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Exploring Smallholder Farmers' Preferences for Climate-Smart Seed Innovations: Empirical Evidence from Southern Ethiopia

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Abstract: Rapid plant breeding is essential to overcome low productivity problems in the face of climatic challenges. Despite considerable efforts to improve breeding practices in Ethiopia, increasing varietal release does not necessarily imply that farmers have access to innovative varietal choices. Prior research did not adequately address whether varietal attributes are compatible with farmers' preferences in harsh environmental conditions. With an agricultural policy mainly aiming to achieve productivity maximization, existing breeding programs prioritize varietal development based on yield superiority. Against this background, we estimated a multinomial logit (MNL) model based on choice-experiment data from 167 bean growers in southern Ethiopia to explore whether farmers' attribute preferences significantly diverge from those of breeders' priorities. Four important bean attributes identified through participatory research methods were used. The results demonstrate that farmers have a higher propensity toward drought-tolerant capability than any of the attributes considered. The model estimates further show the existence of significant preference heterogeneity across farmers. These findings provide important insight to design breeding profiles compatible with specific producer segments. We suggest demand-driven breeding innovations and dissemination strategies in order to accelerate the adoption of climate-smart and higher-yielding bean innovations that contribute to achieve the national and global sustainability goals in Ethiopia.

Keywords: bean attributes; climate-smart variety; drought; Ethiopia; MNL; preference heterogeneity



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1. Introduction

Rain-fed agriculture remains the main source of livelihoods for the majority share of the population in the Sub-Saharan Africa (SSA) region. Rising temperatures and rain-fall variability patterns in the tropics have negatively impacted crop production efforts. Accordingly, climate change has put severe challenges in agricultural production and food security [1,2]. We cannot prevent the occurrence of climate change; hence, adopting climate-adaptable technologies is a key strategy to realize sustainable agriculture. The authors of [3] evaluated the technical efficiencies of technologies specifically to land management practices that are vital to climate change adaptation in Ethiopia. Among the widely suggested other innovative solutions, the rapid plant-breeding technique is one of the most cost-effective strategies suitable to reduce these vulnerabilities and ensure sustainable agricultural development [4–7].

Public plant-breeding programs started in the 1970s aimed at providing higher-yielding varieties to farmers in Ethiopia. Consequently, considerable numbers of crop varieties were released through the national agricultural research (breeding) system [8]. Moreover, the Ethiopian government put in place the Agriculture Development-Led Industrialization (ADLI) strategy since the 1990s with a major aim to generate fast and inclusive agricultural growth and to ensure food security through increased public spending on agricultural research and extension. Despite considerable efforts to realize the ADLI targets, most of the newly developed and released crop varieties are not adequately adopted by the farmers [9,10]. Hence, efforts to release new varieties from these breeding programs do

not necessarily imply that farmers have access to better varietal choices that are compatible with their needs and aspirations, which are driven by household-specific pressing problems and agroecological conditions. Accordingly, the question of whether these public breeding programs are capable of providing farmers' preferred seed varieties to cope-up with the emerging crop production risks is an important empirical inquiry.

The impact of crop improvement research and the extension programs depend upon whether decisions were coordinated in a top-down or bottom-up approach. Studies indicate that, in a top-down research-extension system, unsuitable breeding innovations that do not best fit farmers' priorities might be developed and released in the agricultural research systems [11]. In this regard, research-extension collaboration in Ethiopia is very weak and also characterized as a top-down decision approach [12,13]. Hence, agricultural research practices are conducted independently of the technology transfer, and farmers are viewed as passive technology recipients rather than active stakeholders in problem identification, which is crucial in setting breeding priorities. Due to the weak collaboration between agricultural research and the extension programs, the fate of numerous farm innovations is to end up on a shelf instead of reaching farm fields [10,12].

With an agricultural policy mainly aimed at enhancing yield productivity, the existing public breeding programs are developing uniform varieties with the aim of targeting higher rainfall and potential areas with a major focus on yield superiority. Since these technologies are designed to address the production requirements of high-agricultural-potential areas, the same technologies are distributed to locations frequently affected by drought for replication without taking into account the diverse agricultural systems and farmers' concerns [13,14]. This implies that breeding practices follow a "one-size-fits-all" misguided strategy, and several released innovations are poorly customized to local production conditions [15]. On the other hand, farmers need ranges of crop varieties to meet their varying agricultural systems due to the diverse agroecological constraints and household socioeconomic heterogeneities. Consequently, research evidenced that farmer households in the marginal and harsh environmental conditions do not benefit much from existing crop improvement practices [4,5].

Demand-driven variety development strategies are proposed to meet farmers' and consumers' preferences in the entire food-crop value chain in SSA and South Asia [16,17]. This is basically to include the views of stakeholders from the lab to the plate to accelerate the research impact. Furthermore, projections indicate that approximately more than half of the cultivable land in SSA will experience negative impacts due to climate change in the coming 30 years [18–20]. Researchers and practitioners are constantly warning about the need to utilize climate-smart agriculture (CSA) practices to support the implementation of sustainable agricultural strategies in the face of extreme climatic variability. In this regard, the authors of [20] explained three grand objectives that need to be achieved with any CSA practices so as to sustainably realize food and nutrition security with the necessary adaptation and mitigation strategies, such as increased productivity, enhanced resilience (adaptation), and reduced emissions. Since the relative significance of each objective varies across situations and locations so that the authors further suggested the need to bring a balance between the "triple win" of CSA practices. Accordingly, the utilization of climate-smart breeding innovations targeting to increase resource efficiency and productivity should be a priority in SSA, where low agricultural productivity and food insecurity are the major concerns. Following the launch of the Drought-Tolerant Maize for Africa (DTMA) project, remarkable progress has been achieved in the development and dissemination of drought-tolerant maize varieties across SSA countries in the 2000s [21–24]. Using choice-experiment approach, the authors of [24] found that farmers had a higher preference and were willing to pay a substantially higher price premium for drought-tolerance capability compared to other preferred attributes of maize in Zimbabwe.

Similar study findings on other major food crops grown in rainfall stress locations of Ethiopia with the aim of understanding farmers' decision-making strategies about seed variety selection so as to inform breeding policy priority setting are limited. To fill

this knowledge gap, we employed a choice-experiment technique to investigate whether Ethiopian farmers' preferences for bean attributes are significantly linked with the prevailing climatic conditions in the central Rift Valley locations of Southern Ethiopia. The paper further explores how farmers' bean-variety selection strategies diverge with breeding programs' priority (mainly focus on yield superiority). The observed socioeconomic characteristics were assumed to contribute to the existence of preference heterogeneity across farmers.

The paper is organized into five sections. Section 2 presents a precise overview of the theoretical foundation. Section 3 extensively presents the design of the choice-experiment process and the survey administration. The results and discussion are presented in the subsequent section. Finally, the last section provides the conclusion and policy implications.

2. Theoretical Framework

Discrete choice experiment (DCE) is a widely used stated preference approach in nonmarket valuations. It has a conceptual foundation from Lancaster's theory of consumer choice in that consumers receive utility from the attributes of the good indirectly rather than the amount of the goods [25] and employs random utility models for its econometric specification [26]. Assuming an individual farmer i is provided with j numbers of mutually exclusive and exhaustively listed alternatives with varietal attributes (X_{ij}) and socioeconomic characteristics of the farmer household (R_{ij}), the farmer selects one of the alternative seed varieties that provide the highest level of utility and the utility function is specified as:

$$U_{ij} = U(X_{ij}, R_{ij}), \text{ assuming all } j \text{ are in the given choice set.}$$

The specified utility function is assumed to be deterministic in the sense that the utility is fully determined [27]. However, all the explanatory factors that determine utility are not fully observed, and hence, only a part of the utility function is explained. Accordingly, the utility function is broken down into two components: those that are observed (the deterministic component, V_{ij}) and those components that are unnoticeable (random) to the analyst, ε_{ij} [28]. There are several sources for this randomness, and it arises mainly due to the unobservable attributes of an alternative and the decision maker [29]. Maximizing the amount of information in the observed component of the utility has been widely suggested as a strategy to minimize the unnoticed information accumulated in the random component [30]. Therefore, the two utility components for an individual decision-maker i can be written as:

$$U_{ij} = U(X_{ij}, R_{ij}) = V(X_{ij}, R_{ij}) + \varepsilon(X_{ij}, R_{ij})$$

According to the random utility models, a farmer is assumed to make a choice between options and select the variety h that provides the highest utility from the J number of options, if and only if:

$$U_{ih} > U_{ij} \quad \forall j \neq \text{alternative } h \in \text{choice set.}$$

The suitable econometric choice model is specified with a linear function in the parameters, and the random component enters into the equation in an additive form [31]. Supposing that the utility function is defined over a set of choice options and a farmer i chooses alternative variety h among a number of alternatives based on the utility maximization principle, the equation is specified as:

$$U_{ih} = X_{ih}\beta_i + \varepsilon_{ih}$$

where U_{ij} stands for utility derived from the chosen alternative h by farmer i in the given sample on a specific choice situation; X_{ij} is the observed attribute of the alternatives and also represents the socioeconomic characteristics of the farm household; and β_i represents the corresponding estimated fixed parameter for the attributes of alternative, h . The estimation of fixed parameters implies that the multinomial logit (MNL) model specification fails to account for preference heterogeneity because the estimation procedure is based on the assumptions that preferences are homogeneous (fixed) across farmers. As a solution,

therefore, we introduced socioeconomic characteristics of households into the model estimation to account for these taste variations across the households.

Another important assumption is that the random components are assumed to be independent and identically distributed (IID) across alternatives and choice situations and follow the Gumbel distribution (i.e., skewed to the right) with the mean equal to zero and an identity variance–covariance matrix [30]. Accordingly, the random terms are assumed to have a zero mean with the identity variance–covariance matrix, and they are represented as:

$$\varepsilon_{ih} \sim G(0, \Sigma), \text{ where } \Sigma = \begin{vmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{vmatrix}$$

The diagonal values in the identity matrix imply that the random terms are homoscedastic (constant variance), and the off-diagonal zero values denote the assumption of zero correlation among the error terms (that is, independently distributed) across the alternatives and in every choice situation.

The IID precondition is the other side of the basic behavioral assumption of the MNL model, that is, the independence of irrelevant alternatives (IIA) property. If the error terms across the alternatives have nonzero correlations, the alternatives are correlated with each other and that leads to the violations of the IIA property. The IIA property states that the ratio of choice probabilities among two alternatives in a given choice set is not affected by the inclusion and exclusion of another alternative in the choice set. The choice probabilities that change proportionately indicate the absence of correlation of the error terms across the alternatives [32]. If correlations among the alternatives exist, the ratio of choice probabilities vary when an alternative is included or excluded in the estimable model. Despite these concerns that are originated mainly from its binding assumption, we specified the widely used MNL model for the sake of its computational simplicity [30].

Empirically, the DCE method is increasingly being employed in various applied fields to understand consumer preferences regarding food safety policies and standards [33], commuters preferences for transport modes [34], and to investigate public preferences for natural resource conservation schemes and healthcare programs [35,36]. Despite the growing interest in the application of the choice-experiment method, the use of the methodology to study farmers' choice for suitable agricultural technologies (new crop varietal selection) specifically in developing countries is very scant [37].

3. Research Design and Methods

The choice-experiment method is designed to investigate farmers' preferences toward common-bean attributes to understand their variety selection behaviors so as to inform breeders for priority setting decision making. This requires asking survey participants to make trade-offs among alternative seed varieties specified with a function of bundles of attributes and select a particular option from the given list. The choice-experiment survey development requires a careful definition of product attributes with their levels and experimental survey design [30,31]. The following subsections provide extended explanations of the procedures applied to generate the choice-experiment survey design.

3.1. Definition of Variety Attributes and the Levels

A crop variety selection can be regarded as a discrete choice that involves choosing a suitable variety by making a trade-off among the given alternatives based on the desirability of the attributes. The varietal attributes are characteristics embedded within a crop variety with regard to the production, consumption, and market qualities of a variety. As such, farmers' varietal selection strategies are driven by local agroecological conditions as well as households' specific production goals (for market supply or own consumption) that are described quantitatively (e.g., yield performance) or qualitatively (e.g., yield stability or color).

A mix of qualitative research methods that involve document review, expert consultation, and focus-group discussions were conducted to get firsthand information on breeding programs priority in variety development and the important bean attributes to the farmers. The expert opinions were collected by administering interviews with plant breeders, extension workers, and seed-sector specialists to further understand how the existing bean varietal development and seed delivery programs were performing. This information is relevant because the seed supply chain involves multiple independent organizational structures with regard to breeding, seed production, and distribution of seeds to farmers. Accordingly, a total of six key-informant experts (two representing each organization) from the breeding institutes, extension programs, and public seed enterprises were selected. The selection was based on their experiences in carrying out seed-innovations-related activities in their respective organizations. According to the information mainly obtained from the plant breeders, yield performance (the level of productivity per unit of land), bean growth habits (priority given for the development of bush beans instead of climbers), and bean color were emphasized in varietal development criteria as governing breeding goals.

Additionally, three separate focus-group discussions were held with a total of 42 common-bean growers located in the study areas. The aim was to identify the important bean attributes of farmers' and attribute levels after forming groups based on shared common characteristics. The focus-group studies also helped to understand the common-bean-farming system and the major formidable challenges that smallholders faced in their production process. From the total participants of the focus-group studies, around 17 percent of the discussants came from female-headed households. The three groupings were done with the help of extension workers, and it was based on farmers' wealth status and membership in local seed producer cooperative schemes. Consequently, the first group consisted of "better-off" farmers who own livestock assets (targeting oxen) and land-size ownership of one hectare and above. In this group, farmers representing 16 households participated. The second group was comprised of 14 relatively small farmers (mostly representing farmers who owned half a hectare of land and below). These were also categorized by the government as recipients of food aids through social-security programs. The aim of these groupings based on asset ownership is to exhaustively identify those bean attributes that are more important to the "better-off" and small farmers (see Figure 1). The attendees in the third group of farmers were 12 seed-producing farmers who came from a local cooperative that was established to produce seed and provide to a seed enterprise through contract farming arrangements. According to a key informant in the extension office, the seed-producing farmers are considered to be progressive farmers and are profoundly linked to formal seed markets in the country.

Overall, the group compositions as well as the manageable small group sizes helped to ensure everyone's voice was heard during the session. To this end, each farmer attendee was asked to reflect the strategies employed for variety selection with regard to bean characteristics. Initially, focus-group discussants were asked to list important variety attributes that they consider when selecting a bean variety for planting. Accordingly, inventory of the available bean varieties with 10 attributes (except the agronomic and physiological characteristics) were exhaustively listed out. Then, farmers were again asked to make pairwise rankings of the bean attributes one against the other to select the best attributes from the list (see Figure 1).

The aim of the pairwise ranking was to reduce the number of attributes to manageable sizes so as to reduce the choice complexity. The complexity in the survey resulted in low-quality response generation during the data collection [32,38]. Despite the advantage of collecting rich information with more variety of attributes, increasing the number of attributes exponentially increases the number of choice sets that contributed to the complexity [29]. This was addressed using the pairwise-ranking method that helped to prioritize the attributes which were most important to smallholder farmers (see Figure 1).

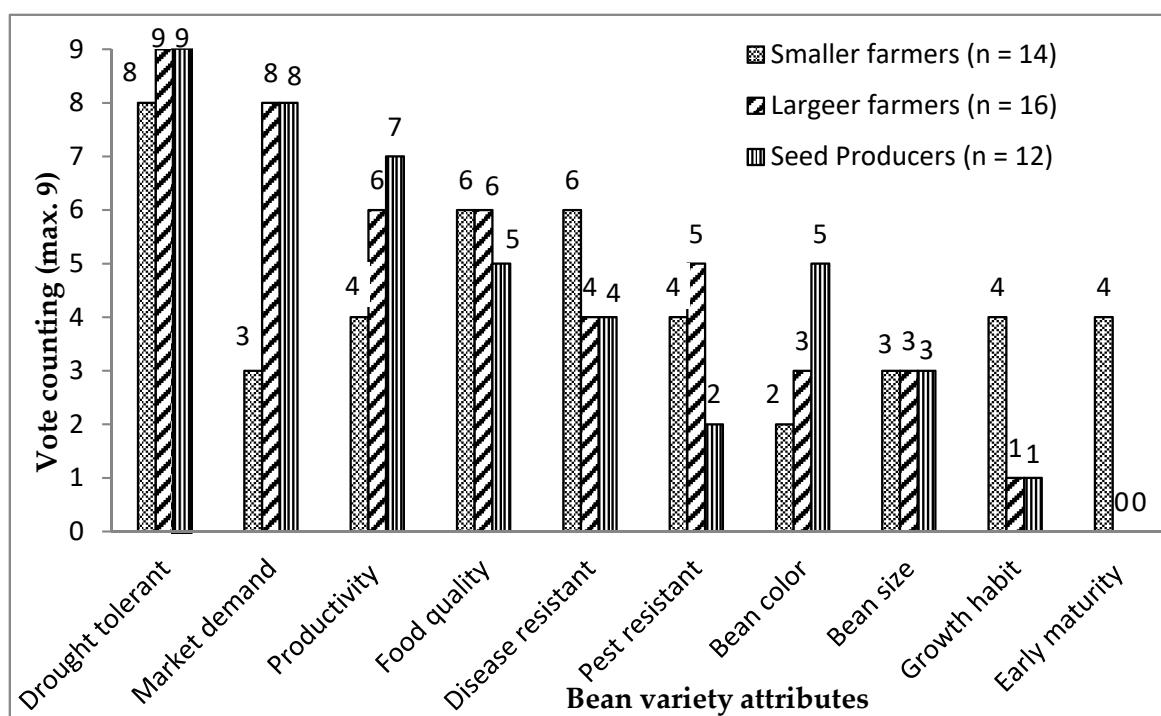


Figure 1. Pairwise ranking of variety attributes in the focus-group discussions.

The most highly ranked attribute is the one with the highest point (the maximum count is 9 in Figure 1) and hence was automatically included in the choice-experiment survey design. Accordingly, drought tolerance was the most important attribute to all farmer groups. This is due to the fact that the study area is vulnerable to frequent drought stress, because climate change involves an increase in temperatures and dry weather that often leads to drought occurrence which further results in plant disease and pest infestation [39]. Hence, three important groups of variety attributes were selected with the goal of minimizing the complexity of the choice process: drought tolerance, yield productivity, and food and market quality attributes—represented by bean color.

In most cases, yield maximization is expected as a major goal for the “better-off” farmers; however, some of the farmers’ variety choices can be determined based on the various bundles of bean attributes that satisfy consumption requirements and taste preferences. Since production and consumption decisions are not separable; responses from the focus-group discussion indicated that farmers’ bean variety selection is partly driven by the food quality and taste preferences of the household members. For instance, one of the discussants in the group formed to represent small farmers explained: “With my limited plot of land, I am producing common beans basically for household consumption. I cannot afford to buy animal products to feed my kids. As a substitution, the red beans are like a bloodless meat for them.” This is also supported by information obtained from expert consultations that food quality preferences and the market values are linked to bean color, and hence, this is the reason to consider bean color in the choice-experiment design.

Furthermore, the use of monetary attribute in choice-experiment design is widely suggested in literature [29,37]. Then, the fourth attribute is the seed cost that farmers spent on the purchase of seed in the formal and informal seed market to cover a hectare of land. Table 1 provides the summary of the selected attributes and the attribute levels after conducting the pairwise ranking.

Table 1. Summary of variety attributes and attributes levels.

Attributes	Attribute Levels		
Productivity (yield in quintal/ha.)	30	22	14
Drought adaptation	High	Low	
Bean color	Red	Speckled	White
Seed cost/ha. (monetary attribute)	ETB 800	ETB 1200	ETB 1600

3.2. The Experimental Design

Designing of choice experiments involves the construction of alternatives that are functions of attributes and attribute levels. With three attributes at three levels and another attribute with two levels, a full factorial design yields a total of 54 ($=33 \times 21$) possible combinations of choice sets. However, the use of a full factorial design is complex and very costly to handle in the survey [40]. As such, the use of fractional factorial designs is recommended to improve the information quality as well as to reduce the choice complexity. The authors of [41] provide interesting suggestions on how to create statistically efficient and best designs by fulfilling two criteria: orthogonality and level balance. We ensured orthogonality by letting attribute levels to vary independently across the choice sets, and level balance is an approximately equal occurrence of levels in the choice sets [42]. We employed the SAS software to combine the selected bean attributes and levels in order to construct the required numbers of the choice cards. Table 2 shows one of the choice cards employed in the field research to collect variety choice information from farmers.

Table 2. An example of the choice card in the experimental design.

Variety Attributes	Bean A	Bean B	Bean C
Yield productivity	14 quintal/ha.	30 quintal/ha.	22 quintal/ha.
Drought adaptation	High	Low	High
Bean color	Red	White	Speckled
Seed cost per hectare	ETB 800	ETB 1600	ETB 1200
I would prefer to plant (Mark X)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Source: Authors own designed choice card, 2018.

The data collection procedure employed a combination of pictorial (image) representation in addition to verbal and text descriptions to display the choice cards to increase respondents' understanding in order to provide reliable responses (see Table 2). In total, eight choice cards were used in this study. Each choice card had three generically designed alternative common-bean varieties. If farmers were provided with labeled seed varieties (instead of the generic labeling, e.g., Bean A, Bean B, etc.) with official released variety names, they would employ a simple shortcut (heuristic) method to choose the familiar variety instead of comparing the attributes in each choice card. Therefore, household respondents were asked to choose one of the three generic alternative varieties that provide the highest level of utility from the preferred attribute for the farm household.

3.3. Administering Survey Instruments

The survey was conducted in 2018 at Boricha district in Southern Ethiopia. Located in the central Rift Valley areas, Boricha's climate is dry, and hence, drought occurrence is frequent. Smallholder farmers were dominantly producing lowland crops such as common beans (*Phaseolus vulgaris* L.), which are the primary source of food and income for poor farmers in these unfavorable lowland locations [43,44]. Additionally, farmers in the district allocate their land for cultivating maize (*Zea mays*) and enset (*Ensete ventricolo-*

sum). Accordingly, most farmers in the study area produce bean intercropped with maize and enset.

A multistage sampling technique was used to select households who participated in the choice-experiment survey. In collaboration with extension workers, a total of six study Kebeles (the smallest administrative unit in Ethiopia) in the district were selected based on the volume of bean production and other observable topographic variations among the Kebeles. Accordingly, Shelo-Abore, Sheleo-Belela, and Sadamu-Challa (abbreviated and hereafter called ABC Kebeles) were purposefully chosen given the relatively larger volume of bean production. On the other hand, farmers in Korangoge, Shondololiwo, and Shamanagodo (shortened, KSS Kebeles) were located in densely populated areas leading to smaller average land ownership. Overall, the household survey was carried out in 2018 in face-to-face interviews with 167 randomly selected common-bean grower respondents.

Prior to implementing the household survey on the sampled households, a pilot study was carried out with six randomly selected households, and the survey materials were further modified in line with the findings from this pre-test. The information in the choice cards (that shows the entire production process from seed acquisition to yield harvesting stage) was briefly explained to the farmers in order to enhance their understanding about the choice situations and thereby easily state their choice. Ultimately, the choice-experiment survey produced a panel of information of 1336 choice tasks yielding a total of 4008 observations. A separate household survey questionnaire was also used to capture household socioeconomic characteristics and their actual seed variety selection strategies. Using the information obtained through the mixed research methods employed in the fieldwork, the next section extensively presents the exploratory analysis.

4. Results and Discussion

4.1. Socioeconomic Statistics

Table 3 presents the descriptive statistics of the socioeconomics for sample farmers involved in the survey. The survey indicated that 86 percent of the respondents were from male-headed households. On average, farmers own 0.63 hectares of farm holding size (ranges from 0 to 3.25 hectares). This indicates that average farm holding size is almost half a hectare. Study evidences indicated that the further dwindling per capita land sizes due to increased population number are considered as the major determinants of food insecurity and poverty problems in Ethiopia [45]. Furthermore, the survey indicated that close to two thirds of the sampled households own not more than half a hectare of cultivable land, and only 25 percent of the sampled farmers own more than one hectare.

Table 3. Descriptive statistics of household respondent characteristics.

Socioeconomic Factors	Mean	Std. dev.	Minimum	Maximum
Gender of the household head	0.86	-	0	1
Total farm-holding size (in ha.)	0.63	0.44	0	3.25
Livestock in tropical unit	2.63	1.73	0	10.32
Lagged off-farm income	0.52	-	0	1
* PED participation	0.36	-	0	1
Access to seed credit	0.18	-	0	1
ABC-Kebele	0.40	-	0	1
Total sample: $n = 167$				

* PEDs = pre-extension demonstrations, Std. dev. = standard deviations.

Livestock assets play a significant role as a source of animal traction in the household economy. Livestock also serves as a vital source of wealth and livelihood security particularly during drought periods. Farmers in the study area kept cattle, sheep, goats, chickens, and equine. To use a standardized single unit for comparison across households,

a weighted score of tropical livestock units (TLU) was used to measure the various types of livestock assets owned by a particular household. To this end, we employed the conversion factors suggested by authors of [46] in their study that specifically address the livestock sector. According to the authors, livestock resources in tropical regions (e.g., SSA) are categorized as: cattle = 0.5, sheep/goats = 0.1, chickens = 0.01, horses = 0.5, and donkeys/mules = 0.6. On average, the survey indicated that a household owned 2.63 tropical livestock units (TLU).

About 52 percent of the respondents earned income through off-farm activities during the year before the survey was conducted. This implies that almost half of the households in the sample do not have off-farm employment opportunities and hence entirely relied on farming income for their livelihoods.

According to one of the breeder key informants, pre-extension demonstrations (PEDs) are platforms employed by breeders to provide first-hand information for farmers about a recently released variety before starting large-scale seed production with the newly released variety. Among the sample farmers, only 36 percent of respondents reported that they got the opportunity to be involved in PEDs. According to one of the key informant breeders, farmers with larger farm holdings have more opportunities to participate because they can provide parts of their plot for the variety verification tests. This indicates that the majority of farm households who participated in this survey had limited opportunities to access information directly through the plant breeders about the desirable characteristics of new cultivars. Majority of the participating farmers in the focus-group discussions allocated their cultivable land for the production of an old bean variety known as Hawassa Dume, which was released a decade ago. According to a breeder key informant, 21 new bean varieties were released after Hawassa Dume through the national agricultural research centers that are mandated to develop and release pulse crop technologies in the country. However, those new innovations are not adequately adopted by farmers, and still, plots are dominantly covered with Hawassa Dume variety. In this regard, the focus-group discussants were asked about the reason for their inclination toward the old variety despite the release of new bean varieties in research institutions. This was the response from one of the discussants: “those bean varieties are not promoted in the same level with new maize varieties. To be honest, I do not have any information about these bean varieties. Many farmers in my surrounding (including me) are planting varied types of improved maize varieties, but we are hesitant to plant a new bean variety fearing a crop failure because we do not know about the adaptability potential of these new varieties to our local conditions.”

The survey response also indicated that only 18 percent of respondents have credit access to buy improved varieties. Compared to the cost incurred for purchasing local bean varieties, farmer responses in the survey indicate that the capital requirement for improved seed varieties is relatively large, and hence this poses a significant challenge for poorer farm households to invest in improved varieties. The credit concern was also apparent in the focus-group discussions, and farmers stated that the high cost incurred to buy improved varieties. Hence, constraint to access credit services were one of the major restricting factors for smallholders' adoption of improved seed technologies in the study areas. This has been explained by one of the discussants in the focus-group studies: “the main hindrance factor for my limited use of improved varieties is its cost compared to that spent to purchase farm-saved seeds in the local grain market. The cost of improved varieties is approximately twice that spent on local seeds. Additionally, fertilizer is a key input that need to be combined with improved varieties, and hence this further raises the cost of using improved varieties. Additionally, the improved bean varieties are not provided in smaller bag packs. These costs are unaffordable to cover a limited plot of land without any credit service, which is currently absent.”

Forty percent of survey households were located in ABC Kebeles, whereas the remaining shares of sample households were in the KSS Kebeles of Boricha district.

4.2. Attribute Ranking in Actual Seed Selection

Before conducting the choice-experiment survey, farmers were asked to state their preferred bean attribute that determines the actual variety selection strategies using a separate survey questionnaire. The goal was to triangulate the information collected through the focus-group studies and choice-experiment surveys and thereby to enhance data quality and validity. To this end, the variety attributes identified using participatory research method were provided to farmers, and they were asked which one of the varietal attributes they focused on most in selecting bean for planting.

The statistics of their responses about attributes ranking is disaggregated across locations given the observable socioeconomic variations among the research sites (Kebeles) (see Figure 2). The survey shows that there is a mean variation in landholding size between the two Kebele categories. Thus, the average farm size that farmers owned in ABC is twice that of their counterparts in KSS. However, most of the farmers in ABC Kebeles were located in the lowland areas where frequent drought problems are common. Given the diverse household and agroecological characteristics, the survey result indicated that the share of households that selected varieties with high-yield productivity attribute in KSS was higher than the proportion of farmers that relied on the same attribute in ABC Kebeles (see Figure 2). Hence, productivity was a highly preferred attribute in KSS, whereas drought tolerance was a primary choice in ABC Kebeles when they selected bean varieties.

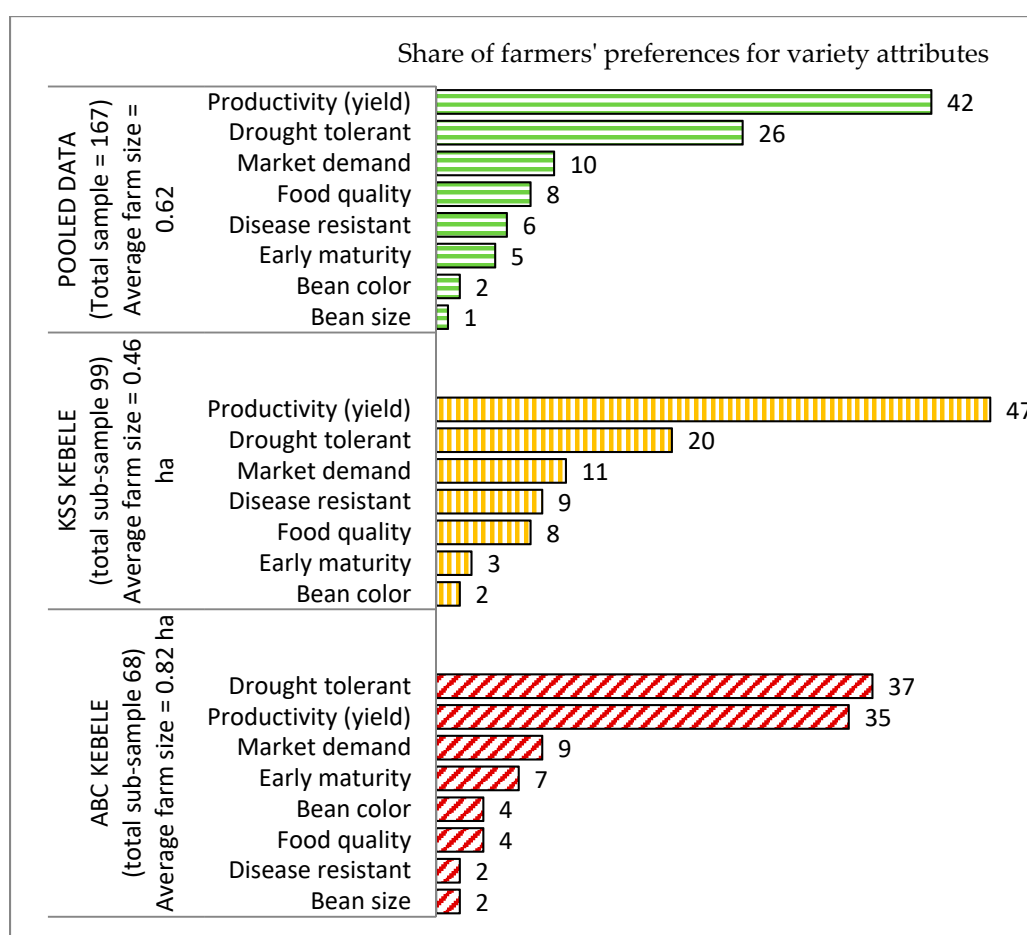


Figure 2. Attribute ranking obtained from household survey.

The survey results further indicated that the share of farmers that preferred high-yield productivity was almost twice as high as those farm households who opted for drought tolerance in KSS (see Figure 2). On the other hand, farmers in ABC had a slightly higher preference for varieties with drought-tolerance capability (37 percent) than for yield

performance (35 percent) due to the concern for the frequent drought conditions in those specific areas.

Overall, the pooled data shows that 42 percent of the survey respondents focused on higher productivity in their actual variety selection. This is followed by 26 percent of the sampled respondents who preferred drought-tolerant varieties. These results imply that farmers mainly consider drought-tolerant capability and high-yielding productivity performance in their cultivar selection in water-stressed and harsh environmental conditions, which is characteristic of the study area.

The previous descriptive analyses could not fully provide quantitative information accounting for the effect of each observation in the variables of interest to aid breeders for priority settings. This is due to the fact that the descriptive statistics (which was explained on average terms) do not provide impactful findings on farmers' specific attribute preferences. Hence, the econometric analysis which is estimated with and without the socioeconomic interactions so as to further provide relevant findings about farmers' varietal selection strategies. Furthermore, the econometric model estimation provides information regarding the existence of attribute preference heterogeneity and taste variations across households.

4.3. Empirical Model Specification and Estimates

The model-estimated results provide quantitative information on farmers' inclination toward specific variety attributes. As noted above, the estimated results were presented in two ways: the basic model (without interactions) and extended model (with interaction terms) analyses. The basic model solely provides the estimated results of the attributes entered into the model, whereas the extended model incorporated the household socioeconomic characteristics to note the existence of farmers' taste variations in variety selection. The decision to include household socioeconomic characteristics has dual purposes. These allow one to investigate the observed preference heterogeneity among the sample respondents and also to increase the explanatory power of the estimated model. This is because the more information included into the estimated model, the less likely that information is to be accumulated in the unobserved error term which also affects the choice outcome [30,31].

The dependent variable (i.e., variety choice) is defined as the respondent's selection of an option from the three hypothetically designed alternative bean varieties. It is coded as a dichotomous variable represented by a value 1 for the chosen variety and 0 for the two remaining varieties.

In specifying the explanatory variables, the attribute levels were entered into the dataset for model estimation as observations. The variables used in the model involve both continuous and dummy types. The levels of productivity and the monetary (cost) attributes are specified as continuous variables, whereas drought adaptation and bean color are qualitative variables and hence coded as dummy variables. To avoid the problem of a dummy-variable trap, the red bean was assigned as a base comparator or reference point. In coding the white dummy variable, for instance, 1 is coded if the variety in the choice card with the white-colored bean is chosen, whereas 0 if one of the remaining varieties is chosen. Similarly, drought tolerance is coded with a value of 1 if the "high" adaptation is chosen or can take a value of 0 otherwise (also this dummy serves as a base comparator).

To estimate the model with interaction variables, some of the households' socioeconomic factors defined in the descriptive statistics part of this section were introduced. Accordingly, farm-holding size was considered to be a proxy variable to measure yield, farm income, and household level of food security. This variable is important because small farmers are more risk cautious and hence assumed to have mainly opted for varieties with yield stabilizing attributes (e.g., drought tolerance). Livestock assets and off-farm income opportunities are included with the assumption that farm households with more livestock assets and access to off-farm income opportunities have a higher tendency toward yield-maximizing attributes. Given breeders' priority to develop new varieties that is mainly based on yield superiority, farmers who participated in PEDs are presumed to

have a higher propensity toward a particular variety with yield advantage. Given the land ownership variations between the two research sites, and also guided by the safety-first principle, farmers located in the KSS Kebeles are assumed to have a higher inclination toward yield-stabilizing attributes.

Model Estimates

The maximum likelihood estimates of the multinomial logit model are generated using Stata 14 software and shown in Table 4. In these analyses, the first two columns indicate results from the basic model whereas the last two columns present results from the extended model.

Table 4. Multinomial logit model estimates of farmers' varietal attribute preferences.

Variables	Coeff.	Basic Model Std. Err.	Coeff.	Extended Model Std. Err.
Yield productivity	0.046 ***	0.006	0.025 **	0.008
High adaptation	1.896 ***	0.077	2.59 ***	0.178
White-colored	−1.298 ***	0.101	−1.311 ***	0.101
Speckled-colored	−0.867 ***	0.096	−0.873 ***	0.097
Seed cost (monetary)	−0.0015 ***	0.0001	−0.002 ***	0.0001
Productivity x Farm size	-		0.002	0.006
Productivity x Livestock	-		0.001	0.001
Productivity x Off-farm	-		0.015 ***	0.005
Productivity x PED	-		0.003	0.005
Productivity x ABC	-		0.020 ***	0.006
High adaptation x Farm size	-		−0.020	0.170
High adaptation x Livestock	-		−0.027	0.040
High adaptation x Off-farm	-		−0.505 ***	0.143
High adaptation x PED	-		−0.059	0.151
High adaptation x ABC	-		−0.724 ***	0.154
Log-Likelihood	−2166.54		−2142.09	
Wald χ^2	830.53		838.88	
Prob > χ^2	0.0000		0.0000	
AIC	4343.09		4314.21	
Number of observations	4008		4008	

***, **, and * are statistically significant at 1% level; 5% level, and 10% level, respectively.

The explanatory powers of the estimated models (that is, the statistics at the bottom of the table) indicate that the model specification best fits the data (at a 1% level). Additionally, the Akaike information criterion (AIC) statistic was presented to further evaluate the model fit performance. The decision rule for the AIC is that the model with the smallest AIC statistic is the best compared to all other candidate models [47]. Hence, the extended model has a lower AIC statistic (e.g., 4311) in comparison to the basic model (e.g., 4343) (see Table 4). This indicates that the explanatory power of the extended model is improved, and this is mainly because of the decision to incorporate the household socioeconomic characteristics interaction variables in the estimated model.

In the basic model estimation, the results demonstrated that all the estimated coefficients hold the expected signs, and the estimated bean attributes are statistically significant (at 1% significance level). These estimated coefficients denote the existence of a significant correlation between farmers' variety selection and their response to changes in the levels

of the bean variety attributes. Supplementing with the pairwise-ranking findings from the focus-group studies, the econometric results overall indicated that farmers have a higher preference for beans with drought-tolerance and higher-yielding characteristics (see Table 4). The negative signs in the coefficients of the white and speckled colored varieties imply that farmers have a higher tendency toward selecting red-colored bean varieties.

The evaluation of the magnitude of the coefficients indicated that drought tolerance is the highly preferred attribute in the model. It has been learned from farmers that droughts had occurred in the survey season. This might be the driving force for most of the respondents to emphasize drought-tolerant varieties in this survey. To express this conceptually, drought-tolerant varieties provide the highest utility (net benefit) to farmers, assuming that everything is held constant. This result confirms the findings of the authors of [48] who attest that farmers will enhance the uptake of tissue culture banana seed in central Uganda only if the given technology is best adapted to drought stress. The cultivation of drought-tolerant varieties ensures yield stability and, hence, risk-cautious farmers are highly inclined to secure subsistence consumption. This finding supports the commonly held intuition that seed varieties with stress-tolerant characteristics have a higher probability of being selected in water-stressed environments so as to ensure yield stability, according to the assumption of the safety-first criterion [49].

The negative coefficients of the dummy-colored variables in the model are consistent with the authors findings of [50], indicating the dominant cultivation of red-colored varieties in the surrounding lowland areas. The result implies that farmers have a lower preference for speckled and white-bean varieties for cultivation in comparison to the red beans, assuming that the other factors remain the same. This is also in line with the findings from the focus-group discussions. The discussants noted that the increased local and national market demand for red beans was the major driver for farmers' preference toward red-colored varieties for cultivation.

The negative sign on the coefficient of the monetary attribute (i.e., seed cost) is consistent with the demand theory in economics, indicating that farmers are less inclined toward the cultivation of expensive seed varieties. Results from the household survey also indicated that the majority of farmers relied on locally accessed farm-saved and cheap local seeds instead of buying relatively expensive but high-yielding seed varieties from formal seed enterprises. These responses further revealed that the high costs of improved varieties relative to the local seeds coupled with limited access to credit for farmers could be the major determinants for low adoption of improved cultivars. As noted earlier, this finding is consistent with the concerns of farmers who participated in the focus-group discussions with regard to the high costs of improved varieties in the market. In this regard, the authors of [51] emphasized the desirability of a short-term government intervention in the agricultural market to ensure farmers are getting a fair price for their produce, proving the technology profitable. The authors further suggested that credits and subsidy strategies are essential to nudge farmers for the adoption of innovative seed varieties in Southern Ethiopia.

The extended model estimation indicated that all the included interaction variables had the expected signs (see Table 4). The positive signs for the interaction variables with productivity attribute prove that the manner of ownership of farmer endowments and the availability of key information (e.g., PED) is determinant for farmers' preference toward higher-yielding varieties. Additionally, the negative signs for the interaction variables with adaptability are consistent with the widely held intuition that risk-averse and subsistence-oriented households (e.g., those who have limited farm endowments) have a higher preference for yield-stabilizing attributes. This is in line with the information obtained from the focus-group discussants in that the lack of supply of drought-tolerant beans is one of the daunting problems in the face of frequent climatic variability. This is because drought is a formidable challenge in complicating agricultural production even for farmers who have bigger farm holding in the study location. A farmer discussant who attended one of the group discussions explained: "Among the several constraints for crop

production in the surroundings, the challenge posed by frequent drought is enormous. This is frequently occurring in our area. I am repeatedly planting a local bean variety for household consumption with an assumption that it matures very quickly before the dry season arrives. To me, the early matured bean varieties are the key to break the cycle of hunger until maize is harvested and helps to provide my family with balanced nutrition.”

The result further indicated that the interaction variables with livestock, off-farm involvement, and the location dummy were statistically significant (see Table 4). These interactions with productivity attribute carry positive signs, whereas the interactions with the adaptation attribute had negative signs. Based on the safety-first theory, households that own more livestock resources and have access to off-farm income opportunities cannot worry equally as compared to those farmers with limited livestock and that lack access to off-farm income-generating activities. This is so because the former group of farmers can smooth household consumption fluctuations in the face of emerging biotic and abiotic crop stresses. Hence, the interactions with productivity attribute had a positive sign implying that affluent farmers have a higher inclination toward yield-maximizing attributes than drought adaptation which contributes to yield stability. In contrast to the descriptive analyses, the coefficient in the location dummy variable indicates that farmers in ABC have higher preferences toward yield-maximizing attributes (productivity) than for yield-stabilizing attributes (high drought adaptation). In this case, the effect of a higher average land ownership in ABC locations in comparison to farm characteristics in the KSS areas outweighs the impact of drought challenge in conditioning farmers’ variety selection.

Overall, the results from the mixed data sources indicate that farmers are in dire need of drought-tolerant crops, mainly due to the impact of the frequent drought occurrence in the region. In addition, according to various sources, the anticipated food insecurity challenges due to the booming population in the SSA region, in general, and in Ethiopia, in particular, can be reversed only when the small-scale farmers can buy and use those newly released breeding innovations that have been proven highly productive in the face of changing climatic conditions. However, due to the diverse agricultural production requirements, it is highly essential to provide the desired and farmers’ preferred crop varieties instead of relying on the usual “one-size-fits-all” approach for crop research improvement and variety release system. Therefore, once farmers are provided with the desired varieties, the results obtained from farmers’ responses demonstrate that farmers are willing to invest in climate-smart and high-yield seed innovations. Nevertheless, this can only be materialized if breeding interventions are supplemented but not supplanted with other pro-poor development initiatives, such as ensuring access to farm credits and insurance services.

5. Conclusions

Despite the government’s efforts to modernize the national seed sector for several decades to realize agricultural development in Ethiopia, the country is yet to achieve major improvements in agricultural production and fostering food security. This is mainly linked to the limited use of divisible agricultural innovations (most importantly, new seed technologies). One of the major reasons for farmers’ relying on the cultivation of older crop varieties is postulated to be associated with the mismatch between farmers’ pressing problems and breeders’ priorities in variety development and release. Accordingly, this study employed a discrete choice-experiment method to explore the major determinants of Ethiopian bean farmers’ variety selection strategies in relation to preferences for bean attributes due to the prevailing extreme climatic conditions. The study was carried out with a major aim of informing policymaking in breeding priority setting based on survey information obtained from the lowland and dryland areas of Southern Ethiopia, where frequent drought stress has become one of the major formidable challenges of agricultural production.

A multinomial logit econometric model was estimated to generate plausible quantitative results about farmers’ bean attribute preferences. The statistical results demonstrated

the existence of divergence in farmers' attribute preferences and breeding programs priorities. Specifically, the econometric results further informed that drought-tolerant seed varieties are more preferred than any other attribute in the estimated model. The higher preference toward drought adaptability than yield performance in the model estimation is consistent with the findings in the focus-group discussions. Hence, results from the focus-group discussions (and since the majority of farmers participated in the survey owned cultivable land below half a hectare) show that these farmers were highly inclined to select drought-tolerant seed varieties compared to any other attribute as evidenced in the pairwise-ranking process. This is mainly due to the fact that climatic challenges have daunting concerns for farmers in their crop varietal selection strategies. Additionally, results from the extended model also indicated that household wealth status (farm size, livestock, and off-farm income), and location-specific variations are significantly correlated with farmers' attribute preferences. The statistically significant interaction variables confirm the existence of attribute preference heterogeneities across farmers as opposed to the existing working condition to supply uniform varieties to varied locations. This is highly essential to design breeding profiles compatible with context-oriented agricultural systems and specific producer segments. Overall, the results confirmed that the top-down crop research improvement and seed delivery programs seem to follow a "one-size-fits-all" for wider technology dissemination approach. Thereby, the provision of the most desirable and preferred crop varieties by farmers has been very limited in environmentally risky and water-stressed locations specifically in Southern Ethiopia.

The substantially higher valuation for drought tolerance as compared to yield potential is a strong argument for setting breeding priorities to target the release of innovative climate-smart cultivar profiles. Accordingly, plant-breeding policies need to be congruent with pressing problems of farmers about crop technology development and selection. Overall, the study provided two interesting insights to guide smallholder farmers toward increased use of the latest breeding innovations. Firstly, putting in place demand-driven breeding strategies in order to develop high-yielding and climate-smart cultivars that cope up the negative impacts of rapidly changing climatic conditions is highly essential. In this regard, the focus should be mainstreaming the development of drought-tolerant bean varieties (replicating the best practices of the initiative called "Drought Tolerant Maize in Africa—DTMA" project) in order to adapt the negative impacts of climate change. Secondly, pro-poor capacity development initiatives through credit, insurance, and subsidy services are vital in enabling poorer farmers to get access to key agricultural innovations. To put it in short, the rapid-breeding strategies targeting to release farmers' preferred innovative varieties compatible to the local contexts is crucial to achieve the national and global sustainability goals in hunger and poverty reduction, fostering economic growth, climate action, and biodiversity protection in Ethiopia.

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