consists of a presentation of an empirical investigation of these questions using the household and community levels surveys conducted in the Hararghe region for the 2002-2003 production year.

V. Farm Household Survey

The farm household survey used to investigate seed systems in greater depth was built around a larger case study of the impacts of a seed system intervention implemented by the Hararghe Catholic Secretariat (HCS), a non-governmental organization, in the drought-prone Hararghe area of Ethiopia. The seed intervention involved selecting and cleaning local landraces of wheat and

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[1] In Ethiopia households are usually selected by administrative officials to receive government distributed emergency aid, so participation in this type of scheme is exogenous to household decision-making. Receiving gifts of food and aid from family members and others in the community is something the household can decide to pursue however.

sorghum for multiplication and distribution to seed-insecure households. Seeds were provided under a credit arrangement which required repayment in the form of seed with a 15% interest charge.

The case study involved a household survey, a community survey, a market survey, an agro-morphological survey, and community focus groups. A total of 720 households were surveyed in 30 Peasant Associations. Of these, about 50% were HCS participants. Of the remaining 50% about half were non-participants residing in participant communities, and half non-participants in non-participant communities. The sample was limited to uplands and midlands area in order to reduce the degree of variation arising from agro-ecological factors and to better isolate the impacts of the project. The non-project participant households (e.g. the control group) were selected to match the characteristics of HCS project participants to the extent possible. The agro-morphological and community focus group surveys were used to collect information for measuring crop genetic diversity and for validating variety names. The market survey involved the weekly collection of quantities and prices of varieties sold in market places over a period of two months. Finally, the community survey provided data on infrastructures, services, distance to main markets, outside interventions and general information common to the entire community where households reside.

The household survey was conducted in two rounds: the first was in August 2002 after the planting of the main crop of the year, and the second was in February 2003 after the harvest. The survey was designed to collect direct information from farmers necessary to measure household well-being as well as farmer's preferences towards varieties and sources of seeds (i.e. household demographics, socio-economic conditions, agricultural and non-agricultural labor and investment activities. Farm level data necessary to control for land endowments and agro-ecological conditions were also collected as well as information on seed acquisition of seeds, including the means of acquiring seeds, the criteria for seed selection, source and price of purchase, access to varieties and to seeds, formal and informal seed markets, and the transaction costs associated to interacting with seed system. Finally, data included the varieties planted, seed acquisition sources, seed information sources, and the household's perception of positive and negative characteristics of different varieties were elicited.

VI. Data and Methods

This paper uses data from the first and second household visit. Descriptive data from the survey is included in Table 1. The relationship between modern sorghum variety adoption and farm and household characteristics receives some preliminary examination in this paper. To examine this relationship, a regression on the binary outcome of whether a household grew a modern variety of sorghum was estimated. The estimated coefficients for the independent variables in the model are useful for seeing the effects on the probability of adoption.

Characteristics of the farm, farmer, and farm household were included in the regresssion. Farm variables included the size of the farm in terms of operated area (i.e. land owned, plus land rented in, less land rented out); the physical characteristics of the plots, including farmer-reported average slope of the land and the average fertility of the land (farm values were calculated as a weighted average of plot-reported variables). The belief that complementary inputs are required for modern variety adoption would be supported by positive correlation with soil fertility, because adoption would not be beneficial on poorer soils. Likewise, complementary inputs, such as fertilizers and water, are less likely to be used on hillsides, so that modern variety adoption would be negatively associated with sloping fields. Two geographic farm descriptions were used, the location of the farm defined both by the municipal association and the farm defined in terms of

altitude. Some evidence that uneven seed distribution and agricultural extension services contribute to patterns of adoption. Likewise, lower elevations are reported to be more favorable to the adoption of useful modern varieties of sorghum. Non-grain demands for sorghum, including demands for stalks by oxen, are presumed to remove incentives to adopt new varieties.

Farmer variables included in the adoption regression include age of the household head, presumed to be negatively associated with adoption. Also, the total number of sorghum varieties cultivated on the farm was included. Theoretically, the relationship would be positive; farm households that meet their differentiated consumption needs through sorghum (own consumption, plus market consumption, plus secondary uses for livestock and construction) might manage a larger portfolio of varieties, and that a larger portfolio would be more likely to include at least one modern variety.

Farm household variables included in the adoption equation include the value of non-farm income, the number of crop failures due to drought suffered by the household over the previous ten years, and the manner by which households reported coping with these losses. We expect that those farmers with greater non-farm income would be able to purchase seeds and complementary inptus, and therefore expect a positive correlation between off-farm income and new variety adoption. We expect that under complete markets the existence of highly uncertain outcomes, characterized by many crop failures due to drought, would encourage the adoption of short-season, modern crop varieties.

Households were also asked to comment on the principal advantages of the sorghum varieties that they chose to grow on their land. We classified these responses according to whether they were advantages that would register in seed or output markets (i.e. marketing-based characteristics) or whether they would provide benefits to field cultural practices (i.e. management-based characteristics). We would expect that modern varieties are adopted in search of production-based characteristics, such as good yield, resistence to adverse climates and pests and maturity-based criteria, while land races are favored by those valuing characteristics related to the quality of grain and fodder, and adaptability to taste and cooking preferences, either at home or in the market.

From the modern variety adoption equation, we estimate an auxiliary regression on the propensity to replant a crop after it failed. This regression made use of many of the same variables included in the adoption regression, but also included a variable that was the "predicted" probability of adopting a modern variety, and a variable based on how households coped with crop losses due to drought in the past.

We expect that households that replant are more likely to use a modern variety of sorghum because modern varieties are quicker to mature. Because replanting is by definition carried out in a shortened growing season, we expect the correlation between modern varieties and replanting to be positive. Another variable included in the replanting regression was one based on how farm households coped with previous crop losses due to drought. The "coping" variable was created that included responses to a question on how they reacted to crop losses. Households that responded that they coped by replanting their crops using either HCS or other government-provided seed; sought work on other farms, replanted, or intercropped were choosing farm-related coping strategies. We expect that households that coped using a household strategy based primarily on agricultural in the past would be likely to do so under the survey year as well.

VII.   Results

Regression results for both e quations are shown in Table 2. Adoption of modern varieties of sorghum were shown to be correlated with smaller farm operations. This is somewhat puzzling, because larger farm sizes are normally associated with more progressive farmers. Next, modern variety adoption was associated with flatter, or nearly flat plots of land compared to more steeply sloping lands. This confirms part of the complementary input hypothesis, but note that fertility, once controlled by slope, has no relationship with modern variety adoption. Some farm-related geographic variables were significant, with chiro having higher rates of adoption than the other two woredas. Further, higher-altitude meta woreda locations also had higher adoption rates of modern varieties.

Farmer varieties overall, such as characteristics of the head of the household, were not significantly different from zero. However, farm houseohld variables, inlcuding the nubmer of different sorghum varieties grown and the average years of formal education within household members, were positively association with modern variety adoption. Moreovoer, we found that those households who said that management-related characteristics were the primary advantage to the particular variety that they grew were more likely to grow a modern variety. The number of sorghum varieties grown was positively associated with modern variety adoption.

Principal findings related to which households took up replanting as a response to crop failures experienced on one or more households are now detailed, with respect to farm, farmer, and farm household variables. Note that only 189 observations are included in this regression, because it only includes those households that had a crop failure on their land. We find that farms with more diversified operations, with less of their overall farm in sorghum, were more likely to replant in the face of failure. Households that were predicted to plant only land race sorghum were more likely to replant after a crop failure than households planting some modern varieties. In general, the more land that households allocated to sorghum production, the more likely that they were to replant. Households that stated that the primary advantage of the sorghum that they grew was its management characteristics were more likely to replant a failed crop.

VIII. Conclusions

Our analysis has indicated that there is an important link between crop genetic diversity and the choice of coping mechanism households adopt in the face of a production shock from drought. A key response to drought in Ethiopia is crop replanting. The ability to replant is dependent on the accessibility to seeds of crops and varieties that are suitable to cope with problematic production conditions such as land fragmentation, low and erratic rainfall and so on. In addition, the choice between a modern and a landrace variety at the initial planting may also be a sort of *ex ante* risk management or coping mechanism, particularly when one variety has a higher resilience to potential production shocks. Choosing a drought resistant but low yielding variety is a means of insuring against the incidence of drought.

Coping mechanisms vary in terms of their effectiveness and accessibility to the poor. Preliminary statistical analyses of our dataset not reported in this paper of the relationship between coping strategy and food security suggest that replanting is fairly effective compared to increasing off farm income. Emergency relief and asset liquidation may not be options available to a household, highlighting the importance of replanting as a strategy. This is an area of inquiry we intend to explore more in depth in future work.

As a further analysis we also examined replanting options and found that poor households, headed by intermediate aged persons, located at high elevations and who are not growing modern varieties are the most likely to replant in response to a crop failure. The negative relationship between replanting and modern varieties is somewhat unexpected, since MVs can be planted late into the season and thus would be expected to be a good replant candidate for farmers with crop failure. Rather, it appears that households less likely to plant modern varieties are more likely to replant in the face of failure. In terms of crop genetic diversity, this presents some external benefit. At least in part, this might be explained by the shorter growing seasons households face after crops fail – perhaps not long enough to attain grain yield from a crop but long enough to produce stalks for on-farm animal or construction uses.

Part of this is explained by the fact that unlike some other cases, for sorghum in Ethiopia the MVs are actually less likely to be affected by drought than the traditional varieties due to their short growing season. We also found that the farmers who planted MV sorghum maintained their landraces as well, which essentially expanded the set of potential attributes they could obtain from the sorghum crop. Sorghum MVs, requiring a shorter growing season, are less susceptible to failure and thus would be less likely to need replanting. This possibility is also reinforced by the positive and significant sign of management-based attributes of modern sorghum varieties that have desirable characteristics while in the field. This seems to suggest that farmers plant landraces more for consumption attributes and modern varieties for management attributes. If and when landraces fail they can switch to modern varieties; on the other hand if they plant modern varieties they are more likely to need to replant because these are more resistant.

The positive relationship between poverty and the replanting decision is interesting to consider in light of the other possible coping strategies to crop failure we have identified: receiving emergency assistance, liquidating assets, or increasing off farm income. Variables measuring the household's are not any more likely to adopt these strategies in response to a shock than households that don't replantl. As a result, replanting appears to be a stand-alone primary coping strategy, particularly for the poorest, rather than an accompanying strategy in response to crop failure. Further work is needed on understanding the tradeoffs and synergies between the strategies and their link to poverty and food security. At this point in our analysis, the results are suggestive of the importance of crop genetic diversity to poor farmers in order to enable an effective strategy of replanting.

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Table 1, descriptive statistics, Hararghe region, Ethiopia

Variable	Description	Mean	SD.
Planted modern varieties	Dummy =1 if yes, else 0	0.118	0.32
Area operated	in timmad (1 timmad=1/8 of a hectar)	3.221	2.97
Totareasq	total area square	19.191	49.85
Age of household head	years	39.716	12.62
Average slope across all plot	1=gentle; 4=steep	2.409	1.11
Average fertility across all plots	1=low; 3=good	1.761	0.67
Consumption advantages to sorghum	dummy=1 if main advantage of sorghum grown is consumption driven, else 0	.0783	.269
Management advantages to sorghum	dummy=1 if main advantage of sorghum grown is management driven, else 0	.878	0.33
Poverty index	1=rich; 2=medium; 3=poor	25.98	14.45
Ave. years education, adults	average number of years of education (adults)	1.150	1.53
Oxen	Nr of oxen owned	0.410	0.62
Irrigated	dummy=1 if any operated plot irrigated, else 0	0.330	0.47
Failure	dummy=1 if any crop planted has failed, else 0	.383	0.49
Kmtomkt	Distance to nearest market in km	9.385	8.81
Wheat	dummy=1 if HH grows wheat, else 0	.383	0.49
HCSparticip	dummy=1 if Hh participates in HCS program, else 0	.781	0.41
Altitude	Altitude of village in meters	2054.685	330.13
_Iwor_2	Meta woreda	0.524	0.50
_Iwor_3	Dire Dawa Woreda	0.137	0.34
cop_aid	dummy=1 if main coping strategy is getting external aid (food or seed), else 0	0.256	0.44
cop_off	dummy=1 if main coping strategy is off farm activities, else 0	0.427	0.49
cop_saf	dummy=1 if main coping stratey is selling assets owned, else 0	.138	0.35
noteat	Dummy=1 if HH food insecure, else 0	0.207	0.41

Table 2, Sorghum modern varieties and replanting after a failure

	(1) Planted modern variety of sorghum	(2) Replanted after a crop failure
Timmads operated	-0.268 [3.41]***	0.373 [3.03]***
Timmads operated squared	0.011 [2.87]***	-0.020 [2.69]***
Age of household head	0.023 [0.71]	0.079 [1.74]*
Age of head squared	-0.000 [0.62]	-0.001 [2.08]**
Altitude	-0.001 [1.28]	0.001 [2.17]**
Average slope across all plot	-0.216 [2.58]***	-0.035 [0.29]
Average fertility across all plots	0.213 [1.63]	-0.111 [0.59]
Market advantages to sorghum grown	0.685 [1.64]	-0.454 [0.97]
Management advantages to sorghum grown	1.442 [2.69]***	0.477 [1.11]
Poverty index, derived	0.006 [1.05]	0.014 [1.86]*
Years of education of adults	0.099 [1.90]*	0.154 [1.55]
Oxen number	0.048 [0.34]	0.011 [0.06]
Irrigated land	0.078 [0.41]	
crop failure	-0.167 [0.89]	
Kilometers to closest market	-0.028 [2.71]***	
Household grows wheat	-0.294 [1.24]	
HCS participant community	0.182 [0.89]	
Pr(Smodern)		-7.229 [2.95]***
Crop failures last 10 years		0.148 [1.72]*
Number on-farm sorghum vars.		0.036 [0.13]
Coped through receipt of aid		-0.271 [0.81]
Coped through off-farm income		-0.367 [1.15]
Coped through smoothing		0.015 [0.04]
Hunger in Hhold at least 2 days		-0.277 [1.01]
total number of adult within the HH		-0.032 [0.40]
Constant	-1.465	-5.326

	[1.18]	[2.73]***
Observations	496	189

Absolute value of z statistics in brackets
* significant at 10%; ** significant at 5%; *** significant at 1%