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Farmers' Preferences for Crop Variety Traits

Lessons for On-Farm Conservation and Technology Adoption

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Abstract

Although in-situ conservation is increasingly considered an efficient way of conserving plant genetic resources, little is known about the incentives and constraints that govern conservation decisions among small farm holders in developing countries. Using a choice experiment approach, we investigated Ethiopian farmers' crop variety preferences, estimated the mean willingness to pay for each crop variety attribute, and identified household-specific and institutional factors that governed the preferences. We found that environmental adaptability and yield stability are important attributes for farmers' choice of crop varieties. Farmers are willing to forgo some income or output in order to obtain a more stable and environmentally adaptable crop variety. Among other things, household resource endowments (particularly land holdings and livestock assets), years of farming experience, and contact with extension services are the major factors causing household heterogeneity of crop variety preferences. Based on our experimental results, we derived important policy implications for on-farm conservation, breeding priority setting, and improved variety adoption in Ethiopia.

Key Words: biodiversity, choice experiment, crop variety, random parameter logit

JEL Classification: Q18, Q51, Q57

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Introduction

Farmers, plant breeders, gene-bank managers, and crop scientists draw on diverse crop genetic resources to innovate, support, and benefit society at large (Smale 2006). Biodiversity is an important component of ecological systems (e.g., Heal 2000; Tilman and Downing 1994; Tilman et al. 1996), and its loss can have adverse effects on the functioning of these systems, including impairment of their capability to produce (e.g., Loreau and Hector 2001; Naeem et al. 1994). Crop genetic resources are natural assets that are renewable, but also vulnerable to losses from natural or man-made interventions (including disruptions caused by droughts, floods, or wars) and to the gradual process of social and economic change. Loss of diversity in local seeds, a major source of planting material, threatens the livelihoods of millions of smallholders because it weakens the possibility of combining complementary plants that are adaptable to moisture, temperature, and soil type variability. It also reduces the available pool of genetic materials for breeding to enhance productivity and ensure environmental stability. A number of economic studies have also noted that crop genetic diversities can boost agricultural productivity (Tilman and Downing 1994; Tilman et al. 1996; Di Falco and Chavas 2006; Smale et al. 1998).

The main challenge faced by policymakers in developing countries is how best to conserve crop genetic diversity while fulfilling the growing demand for food production and ecological services. In the literature, maintaining diverse plant varieties in farmers' fields (now known as in-situ conservation) is increasingly considered an effective means of conserving plant genetic resources (Benin et al. 2003). However, Benin et al. (2003) observed that on-farm

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conservation of crop diversity poses obvious policy challenges in terms of the design of appropriate incentive mechanisms and possible tradeoffs between conservation and productivity. Smale et al. (2003) noted one fundamental problem that affects the design of policies meant to encourage on-farm conservation: crop genetic diversity is an impure public good, meaning that it has both private and public economic attributes. This leads to suboptimal in-situ conservation of crop genetic diversity.

Even if in-situ conservation could be an effective means of conserving crop genetic resources, the degree of success is highly dependent on individual farmers' decisions. Thus, it is important to understand the farm-level incentives and constraints for in-situ conservation. This study contributes to the literature by providing insights into farmers' crop variety attribute preferences, using a choice experiment approach in a typical developing country setting—Ethiopia. It also identifies the household contextual factors that govern these decisions. There are several reasons for using a survey-based approach instead of relying on actual behavior. The most important is that, due to high transaction costs and limited information, there is no well-functioning market for varieties (seeds) in Ethiopia. Consequently, farmers often rely on past harvests or obtain seeds from neighbors. However, even if a market for crop variety did exist, it would be difficult to identify the effects of each characteristic of a crop variety separately from the market data, since there might be correlations between characteristics.

The rest of the paper is organized as follows. Section 1 provides background on the current state of crop biodiversity and crop production in Ethiopia, with special reference to the two major cereals in the country, teff and sorghum. Section 2 describes the details of the choice experiment design and administration of the survey. Section 3 presents the econometric approach, and section 4 discusses the empirical results. Finally, section 5 concludes the paper.

1. Crop Biodiversity and Agricultural Production in Ethiopia

As in many other developing countries, agriculture is the mainstay of the Ethiopian economy, accounting for 85 percent of all employment, 40 percent of gross domestic product (GDP), and 90 percent of export earnings. However, the real agricultural GDP and per capita cereal production have been declining over the last 40 years, with a cereal yield that has been stagnant at only 1.2 metric tons per hectare (World Bank 2005). Despite huge investments and extension programs to promote improved seeds, the use of improved seeds is very low—only 3–5 percent of Ethiopia's cultivated agricultural area is covered with improved seeds—leaving a great proportion of the farm households to depend on traditional varieties (World Bank 2005). The low rate of adoption of improved varieties is often attributed to a number of socioeconomic, natural, and institutional factors (Bezabih 2003; Degnet et al. 2003; Legesse 2003; Chilot et al. 1996; Kidane and Abler 1994; Yohannes et al. 1990).

Given its agro-ecological diversity and high altitudes, Ethiopia is both the center of origin and a center of diversity for many crops, including sorghum, teff (*Eragrostis abyssinica*), coffee (*Arabica*), and ensete (*Ensete ventricosum*). Sorghum and teff are the two major cereals grown in the country, with teff being the most dominant, occupying 22 percent of all cultivable land. As a source of staple food for many parts of the country, teff is primarily grown to prepare *injera* (Ethiopian bread), porridge, and some native alcoholic drinks. The straw is mainly used for animal feed. Sorghum, the major crop second to teff and grown all over the country, contributes about 15–20 percent of Ethiopia's total cereal production (Edilegnaw 2004; 2008). Sorghum is used for many purposes, such as food, animal feed, fuel, house construction, and fences, and consists of more than 20 different species; some come from East Africa and some from western, central, and southern African regions. Ethiopia holds, ex situ, 4 percent of the world's sorghum genetic stock (FAO 1998 and Hawkes et al. 2000). The crop exists in tremendous variety throughout the areas of sorghum production in Ethiopia (Gebrekidan 1979; de Wet and Harlan 1971).

The National Biodiversity Strategy and Action Plan (NBSAP) of Ethiopia shows that agricultural intensification is potentially the major cause of loss of agricultural biodiversity in the world, and particularly in Ethiopia (FDRE 2005). The report argues that replacing traditional crop varieties with high-yielding varieties that are dependent on high levels of agricultural inputs can result in genetic erosion of resilient native varieties. It is, thus, both a challenge and an opportunity for Ethiopia to design conservation policies that enable its agriculture-based economy to make the best use of its crop diversity (Edilegnaw 2004).

As said earlier, a loss of diversity implies a big threat to the livelihoods of millions of smallholders who depend on local seeds as their major source of planting material. Loss of diversity implies limited possibilities for breeding crop verities that are adoptable to climatic and soil factors and at the same time meet the growing demand for food millions. Thus, understanding the preferences and driving forces behind crop variety choices is crucial for designing effective on-farm crop genetics conservation policies for small Ethiopian farmers who rely on local varieties.

2. Survey Design and Study Sites

In this study, we employed a choice experiment approach to evaluate farmers' preferences for the various attributes of crop varieties. As discussed in the introduction, we could not rely on actual behavior because currently there is no well-functioning market in Ethiopia. In a choice experiment, individuals are given a hypothetical setting, and then asked to choose their preferred alternative (usually repeatedly) from several alternatives in a choice set. Each alternative is described by a number of attributes that take on different levels.[1] In our case, the farm households were given choice sets with three different alternative crop varieties. The most important crop variety attributes and their levels were identified in consultation with experts (crop breeders and researchers with hands-on experience and practical knowledge of the relevant variety attributes), by reviewing previous studies and historical data, and by identifying the most important seed selection criteria put forward by a focus group of surveyed households. (This is explained in more detail at the end of this section.) The crop variety attributes and levels used in the choice experiment include yield levels, yield stability, environmental adaptability, and selling unit price for each crop variety. The experiment was conducted using the two major cereals grown in Ethiopia, sorghum and teff. A full description of the attributes and the levels of each attribute are presented in table 1.

At first glance, table 1 seems to show a strong correlation between market price and productivity attributes, making the tradeoffs between these two attributes difficult. This is true where output markets function well and production and consumption decisions are separate. However, this was not the case in our sites, or in many developing country settings, where production decisions are mainly subsistence oriented and production and consumption decisions are nonseparable. Under these circumstances, productivity attributes become important considerations for all farm households (net buyers, net sellers, and the self-reliant). On the other hand, the price attribute is relevant only for farm households that have better access to output markets and that are net sellers. Thus, as we confirm in section 4, we expected that price and productivity attributes would play a distinct role in governing farm households' preferences for different crop varieties and in designing appropriate incentive-based policies for our sites.

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[1] For detailed reviews on the choice experiment method, see Alpizar et al. (2003) and Louviere et al. (2000), for example.

Table 1. Attributes and Attribute Levels Used in the Choice Experiment

Attributes	*Definition*	*Attribute levels*
Sorghum		
Producer's price	The amount of money the farmer earns by selling 100 kg of harvested sorghum of a particular sorghum variety	(1) ETB 110, (2) ETB 150, (3) ETB 200
Productivity	Average production harvested per hectare from planting a particular sorghum variety	(1) 1400 kg, (2) 1900 kg (3) 2500 kg
Environmental adaptability	Whether the variety is resistant or tolerant to drought and frost	(1) The variety is adaptable (resistant); (2) the variety is not adaptable (nonresistant)
Yield stability	Whether the variety gives stable yield year-after-year, despite occurrences of crop disease and pest problems	(1) The variety gives stable yield year-after-year; (2) the variety gives variable yield year-after-year.
Teff		
Attributes	*Definition*	*Attribute levels*
Producer's price	The amount of money the farmer earns by selling 100 kg of harvested teff of a particular teff variety	(1) 210 ETB, (2) 270 ETB, (3) 330 ETB
Productivity	Average production harvested per hectare from planting a particular teff variety	(1) 800 kg, (2) 1500 kg (3) 2000 kg
Environmental adaptability	Whether the variety is resistant or tolerant to drought and frost	(1) The variety is adaptable (resistant); (2) the variety is not adaptable (nonresistant)
Yield stability	Whether the variety gives stable yield year-after-year, despite occurrences of crop disease and pest problems	(1) The variety gives stable yield year-after-year; (2) the variety gives variable yield year-after-year.

Note: ETB = Ethiopian birr; ETB 9.7 = US$ 1 (October 2008)

Given the attributes and their levels as presented in table 1, we constructed different choice sets using a cyclical and fractional main effect design principle (Bunch et al. 1996).[2] Each household made nine choices: there were three alternatives in each choice set. Separate choice

[2] A cyclical design is a straightforward extension of the orthogonal approach. First, each of the alternatives from a fractional factorial design is allocated to different choice sets. Attributes of the additional alternatives are then constructed by cyclically adding alternatives into the choice set, based on the attribute levels. That is, the attribute level in the new alternative is the next higher attribute level to the one applied in the previous alternative. If the highest level is attained, the attribute level is set to its lowest level.

sets were presented for teff and sorghum varieties. Table 2 presents an example of a choice set for sorghum.

Table 2. Example of a Choice Situation

Assuming that the following sorghum varieties were your ONLY choices, which one would you prefer to plant?

Sorghum variety characteristics	**Sorghum variety 1**	**Sorghum variety 2**	**Sorghum variety 3**
Producer's price	150	200	110
Productivity	1400 kg	1900 kg	2500 kg
Environmentally adaptable	Yes	No	Yes
Stable-in-yield	No	Yes	No

I would prefer to plant **sorghum variety 1**, **sorghum variety 2**, or **sorghum variety 3**.
Please check (√) *one option.*

We carried out the experiment in two peasant associations (PAs) in the northeastern part of the country (the North Wollo Zone of the Amhara Regional State) in June and July of 2007, and adopted stratified multistage sampling to identify zones, districts, PAs, villages, and farm households. All sampled households are located in two PAs of the Guba Lafto district, North Wollo, Amhara. The PA villages are located in temperate agro-ecology and have an average annual rainfall of 630–970 mm per year and a mean temperature of 15–20^{o} C. In addition, they have experienced recurrent drought over the past decades. Teff, sorghum, and maize are among the most important food crops in both study sites.

To check the relevance of the choice experiment questions about local conditions, farmers' expectations, and level of understanding, the questionnaires were pre-tested on a focus group of 16 farmers (8 from each PA). The pre-test results were discussed with the enumerators and necessary changes were made according to farmer responses. Overall, a total of 131 farmers were selected. Of these, 66 were randomly selected and presented with choice sets for the sorghum variety and the remaining 65 were assigned the teff variety. Enumerators used the local language and choice cards to present the various choice sets. Overall, 1,179 choices were elicited from the surveyed households. To complement the experimental data, a separate survey was employed to collect data on socioeconomic characteristics. (See table 3 for descriptive statistics.)

Table 3. Descriptive Statistics of Sampled Farm Households

Variable	Description	Mean	Std. dev.
Household characteristics			
Male	= 1 if the household head is male	0.90	0.299
Household size	Number of household members who share the same food stock	5.38	2.04
Experience	Farming experience of the household head in years	25.38	11.64
Off-farm work	= 1 if at least one member works off-farm	0.32	0.468
No. of dependents	Number of dependents with no labor or money contribution in the household	1.15	1.45
Agricultural output surplus	=1 if the household is a net-seller of agricultural outputs	0.27	0.444
Drought frequency	The number of times the household faced drought problems during the last ten years	2.45	1.709
Farm and livestock characteristics			
Land shortage is major problem	= 1 if the household head considers land shortage to be the primary problem	0.64	0.479
Total land size (in hectares)	Total land size operated by the household	0.75	0.52
Livestock value (in ETB)	Total value of livestock (including poultry and bee hives) currently owned by the household	5016.5	4745.5
Access to infrastructure and extension services			
Average distance to household services* (in minutes)	Average walking distance to basic infrastructure and services	48.24	27.07
Participate in extension programs	= 1 if the household has been participating in the agricultural extension program	0.70	0.457
Experience in extension programs	Years of participation in agricultural extension program	4.14	5.226

Notes: ETB = Ethiopian birr; ETB 9.7 = US$ 1 (October 2008)

* Services include electricity, piped water, telephone, primary school, secondary school, all weather roads, and irrigation. Respondents were asked to specify the walking distance (in minutes) to each type of service, and an average walking distance to services was then calculated for each respondent.

3. The Econometrics Approach

Since respondent preferences are observed in terms of their choices, we employed a random utility framework to analyze the responses to the different choice sets (McFadden 1974).

Assuming a linear indirect utility function, the utility for alternative *i* in choice situation *t* for farmer *h* is given by:

$$V_{ith} = \boldsymbol{\beta}' A_{\mathbf{it}} + \lambda price_{it} + \varepsilon_{ith} \ , \tag{1}$$

where A_{it} is the attribute vector, except prices β is the corresponding parameter vector including an alternative specific constant, $price_{it}$ is the price attribute for alternative *i*, λ is the marginal utility of money, and ε_{ith} is an error term. The probability that individual *h* will choose alternative *i* can be expressed as:

$$P_{ith} = P\{\beta' A_{it} + \lambda price_{it} + \varepsilon_{ith} > \beta' a_{jt} + \lambda price_{jt} + \varepsilon_{jith}; \forall j \neq i\}. \tag{2}$$

From this specification, the mean marginal WTP (willingness to pay) for a certain attribute is given by the ratio of the attribute coefficient to the marginal utility of income (Hanemann 1984). In the analysis, we employed a random parameter logit model where the non-monetary attributes are random normally distributed. We can then write utility as:

$$V_{ith} = \lambda price_{it} + \beta' A_{ith} + \varepsilon_{ith} = \lambda price_{it} + \overline{\beta}' A_{ith} + \tilde{\beta}_h' A_{ith} + \varepsilon_{ith}. \tag{3}$$

Thus, each individual's coefficient vector β is the sum of the population mean $\overline{\beta}$ and individual deviation $\tilde{\beta}_h$. The stochastic part of utility $\tilde{\beta}_h A_{ith} + \varepsilon_{ith}$ is correlated over alternatives, which means that the model does not exhibit the IIA (independent of irrelevant alternatives) property. Let tastes β vary in the population with a distribution with density $f(\beta \mid \theta)$, where θ is a vector of the true parameters of the taste distribution. If the $\varepsilon' s$ are IID (independent and identically distributed) type-I extreme value, we have a random parameter logit (RPL) model. We assume that the randomly distributed parameters are constant across the choice situations for each individual. This reflects an underlying assumption of a stable preference structure for all individuals over the choice experiment (Train 1998). Since the choice experiment is relatively small and simple, this seems to be a realistic assumption.

First, we estimated one model for each crop with only the attributes of the experiment. Then, we estimated two models, where a number of socioeconomic characteristics interact with the attributes. The models are estimated with simulated maximum likelihood, using Halton draws with 500 replications.[3] Although the experiment was generic, we included two alternative

[3] See Train (2003) for details on simulated maximum likelihood and Halton draws.

specific constants, since we wanted to test whether any factors other than the attributes themselves affected the choices.

4. Results and Discussions

The results of the RPL models (without and with socioeconomic characteristics) are presented in tables 4 and 6, respectively. We begin by commenting on the results of the models without socioeconomic characteristics.

Table 4. Results of Random Parameter Logit Estimates for Choice of Crop Variety

	Sorghum		Teff	
	Coefficient	***Standard error***	***Coefficient***	***Standard error***
Mean parameters				
Alternative 1	0.306***	0.174	0.549***	0.165
Alternative 2	1.418***	0.304	1.25***	0.304
Producer's price	1.973***	0.241	1.065***	0.169
Productivity	0.308***	0.034	0.293***	0.038
Environmental adaptability	5.068***	0.932	4.489**	0.604
Yield stability	4.429***	0.908	2.610**	1.12
Standard deviation parameters				
Productivity	0.126***	0.034	0.189**	0.038
Environmental adaptability	3.226***	1.1621	2.239**	0.345
Yield stability	2.987***	0.670	2.438**	0.472
Number of respondents	66		65	
Number of choices	594		585	
ρ^2	0.574		0.545	

Notes: Standard errors are in parentheses. ***, **, and * denote significance at 1%, 5%, and 10%, respectively.

All the attribute parameters are highly significant and have the expected signs. Thus, farmers cared not only about the productivity of the crop varieties but also about environmental adaptability and yield stability. The estimated standard deviations are also significant and sizeable, indicating that we captured unobserved heterogeneity with the random parameter specification. The two alternative specific constants are also significant. Since the experiment was generic, this indicates that factors other than attribute levels affected behavior. With this caveat in mind, we moved on to investigate the marginal WTP for the attributes. The mean marginal WTP is computed as the ratio of the respective attribute coefficients to the price coefficient (Hanemann 1984); table 5 presents the results. Note that the attributes for environmental adaptability and yield stability are binary variables and, hence, they can be directly compared. The marginal WTP for the productivity trait is calculated as the WTP for an increase in productivity by 100 kg per hectare.

Table 5. Mean Marginal Willingness to Pay for Each Variety Attribute by Crop

	Sorghum	Teff
Productivity	15.62 (1.93)	27.47 (4.66)
Environmental adaptability	258.86 (53.34)	421.47 (73.21)
Yield stability	225.51 (52.71)	245.07 (53.63)

Note: Standard errors are in parentheses.

The farmers in the experiment had a higher WTP for environmental adaptability than for yield stability. One reason for this could be the frequent droughts experienced by the respondents. Comparing productivity with the adaptability and stability attributes, we see that there is strong preference for adaptability and stability. For example, for teff, increasing yield stability is equivalent to increasing productivity by 892 kg per hectare. For sorghum, the preferences are even stronger. High WTP for environmental adaptability and yield stability, compared to productivity, points to farmers' strong preference for resilient crop varieties. In countries like Ethiopia, where crop production is mainly rain-fed and commonly subject to various natural calamities, output risk is an important consideration when making production decisions. This is perhaps one major reason behind the low adoption rates of high yield varieties, which are generally believed to be less resilient to environmental hardships. This result has important implication for targeting in-situ conservation of crop genetic resources. It demonstrates how important the environmental adaptability and yield stability attributes are in motivating farmers to participate in any in-situ conservation effort.

It is likely that there are large heterogeneities of preferences across farm households. Any in-situ conservation effort should take these heterogeneities into consideration. To account for observed heterogeneity of preferences across farm households, we also estimated models where a set of socioeconomic characteristics were interacted with the attributes. Due to possible multicollinearity problems, it was not possible to include all interactions between the explanatory variables collected in our survey and the four crop variety attributes. Table 6 presents the results of the RPL model interacted with socioeconomic variables.

Table 6. Results of Random Parameter Logit Model with Socioeconomic Characteristics for Choice of Crop Variety

	Sorghum		Teff	
	Coefficient	*Standard error*	*Coefficient*	*Standard error*
Mean parameters				
Constant	1.700***	0.333	1.379***	0.344
Producer’s price	0.020***	0.003	0.012***	0.002
Productivity	-0.014	0.080	0.160	0.207
Environmental adaptability	1.691	2.457	-10.252*	5.411
Yield stability	4.113	2.562	7.787	6.124
Productivity × Male	0.132	0.086	-0.156	0.189
Productivity × Experience	0.005	0.003	0.003	0.003
Productivity × Off-farm work	0.120*	0.073	-0.029	0.079
Productivity × Total land size	-0.087	0.072	0.276***	0.095
Productivity × Livestock value	0.002	0.009	-0.004	0.006
Productivity × Drought frequency	-0.009	0.017	0.088***	0.030
Productivity × Exper. agric. extension	0.012	0.008	0.010	0.006
Productivity × Household size	0.021	0.017	-0.026	0.019
Productivity × Agric. output surplus	-0.014	0.065	0.039	0.079
Env. adaptability × Male	1.702	1.644	6.119	4.276
Env. adaptability × Experience	0.125*	0.067	0.096*	0.052
Env. adaptability × Off-farm work	-0.779	1.203	-0.895	2.451
Env. adaptability × Total land size	-3.323**	1.331	1.877	2.902
Env. adaptability × Livestock value	0.033	0.162	-0.553***	0.178
Env. adaptability × Drought frequency	-0.089	0.303	0.722	0.735
Env. adaptability × Exper. agric. extension	-0.055	0.118	0.461	0.344
Env. adaptability × Household size	0.418	0.317	1.440**	0.657
Env. adaptability × Agric. output surplus	-0.753	1.226	0.933	2.100
Yield stability × Male	0.008	1.733	-3.095	5.034
Yield stability × Experience	-0.043	0.067	-0.031	0.057
Yield stability × Off-farm work	0.143	1.259	1.304	2.511

Yield stability × Total land size	-0.601	1.448	-1.136	2.846
Yield stability × Livestock value	0.213	0.180	-0.396**	0.163
Yield stability × Drought frequency	-0.103	0.321	-1.059	0.739
Yield stability × Exper. agric. extension	-0.327**	0.144	0.448	0.348
Yield stability × Household size	0.470	0.343	0.938	0.673
Yield stability × Agric. output surplus	0.011	1.298	0.474	2.200
Standard deviation parameters				
Productivity	0.117***	0.0354	0.190***	0.038
Environmental adaptability	1.932***	0.541	2.950***	0.980
Yield stability	2.429***	0.551	3.826***	1.264
Number of respondents	66		65	
Number of choices	513		531	
ρ^2	0.613		0.600	

Notes: Standard errors are in parentheses. ***, **, and * denote significance at 1%, 5%, and 10%, respectively.

These results reveal that differences among farm households in terms of household characteristics, endowments, and constraints, and degree of access to agricultural extension do affect farmers' private valuation of crop variety traits. Our results indicated that the highly productive teff varieties are valued the most by larger farm households and farm households with more drought experience, and less by medium-size farm households and those with moderate experience with drought. The demand for environmental adaptability varied across crops; the preferences for environmentally adaptable sorghum varieties was stronger in smaller households and in households with more years of farming experience; smallholders and households with large livestock value and small families had a weaker preference for environmentally adaptable teff varieties.

Farm households which have participated in the agricultural extension package the longest derived the lowest positive utility from more stable yielding sorghum varieties. On the other hand, farm households with higher value of livestock derived the lowest positive utility from more stable yielding teff varieties.

In general, there appears to be heterogeneity in preferences for crop varieties, especially across large- and smallholder farmers and farmers with high and low values of livestock. Larger farm households and households with a high value of livestock gave more weight to productivity than to environmental and yield stability attributes than did smallholders and households with low value of livestock. This result is very intuitive, in that larger farm households are less risk averse and are ready to adopt crop varieties that are less resilient and less stable in terms of yield. Households with higher value of livestock also gave livestock biomass production as a major consideration in terms of their preferences for crop genetic varieties, and as a result gave more weight to productivity than to environmental adaptability and yield stability. Their livestock assets also gave them the leverage to make riskier production decisions in terms of choice of crop varieties.

5. Conclusions and Implications

Given the growing concern for food insecurity and adverse effects of long-term climate changes, crop biodiversity is an important asset both for increasing agricultural productivity and minimizing the downside risk of adverse climate change. However, due to lack of appropriate in-situ conservation strategies, crop biodiversity is subject to irreversible losses. Design of appropriate in-situ conservation strategies requires an understanding of farmer incentives and constraints when they make their choice of crop varieties. This study employed a choice experiment approach to 1) investigate farmer preferences for crop variety attributes, and 2) to identify the most important socioeconomic forces driving these preferences. Farmers revealed strong preferences for environmental adaptability (resistance to drought and frost occurrences). Yield stability (from resistance to disease and pest problems) was also more important than increased productivity. These findings may explain the low adoption rates of high-yield variety seeds in Ethiopia over the last several decades. The fact that farmers attach sizeable weights to both environmental adaptability and marketability traits of sorghum and teff points to the need for supplying a crop genetic variety with additional attributes of resilience to harsh environmental conditions, rather than a crop genetic variety that targets enhanced agricultural productivity but is risky in terms of other environmental attributes.

We also found that there are differences among farm households in terms of household characteristics, resource endowments, and level of access to agricultural extension that affect farmers' private valuations of crop variety traits. There are significant differences between smaller and larger farmholders, and between households with low and high values of livestock.

These results have important implications for on-farm conservation, contextual variety development, breeding priority setting, and targeted diffusion of improved varieties in Ethiopia.

First, the farm households, which now attach the highest values to attributes already embedded in traditional crop varieties managed by peasants on their farms, would maintain the varieties de facto. To minimize conservation costs and enhance compliance, these farmers have to be targeted in future on-farm conservation activities. For instance, de facto conservation of environmentally adaptable sorghum varieties by more experienced farmers with small land areas implies that there is no need to design external incentives for these varieties in order to encourage the farmers to maintain them.

Second, understanding farmers' variety-trait preferences also informs decisionmakers about the variety attributes that have to be considered for on-farm conservation. For instance, more experienced farmers and small farmholders with smaller livestock assets are affected the most when they have to forego teff and/or sorghum varieties with better yield stability and environmental adaptability. They are, therefore, less likely to cooperate with on-farm conservation activities that deny them varieties with these attributes unless they get equivalent compensation.

The third important policy implication relates to the area of variety adoption. For agricultural technologies to be successful, their attributes should address farmer concerns. Clearly, understanding farmers' variety-trait preferences is necessary to this end. For instance, according to the results, in order to target the variety demands of income shock-vulnerable and segmented farmers, the variety attributes of environmental adaptability and yield stability should be prioritized over productivity traits, which seem less important.

The fourth policy implication is in the area of breeding priority setting. Given that farmers' variety-attribute preferences determine both their propensity to use improved varieties and the chance of using them successfully, breeding should satisfy the demands of different farm household types classified according to resource endowments, preferences, and constraints. To this end, analyzing farmers' variety-attribute preferences will help target farmer demands in the making of a technology. For instance, we found that farmers attach the highest private value to the environmental adaptability trait, followed by the yield stability attribute of both sorghum and teff. If the breeding priority cannot address all desired traits for capacity reasons, it should, then, primarily target environmental and yield attributes in both sorghum and teff varieties. Moreover, as breeding attempts to improve the cross-cutting attribute (environmental adaptability) in the studied crops, we found that farmers in Wollo would be better off if this improvement comes first in teff varieties and then in sorghum varieties.

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