Plant Genetic Resources: Characterization and Utilization

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Tree seed supplier alternatives and growers-specific factors on utilization in Northwest Ethiopia

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Research Article

Cite this article: Mehari AB, Abtew AA, Mulatu YM (2025). Tree seed supplier alternatives and growers-specific factors on utilization in Northwest Ethiopia. *Plant Genetic Resources: Characterization and Utilization* 1–9. https://doi.org/10.1017/S1479262124000443

Received: 12 January 2024
Revised: 5 June 2024
Accepted: 6 June 2024

Keywords:
growers; mixed logit regression; tree seed suppliers; tree seed

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Abstract

This study investigated the factors influencing growers in the selection of seed suppliers in the Amhara region of Ethiopia. A total of 385 grower were selected using simple random sampling method. A mixed logit regression model was used to the analysis data that have 1284 observation. The result reveal that high seed purity was negatively related to the selection of alternative supplier. As the rating of seed purity increased, the probability of selecting very high-quality seed suppliers also increased. The availability of tree seeds during the desired time period had a significant influence. Higher perceived availability, categorized as high or very high, decreased the likelihood of promptly obtaining seeds from suppliers compared to when the seeds were not available. The evaluation rating of germination increases the probability of choosing suppliers with high or very high germination rates in the respective category. Growers with more experience are more likely to choose private enterprise suppliers. The implementation of appropriate quarantine measures has a positive influence on supplier selection for the groups AFE and EFD-CEC. Training in tree seed collection reduces the likelihood of choosing enterprise and AFE suppliers. Moreover, the successful production of a greater number of tree species in the nursery positively influences the probability of sourcing from enterprise suppliers. This analysis highlights the significance of seed purity, germination, quarantine measures, and the number of species produced, as factors that influence the likelihood of selecting alternative seed suppliers.

Introduction

The tree seed suppliers can be characterized by the tree seed growers based on the desired seed they offer and the supplier's ability to attract them. While there is an opportunity to obtain tree seeds from multiple suppliers, the availability of the desired tree seed is uncertain. Utility theory guides decision-making by providing rules for combining the modeling of probabilities and human preferences when choosing different objects (Fishburn, 1989; Zhang and Neumann, 2014; Akkaya, 2021; Vilela and de Carvalho Lopes, 2022; Chakrabarty and Kanaujiya, 2023; Lahiri, 2023). It offers a mathematical approach to measure and utilize qualitative information, allowing decision-makers to be included in complex models (Zhang and Neumann, 2014; Akkaya, 2021; Vilela and de Carvalho Lopes, 2022; Lahiri, 2023). It breaks down decisions into these two components, enabling individuals to consider both the likelihood of outcomes and their personal preferences (Lak and Khairabadi, 2022; Shakerinava and Ravanbakhsh, 2022). The provision of tree seeds, as a valuable natural resource and essential utility sought by growers, holds appeal for various types of growers due to the benefits they offer.

Ethiopia has set a forest development goal that requires genetic improvement to address climate change resilience and biodiversity degradation (Gebreegziabher *et al.*, 2021; Rawat and Tekleyohannes, 2021). This involves increasing the demand for forest products and engaging in land restoration missions. The initiatives could require the physiological and morphological quality, as well as sustainable supply, of tree seeds to achieve the desired development of forest land. The identification and analysis of genetic resources are crucial in ensuring the development of new varieties with a broader genetic background as seed sources, ranging from natural forests to agroforestry areas (Bantihun Mehari and Abera, 2019; Korpelainen, 2023; Lovrić *et al.*, 2023; Visioni *et al.*, 2023). Forest biodiversity also plays a significant role in mitigating the adverse impacts of climate change. Therefore, the introgression and conservation of local germplasm are necessary to facilitate the development of new varieties that can thrive under different conditions and respond to various forms of stress (Zhang *et al.*, 2020; Sharma *et al.*, 2020; Van de Peer *et al.*, 2021).

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Generally, to prevent large-scale failure in forest landscape restoration (FLR), several measures are recommended. These include conducting national assessments of seed supply and demand for restoration, reviewing FLR targets and funding cycles, promoting knowledge sharing and experiences related to seed supply and selection, facilitating seed exchange across landscapes, and implementing regulations for seed quality (César *et al.*, 2020; Höhl *et al.*, 2020; Stanturf and Mansourian, 2020). This study aims to answer the research question: How would increasing the number of suppliers for a certain priority species of tree seed affect the likelihood of more growers buying that seed?

This study employs various professional terms that are consistently used throughout the article and should be defined. Tree nurseries play a vital role in nurturing tree seedlings. In this context, the term 'nursery' specifically refers to a 'tree nursery'. Growers are individuals who receive, purchase and sow tree seeds in nursery fields or land restoration areas for their specific purposes. They serve as the respondents for data collection in this research. Tree seed suppliers, on the other hand, are individuals who provide tree seeds to these growers.

While a draft tree seed proclamation has been prepared for review at the national level in Ethiopia, there is currently no existing proclamation that introduces the tree seed system. This study focuses on examining the management of the tree seed system in Ethiopia, particularly in the Amhara region.

Forest trees make significant contributions to the productivity and conservation functions of the global community. In Ethiopia, they have played a crucial role in restoring degraded landscapes for various purposes. The objective of this study is to examine the preferred tree species of growers and compare them with the actual species they utilize. The study aims to explore the factors that influence growers' preferences for tree seed suppliers, focusing on the attributes of the seeds and the behavior of the suppliers. The study seeks to provide insights into the impact of supplier type availability on grower decision-making, contributing to a better understanding of market dynamics and strategies for promoting and distributing priority tree species seed.

Methodology

The research was conducted from May 2022 to December 2022 in Amhara National Regional State (ANRS), Ethiopia. It covers a land area of 15.7 million hectares, of which approximately 35% consists of forests, shrub lands or woodlands (Sisay *et al.*, 2017). The region has an estimated population of 20,558,851 in 2016 (CSA, 2016). The region is characterized by a predominantly warm and temperate climate with mean maximum temperatures of 26.0, 35.8 and 23.6°C for different areas (Ayalew *et al.*, 2012).

Research design

The research utilized a survey research design, which involved both formal and informal seed suppliers. The self-supplying category was represented by informal suppliers, while the AFE seed suppliers belonged to the formal seed supplier category.

Sampling size

Tree seed growers were selected as the sampling unit for this research project. The respondents consisted of individuals from private and governmental nurseries, as well as seed business employees. A multistage sampling method was employed to select the sample of respondents. In the first stage, four districts were identified and chosen from the Amhara region using stratified sampling. The Amhara region was selected as the study area due to the observed severe degradation and deforestation, aligning with the goal of achieving the national Green Economy objective (Lemenih and Kassa, 2014; Federal Democratic Republic of Ethiopia, 2019). The survey area was selected based on initial observations that indicated a substantial number of tree seed sources and growers in the area. The districts were identified and selected using systematic sampling. Four administrative districts in Amhara that was chosen for the study were Bahir Dar, Debre Markos, Gondar, and Dessie. The respondents were selected from the total district tree seed growers who were bought from tree seed suppliers involving self-suppliers, communal, private enterprises, AFE and EFD-CEC.

The selection was based on the criteria: the proportion of area actively engaged in seed production, the closeness of the area for infrastructure and program on the planting campaign at the time of data collection. Appropriate structured clothed ended questions were asked to consider the respondents' involvement.

In the second stage, the study focused on tree seed growers. Respondents were identified from among a group of active tree seed growers. These included individuals, self-supplying groups, Enterprise TS suppliers, AFE and EFD-CEC.

In the third stage, systematic random sampling was used among the total number of growers. Thus, to calculate the amount of sample the following equation (equation 1) was employed. Moreover, using systematic random sampling technique, 385 tree seed producers were determined and selected using a formula that is used for large size sample formulate by (Cochran, 1977).

$$n = \frac{Z^2 pq}{e^2} \tag{1}$$

$$\frac{1.96^2 0.5 \times 0.5}{0.05^2} = 385$$

To estimate this equation, the following concepts were considered:

Sample Size – n: It is the total number of growers in the study area. The main design question here is: how many of the *n* growers should be selected for the interviews.
The margin of Error: A ± 10% close estimation of any common socioeconomic characteristics were considered to estimate the sample size.
Confidence Interval: A 95% confidence level with a 5% standard error were considered. That is, $e = 0.05$ and $z = 1.96$. However, in this research case, the population size were sourced from Bureau of Amhara Agricultural finite.

The final sample consisted of approximately 385 tree seed growers were dispatched proportionally to the group of growers, including governmental, communal, nongovernmental organization and enterprise populations from the four study areas. The sampling was conducted using simple random sampling, with proportions determined for each sampling area.

Data collection

The respondents who were selected for this research need to primarily categorize as the tree growers whose tree seed supplier were

https://doi.org/10.1017/S1479262124000443 Published online by Cambridge University Press

first priority. So that, the first question 'From whom tree seed supplier did you obtained the tree seed?' were asked.

The variables listed in Table 1 were selected based on literatures and manuals in accordance with the research context on tree seed of prioritize species. However, it does not focus on a specific single species. Instead, the species that this research were focused on preferences by growers were ranked. The type of variables were excluded as a result of the species the research concerned. For example, the treatment the growers applied were excluded owning to the preferred species could require and not required pretreatment for germination. Instead of this leveling the germination status of the seed were ordered with ordered scale.

Data analysis

Mixed logit choice model

In contrast, mixed logistic regression models do not rely on the IIA assumption. These models are more flexible and can handle dependencies and correlation among observations within groups or clusters. By including random effects, mixed models can capture unobserved heterogeneity and account for potential correlations within groups, making them suitable for analyzing hierarchical or clustered data.

Mixed logistic regression and multinomial logistic regression are distinct methods used for different purposes. Mixed logistic regression is appropriate for hierarchical or clustered data with a binary outcome variable, allowing for modeling fixed and random effects. Multinomial logistic regression is suitable for categorical outcomes with more than two response options. The choice between the two methods depends on the nature of the outcome variable and research objectives. Mixed logistic regression assumes independence of observations within groups, linearity of fixed effects and normality of random effects. Multinomial logistic regression assumes independence of observations and proportional odds across response categories. Mixed logistic regression provides more flexibility and can handle dependencies and correlations within groups, while multinomial logistic regression relies on the IIA assumption, which can be restrictive. If the IIA assumption is violated, mixed logistic regression may be preferred. Ultimately, the choice should consider the data characteristics, research goals and assumptions of each method. So overlapping or nested categories of the date resulting in pushes to use accepting mixed and excluded the multinomial logit regression method. If the categories within the outcome variable are not mutually exclusive or exhibit a nested structure, the IIA assumption may not hold.

The presence of correlation in choices among alternatives challenges the assumption of independence of irrelevant alternatives (IIA) in traditional multinomial logit and conditional logit models.

The mixed logit model, also known as the mixed multinomial logit model, random-parameters logit model, logit kernel model,

Table 1. The variable description and expected interaction

No.	Variables	Description of the variable	Type of variable	Expected interaction
1.	Tree seed suppliers	The supplier is categorized under informal coded as individual = 1, self-suppliers = 2, Group-organized = 3, Enterprise = 4, AFE = 5, and EFD-CEC = 6	Outcome/ categorical	
2.	Number of species produced	The number of preferred species the respondent raised in nursery is producing in this year. The respondents were selected tree species from a total of 28 species that are familiar in the study area.	Continuous	(+)
3.	Number of seedlings produced	The number of seedlings produced in the nursery.	Continuous	(+)
4.	The goodness of seed germination	The not good and good answer of the foreman to the germination of the received tree seed. 0 = low, 1 = high	Ordinal	(+)
5.	Quality of tree seed	Supplier's tree seed quality jugged by planters while they observe and use it how they are level it based on the code provided. The code is given as 1 = Lower; 2 = medium; 3 = higher; and 4 = very high	Ordinal	(+)
6.	Expensiveness	The expensiveness of the tree seed the planters purchased from suppliers. Coded as 0 = Expensive and 1 = Cheap.	Ordinal	(+)
7.	Available in time	The agreement of the planters that the availability of the tree seed that the suppliers supply. Do you agree on the time that tree seed is supplied in time from the suppliers? 1 = Disagree; 2 = agreed; 3 = Strongly agreed; 4 = Very strongly agreed	Ordinal	(+)
8.	Germination	Does the obtained or purchased tree seed from primary suppliers germinated well? The code provided as 1 = Low; 2 = Medium; 3 = Higher; 4 = Very high	Ordinal	(+)
9.	Species need satisfaction	The observation the planter possessed jugged to the level of their primary seed demand satisfaction resulting from tree seed seedling. The code provided as 1 = Low; 2 = Medium; 3 = Higher; 4 = Very high	Ordinal	(+)
10.	Experience	Number of experience the planter have	Continuous	(+)
11.	Quarantine	Number of times the planter get inspection from quality assurance quarantine office	Continuous	(+)
12.	Training	Number of times the planter get training from forestry experts	Continuous	(+)

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or hybrid logit model, is commonly used to analyze the probability of selecting one of several unordered alternatives. It accommodates the violation of the IIA property by allowing for individual-specific parameters and capturing heterogeneity in decision-making processes.

In the context of this study on tree seed supplier selection, the decision-making process of tree growers is assumed to align with random utility theory. According to this theory, individuals are rational and prefer options that offer the highest level of satisfaction. The satisfaction derived from a particular choice comprises deterministic and random elements.

The chosen mixed logit model is suitable for the data in this research because it accounts for the unequal heterogeneity of alternatives considered by respondents. It satisfies the assumption that all alternatives are equally related to the attributes that cannot be manipulated by mixed logistic regression.

The mixed logit model is particularly advantageous over the conditional logit model in certain situations, as discussed by Hess *et al.* (2012) and Perez-Lopez *et al.* (2022). It is better equipped to handle choice sets with multiple dimensions, nested alternatives and heterogeneity among respondents. In the context of supplier alternatives, where multiple combinations of suppliers exist, the mixed logit model is well-suited.

Hess *et al.* (2012) emphasize that the mixed logit model allows for estimating individual-specific parameters, which is essential when alternatives are heterogeneous for respondents. This is relevant when different suppliers offer varying attribute combinations, and individuals assign different values to these attributes based on their preferences and circumstances.

Furthermore, Perez-Lopez *et al.* (2022) highlight the appropriateness of the mixed logit model when choice sets involve multiple dimensions and alternatives can belong to more than one category. In the case of supplier alternatives, individuals consider various dimensions such as cost, quality, availability and other factors. Additionally, suppliers may belong to different categories or groups, and the mixed logit model can account for this nesting structure in the analysis.

In the realm of discrete choice analysis, individuals select the alternative that provides the highest value of an unobservable ranking index referred to as utility. Utility represents a latent variable influenced by observed attributes of both individuals and alternatives, along with random coefficients and a random element. In different contexts, like classification analysis, utility is simply an unobserved random index. However, in this particular model, it is termed utility due to its common application in discrete choice data analysis.

The utility of person n for alternative i in the mixed logit model is:

$$U_{ni} = \beta n x_{ni} + \varepsilon_{ni} \tag{2}$$

with

$\epsilon_{ni} \sim iid$ extreme value

$$\beta n \sim f(\beta|\theta)$$

where θ are the parameters of the distribution of βn's over the population, such as the mean and variance of βn.

Conditional on βn, the probability that person n chooses alternative i is the standard logit formula:

$$L_{ni}(\beta n) = e\beta n X_{ni} / \sum_j e\beta n X_{nj} \tag{3}$$

However, since βn is random and not known, the (unconditional) choice probability is the integral of this logit formula over the density of βn.

$$P_{ni} = \int L_{ni}(\beta) f(\beta|\theta) d\beta \tag{4}$$

This model is also called the random coefficient logit model since βn is a random variable. It allows the slopes of utility (i.e. the marginal utility) to be random, which is an extension of the random effects model where only the intercept was stochastic.

Any probability density function can be specified for the distribution of the coefficients in the population, i.e., for $f(\beta \mid \theta)$. The most widely used distribution is normal, mainly for its simplicity. For coefficients that take the same sign for all people, such as a price coefficient that is necessarily negative or the coefficient of a desirable attribute, distributions with support on only one side of zero, like the lognormal, are used. When coefficients cannot logically be unboundedly large or small, then bounded distributions are often used, such as the *Sb* or triangular distributions.

For the mixed logit model, the utility that individual i receives from alternative a, $a = 1, 2, \ldots, A$, The mixed logit denoted by U_{ia}.

$$U_{ia} = x_{ia}\beta i + w_{ia}\alpha + zi\delta a + \varepsilon_{ia} \tag{5}$$

βi are random coefficients that vary over individuals in the population, and x_{ia} is a vector of alternative specific variables.

α are fixed coefficients on w_{ia}, a vector of alternative-specific variables.

δa are fixed alternative-specific coefficients on zi, a vector of case-specific variables. ϵ_{ia} is a random term that follows a type I extreme value distribution.

The systematic component of the utility function in the mixed CL model is given as:

$$V_{nj} = zn\gamma j + x_{nj}\beta \tag{6}$$

x_{nj} contains the values of the choice-specific variables for outcome j and individual n, while zn contains Individual-specific independent variables for individual n. So, the utility of individual n for choice j is:

$$U_{nj} = zn\gamma j + x_{nj}\beta + \varepsilon_{nj} \tag{7}$$

To see all of this more clearly, let's imagine that our systematic component might be something like the following:

$$\begin{aligned} Vnj = {} & \gamma_{10} + \gamma_{11} Purity_n + \gamma_{12} Expensiveness_n \\ & + \gamma_{13} Germination_n + \gamma_{14} experience_n + \gamma_{15} quarantine_n \\ & + \gamma_{16} training_n + \gamma_{17} number\ of\ spp_n + \gamma_{18} number\ of\ seedling_n \\ & + \gamma_{19} species\ need\ sutisfaction_n + \gamma_{110} Survivalrate_n \\ & + \gamma_{111} Availability_n + \beta_1 Purity_{nj} + \beta_1 Expensiveness_{nj} \\ & + \beta_1 Availability_{nj} + \beta_1 Germination_{nj} + \beta_1 Need\ satisfaction_{nj} \\ & + \beta_1 training_{nj} + \beta_1 number\ of\ spp_{nj} + \beta_1 number\ of\ seedling_{nj} \\ & + \beta_1 species\ need\ sutisfaction_{nj} + \beta_1 Survivalrate_{nj} \end{aligned} \tag{8}$$

https://doi.org/10.1017/S1479262124000443 Published online by Cambridge University Press

Now substituting the systematic components into our utility equation, we have:

$$\begin{aligned} Unj = {} & \gamma_{10} + \gamma_{11} Purity_n + \gamma_{12} Expensiveness_n \\ & + \gamma_{13} Germination_n + \gamma_{14} experience_n + \gamma_{15} quarantine_n \\ & + \gamma_{16} training_n + \gamma_{17} number\ of\ spp_n + \gamma_{18} number\ of\ seedling_n \\ & + \gamma_{19} species\ need\ sutisfaction_n + \gamma_{110} Survivalrate_n \\ & + \gamma_{111} Availability_n + \beta_1 Purity_{nj} + \beta_1 Expensiveness_{nj} \\ & + \beta_1 Availability_{nj} + \beta_1 Germination_{nj} + \beta_1 Need\ satisfaction_{nj} \\ & + \beta_1 training_{nj} + \beta_1 number\ of\ spp_{nj} + \beta_1 number\ of\ seedling_{nj} \\ & + \beta_1 species\ need\ sutisfaction_{nj} + \beta_1 Survivalrate_{nj} + \varepsilon_{i1} \end{aligned} \quad (9)$$

As explained in the data analysis section, the mixed logistic regression model investigates how specific variables related to supplier alternatives and grower-specific factors influence the likelihood of selecting different tree seed suppliers at the regional level. The dependent variable in this model is the choice of primary tree seed suppliers, which is a categorical variable with six non-hierarchical categories. The reference category for comparison is self-suppling, and the coefficients in the model are expressed in terms of relative risk ratios (RRRs).

Result

Fictitious data were available on 385 growers and their choice of tree seed suppliers. Each growers was given the option to choose among Individuals, Self-Supplying, Group-organized, Enterprise TS Suppliers, AFE and EFD-CEC as their preferred suppliers (variable Supplier person). In total 1284 observations were entered for data analysis. Additionally, there were alternative-specific variables such as supplier tree seed quality, expensiveness, availability of tree seed in time, germination, survival rate and species need satisfaction for each type of tree seed in the grower's community that were included as predictors. In certain situations, it was also necessary to examine the relationship between the choice of tree seed supplier and the grower's case-specific variables, which included experience in tree seed planting, quarantine inspection, training for seed collector, number of species and number of seedling.

The labeling values of the tree seed suppliers from Table 2 are given as 1 = Individuals, 2 = Self-Supplying, 3 = Group-organized, 4 = Enterprise TS Suppliers, 5 = AFE and 6 = EFD-CEC. 29% of the growers do not have an alternative of 3 = Group-organized, 4 = Enterprise TS Suppliers, 5 = AFE and 6 = EFD-CEC; 9% of the growers do not have an alternative of 4 = Enterprise TS Suppliers, 5 = AFE and 6 = EFD-CEC; 38% of the growers do not have an alternative of 1 = Individuals and 6 = EFD-CEC; and 24% of the growers do not have an alternative of 1 = Individuals and 4 = Enterprise TS Suppliers.

Table 2. Tabulation of choice-set possibilities

Choice set	Freq.	Percent	Cum.
1 2	110	28.57	28.57
1 2 3	36	9.35	37.92
2 3 4 5	148	38.44	76.36
2 3 5 6	91	23.64	100.00
Total	385	100.00	

When the self-suppliers become the base outcome

When the self-supplying is the base outcome the result were indicated in the next Table 3.

Table 3: Odds ratio and relative risk ratio expressions of the mixed logistic regression.

Alternative-specific factor variables

The alternative-specific variables expensiveness, availability and germination are significantly related to the likelihood of choosing a supplier in the tree seed supply system.

Purity of tree seed

The odds ratio is a measure of the likelihood of choosing seed supplier alternatives compared to reference category, based on the quality of tree seeds obtained. In this case, the odds ratio indicates that for every one unit increase in the odds ratio of obtaining high-quality tree seeds, the likelihood of choosing a seed supplier decreases by 0.4 times compared to low-quality seeds. This suggests a negative association preference for seeking external suppliers when obtaining high-quality seeds.

As the grower evaluation of seed purity level increases by one unit, the odds ratio of choosing very high-quality seed suppliers over low-quality seed suppliers increases by a factor of 1.74.

The finding highlights the recognition of the benefits associated with superior seed quality in tree planting projects, leading to a substantial increase in the likelihood of choosing alternative seed suppliers.

Essentially, the odds of purity variable relative to the not pure seed observation is positive. This implies that pure tree seed reduces the probability of decision to obtain tree seed from all tree seed suppliers other than the reference category of low quality seed suppliers. Being high in purity of tree seed highly initiate the growers to decide to get the seed from the suppliers, but it increase the decision to find the seed from low quality seed suppliers. Therefore, purity level is a key factor in the explanation of decision making on tree seed obtaining from suppliers.

Available in time

When the grower evaluates the availability of tree seeds during the desired time period, for every one unit increase in the odds ratio of availability, the likelihood of obtaining the tree seed from suppliers in a timely manner decreases by 0.36 times compared to the reference category of less availability. This finding highlights a negative association between the perceived availability of tree seeds and the probability of obtaining them from suppliers of not availing the tree seed in time. Importantly, it should be noted that the effects of other explanatory variables remain constant in this interpretation.

For the availability variable of the grower's agreement in the odds of one unit increase of availability the likely to decrease by 0.43 times prefer to use compare to seed from reference category the use of seed less available evaluated seed supplier.

When the growers obtains the tree seeds as needed and in a timely manner, it increases their motivation to use or purchase the seeds. This is because when the growers has access to tree seeds exactly when they need them, they can proceed with their growing plans without delays or the need to search for alternative

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Table 3. Odds ratio expressions of the mixed logistic regression

Chosen	Odds ratio					
Supplier alternative-specific Variables						
Supplierperson1						
Supplier seed purity (Low)						
3 (high)	0.4*** (0.09)					
4 (Very high)	1.74** (0.38)					
Expensiveness (Expensive)						
1 (Cheap)						
Available in time (not)						
3 (High)	0.36 ** (0.14)					
4 (Very high)	0.43** (0.16)					
Germination (Very low)						
3 (High)	2.79 *** (0.68)					
4 (Very high)	4.71*** (1.8)					
Survival rate						
Species need satisfaction						
	Alternative seed suppliers relative risk ratio (RRR)					
Planter case – specific variables	Individuals	Self – supplying (base)	Group organized	Enterprise private	AFE	EFD- CEC
Experience				0.38** (0.15)		
Quarantine			2.19*** (0.44)		2.73*** (0.75)	4.42*** (2.22)
Training for Seed collector				0.03*** (0.03)	0.29** (0.15)	
Number of Species				2.03*** (0.42)	1.21** (0.11)	
Number Seedling						
***Significant to only one of 1%; **significant to only one of 5%; *significant to only one of 10%.						
Conditional logit choice model						Number of obs = 1284
Case ID variable: Gowers ID						Number of cases = 385
Alternatives variable: Supplier person						Alts per case: min = 2
						avg = 3.3
						max = 4
						Wald $\chi^2(42) = 216.78$
Log likelihood = −293.41,986						Prob > $\chi^2 = 0.0000$

sources. The timely availability of tree seeds gives the growers confidence in relying on their preferred self-suppliers. They can also align their growing activities with optimal conditions, such as suitable weather or soil conditions, and budget accordingly. By efficiently allocating resources and time, they can ensure more effective and successful tree growing efforts.

Germination

The odds ratio of 2.79 indicates that as the grower's evaluation of germination level increases by one unit, the likelihood of choosing to receive the tree seed from suppliers with a high germination level increases by approximately 2.79 times compared to choosing suppliers with low germination tree seeds. This finding suggests a strong positive association between the grower's evaluation of germination level and their preference for obtaining tree seeds from suppliers with a germination rate.

The odds ratio of 4.71 suggests that tree seed suppliers evaluated as having a very high germination rate are 4.71 times more likely to be chosen by the growers for obtaining tree seeds, compared to the reference category of suppliers with low germination rates. These results were obtained while holding all other variables constant. This finding indicates a strong positive association between the evaluation of germination level and the preference for suppliers with a very high germination rate.

Case-specific variables

The question of how the increased number of growers or case-specific variables for certain tree seed suppliers would impact

https://doi.org/10.1017/S1479262124000443 Published online by Cambridge University Press

the likelihood of more growers purchasing seeds from alternative suppliers is addressed by the study's findings. The selection decision was influenced by case-specific variables such as experience, training and the number of species. It was observed that these variables were significantly associated with the enterprise's choice of alternative tree seed suppliers in comparison to the base alternative variable.

Experience

As the grower's experience in using the tree seed for growing increases by one unit, the relative risk ratio (RRR) of retaining or using the tree seed from private enterprise tree seed suppliers is expected to be decreased by a factor of 0.38 compared to the reference category of self-supplying. This finding suggests a positive association between the grower's experience and the likelihood of choosing to obtain and use tree seeds from private enterprise suppliers. In other words, as the grower's experience increases, they are more likely to choose AFE tree seed suppliers. It is important to note that this interpretation assumes that all other variables in the mixed logistic regression model are held constant.

Quarantine

There were significant values for the variable 'quarantine follow-up' among the suppliers, specifically group-organized, AFE and EFD-CEC. This can be interpreted as follows: when growers tested their tree seeds and utilized quarantine office services, a one-unit increase in the relative risk ratio (RRR) was associated with a 2.19-fold increase in the likelihood of growers retaining or using the tree seeds from group-organized suppliers, rather than choosing self-suppliers.

Regarding the quarantine variable, it decreased the likelihood of choosing tree seeds from Amhara Forest Enterprise suppliers by a relative risk ratio of 2.73 compared to the reference category of self-supplying.

On the other hand, this implies that a one-unit increase in the relative risk ratio driven by quarantine office increases the probability of choosing tree seed suppliers from EFD-CEC by 4.42 times compared to self-supplying.

Training

The relative risk ratio (RRR) suggests that obtaining training on tree seed collection, compared to not obtaining training, decreases the likelihood of choosing to receive the tree seed from enterprise suppliers by a factor of 0.03. In other words, those who receive training on tree seed collection are significantly less likely to choose enterprise suppliers for obtaining tree seeds compared to those who do not receive training.

As the number of trainings attended by the grower increases by one unit, the likelihood of relative risk ratio to decide to receive the tree seed from enterprise supplier decrease by 0.29 compared to the base category (self-supplying). This indicates that each additional training the growers attends slightly decrease their preference for obtaining the seed from enterprise suppliers.

Number of species

The relative risk ratio of 2.03 suggests that for each additional unit increase in the number of tree species that successfully produce in the nursery, the likelihood of obtaining the tree seed from enterprise suppliers (compared to the reference category of self-supplying) is expected to increase by approximately 2.03 times, while holding all other variables constant. This finding indicates a positive association between the number of tree species in the nursery and the probability of sourcing tree seeds from enterprise suppliers. Therefore, as the number of tree species successfully produced in the nursery increases, there is an increased likelihood of choosing to obtain tree seeds from enterprise suppliers rather than self-supplying.

The relative risk ratio of 1.21 suggests that for every one-unit increase in the grower's number of tree species, the likelihood of choosing to receive the seed from the Amhara Forest Enterprise supplier becomes 1.21 times more likely compared to the reference category of self-supplying. This finding indicates a significant positive relationship between the number of tree species grown by the growers and their preference for obtaining seed from the Amhara Forest Enterprise supplier. In other words, as the growers increases the number of tree species they grow, they are more likely to choose the Amhara Forest Enterprise supplier for obtaining seed.

Discussion

Very little was found in the literature on the question of how to use mixed logistic regression in tree seed suppliers. Preference for obtaining tree seeds from suppliers with a high germination rate, availability and seed purity might be influenced by various factors (Pedrini *et al.*, 2022). Growers prioritize suppliers with a high germination rate as it increases the chances of successful seedling establishment. Higher germination rates ensure a greater number of viable seeds, leading to a higher probability of achieving desired outcomes (Atkinson *et al.*, 2021; Shackelford *et al.*, 2021; Dalziell *et al.*, 2022).

Suppliers that prioritize seed purity, free from contaminants and other unwanted materials, are favored by growers (Pedrini *et al.*, 2022). High seed purity ensures that growers receive seeds that are true to the desired species or cultivar, minimizing the risk of introducing unwanted traits or genetic variability.

Availability of tree seeds is crucial for growers to meet their planting requirements (Atkinson *et al.*, 2021; Bosshard *et al.*, 2021; Gibson-Roy *et al.*, 2021; Fremout *et al.*, 2022). Suppliers with a consistent and ample supply of seeds are preferred as it ensures an uninterrupted availability of seeds when needed. This allows growers to plan and execute their planting activities without delays or shortages.

Growers might seek suppliers that offer a wide range of seed varieties and species to enhance genetic diversity in their growing areas. This allows for a broader selection of trees, enabling growers to choose species that are best suited to specific environmental conditions and desired outcomes.

Growers often rely on suppliers with a reputable and trustworthy image in the industry. Suppliers known for consistently providing high-quality seeds with good germination rates, availability and purity build trust among growers, increasing their preference for sourcing seeds from these suppliers.

Suppliers that offer additional support, such as technical guidance and advice on seed selection and planting, might be preferred by growers. This assistance might help ensure successful seedling establishment and overall project success.

The growers who have experience in tree seed collection and management are more likely to prefer the seeds they collect themselves rather than relying on seeds supplied by a private enterprise. Experienced growers might prefer collecting seeds themselves to have better control over the quality and characteristics of the seeds (Marques *et al.*, 2022). They might personally

https://doi.org/10.1017/S1479262124000443 Published online by Cambridge University Press

ensure that the collected seeds meet their specific requirements and standards. Self-collection of seeds can be a cost-effective option for experienced growers (Pedrini *et al.*, 2022). By collecting seeds on their own, they might avoid additional expenses associated with purchasing seeds from private enterprises. Growers with experience might have access to local seed sources that are well-suited to their specific planting site conditions (Atkinson *et al.*, 2021; Di Sacco *et al.*, 2021). They might prefer using locally collected seeds that are more adapted to the local environment, rather than relying on seeds supplied by private enterprises that might not be as well adapted.

Seed certification is the main instrument in the process of quality assurance, and seeds intended for domestic and international markets are controlled and inspected by official government seed authorities (Holding Anyonge *et al.*, 2005). Accreditation allows seed quality control to be performed by individuals, third parties, seed laboratories and seed certification schemes include minimum quality standards for different classes of seeds of inspection processes in both the field (seed crop) and post-harvest stages (Marques *et al.*, 2022; Misra *et al.*, 2023). Additionally, tree seed education for agricultural and forestry technicians can help to increase knowledge exchange and learning on tree seed handling and management, which can help to increase successful land restoration activities (Holding Anyonge *et al.*, 2005). Therefore, growers who obtain training might prefer to buy tree seed from accredited tree seed suppliers due to the assurance of seed quality and genetic purity.

It is possible that growers who receive training in tree seed collection might prefer to source seeds from public or non-profit organizations, such as government forestry agencies or research institutions, due to their focus on genetic diversity, seed quality and conservation efforts (Holding Anyonge *et al.*, 2005). Private enterprise suppliers, on the other hand, might be more focused on commercial interests. Additionally, some training courses might cover topics such as seed collection, handling and quality evaluation, which might help growers identify reliable seed sources and make informed decisions about seed procurement (Bonner *et al.*, 1994).

An increase in the number of tree species grown in a nursery could lead to a higher likelihood of choosing a governmental Forest Enterprise supplier for obtaining seeds compared to self-supply. This might be due to the governmental supplier's potential to offer a wider variety of tree species and the assurance of seed quality and authenticity. Such growers could reflect long-term objectives for the planting (Davis and Pinto, 2021). Additionally, governmental suppliers might have resources for research and development of diverse tree species, which can be beneficial for nurseries aiming to expand their offerings.

Conclusion

The study findings reveal that alternative-specific factor variables, including seed purity, availability and germination rate, significantly influence the likelihood of choosing a supplier in the tree seed supply system. The evaluation of these factors affects the decision-making process of growers when it comes to obtaining tree seeds from different suppliers. The purity of tree seeds plays a crucial role, as higher seed purity increases the likelihood of choosing suppliers that offer high-quality seeds. Availability of tree seeds during the desired time period also influences the decision, with timely availability decreasing the probability of seeking alternative suppliers. Additionally, the evaluation of germination level positively correlates with growers' preference for suppliers with a high germination rate.

Recommendation

Based on the study findings, it is recommended that tree seed suppliers focus on improving the purity, availability and germination rate of their seeds to attract more growers. Enhancing the quality assurance processes to ensure high seed purity, implementing efficient inventory management systems to maintain adequate seed supply, and investing in techniques to improve germination rates can be beneficial. Suppliers should also consider providing additional support and expertise to growers, such as technical guidance on seed selection and planting, to build trust and enhance their reputation.

The future research should consider exploring additional factors and using experimental and case-study research designs to understand the choice of suppliers in the tree seed supply system. Further research should include comparative analyses to assess the applicability of the study findings across different regions or contexts.

Policymakers should prioritize timely seed availability through coordinated collection and distribution, improved forecasting and enhanced communication. Supporting educational initiatives, training programs, capacity-building and providing collection material for growers can foster self-sufficiency and decrease reliance on external suppliers.

Competing interests. None.

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https://doi.org/10.1017/S1479262124000443 Published online by Cambridge University Press