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Determinants of adoption and intensity of improved haricot bean (*Phaseolus vulgaris* L.) varieties: A Socio-agronomic study from southern Ethiopia

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ABSTRACT

The Haricot bean (*Phaseolus vulgaris* L.) is an important legume crop in Ethiopia, serving as the main cash crop and the least expensive protein source for farmers in many of the lowlands and midlands of the country. This study examines the factors that influence the adoption and intensity of improved haricot bean varieties and associated agronomic techniques in the study area. To choose four rural kebeles (purposive sampling) and 100 (technology user) respondents (systematic random sample), a two-stage selection approach was used. In addition, focus group discussions and key informant interviews were held. The findings of the Tobit econometric model revealed that a wide range of factors had varying effects on adopting better haricot bean production practices. The adoption and intensity of improved haricot bean varieties and related agronomic practices were positively and significantly influenced by the gender of the head of the household, attendance at improved training in haricot bean production, field day programs, demonstrations, access to improved seed credit, and membership in a seed multiplication group, while the market distance was negatively influenced. When evaluating and choosing improved haricot bean varieties, farmers in the study area gave high yield, market demand and price advantage, maturity time, grain color, grain size, disease resistance, and storage priority. The Nasir cultivar comes first based on these criteria, followed by the Dimtu cultivar. Furthermore, fewer farmers in the study area applied fertilizer and seed at rates than advised by research and extension. Lack of extension assistance, high fertilizer costs, and lack of funds contributed to farmers' departure from advised packaging practices. To enhance the adoption of improved cultivars, it is suggested that the promotion of improved haricot bean cultivars, as well as improved farmers' access to extension services and timely market information, be emphasized.

1. Introduction

1.1. Background

Most Ethiopians live in rural areas and depend on agricultural products to survive [1]. With little investment in better crops, fertilizers, herbicides, and other technologies, agriculture is primarily traditional and traditional [2]. The amount of land per home also decreased as a result of increased population pressure, leaving little production left to satisfy precise household consumption needs [3].

To achieve food security, family-level agricultural productivity should be increased [4]. However, any marketable surplus could be offered to agricultural and non-agricultural organizations for purchase [5]. Therefore, improvements in output and productivity over time may reduce food shortages [6]. The Ethiopian rural development policy and strategy document highlighted specialization and diversity in production systems, as well as increased access to and use of agricultural technologies as a means of achieving household food security [7]. New technologies must be widely adopted and distributed to achieve long-term increases in agricultural production and productivity [8].

Pulses are crucial to crop production in Ethiopia, although cereal crops are crucial to providing the population with the country's staple foods [9]. Pulses provide small farmers with an affordable alternative source of protein, financial rewards, and food security [10]. The haricot

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bean legume is crucial to Ethiopian cooking [11]. The haricot bean is also the most important food legume produced in the nation because it has long been grown as a field crop [12]. In Ethiopia, Haricot beans are a significant food crop, particularly in the south and east, where they are frequently combined with maize and sorghum to boost farmer income [13]. Haricot bean production in Oromiya and the Southern Nations, Nationalities, and People's Region (SNNPR) accounts for 70 and 60 thousand tons and 85% of the nation's output, respectively [14].

Although Haricot beans are a common crop in Ethiopia, the average yield is between 0.5 and 0.8 tons per hectare, which is much lower than the comparable yields observed at research sites (between 2.5 and 3 tons per hectare) when improved varieties are used [15]. The low national mean yield of Haricot beans may be caused by a lack of modern farming equipment, drought, and a lack of superior varieties, substandard cultural practices, disease, and environmental degradation [16]. In other words, the creation and spread of technology is not a goal in and of itself. Farmers who use new technology that has been developed through research will, however, increase the productivity and production of Haricot beans. Therefore, efforts have been made to spread information about the new technology through both research and extension systems. The Ethiopian agricultural research organization (now the Ethiopian agricultural research institute) research centers have innovated by releasing a cultivar of improved Haricot bean varieties with their agronomic practices and disseminating them to farmers with a comprehensive information package.

Growing output consistently through broad farming is becoming a more challenging agricultural endeavor due to limited opportunities for area expansion [17]. Therefore, the solution to the food crisis would depend on policies that allow farmers to increase productivity through intensification, such as a cultivar of better agricultural technologies [18] found that despite the value of agricultural innovations in increasing output and revenue, the country's adoption rate of new agricultural technology is comparatively low. To make long-term strides in agricultural productivity and production, developing countries must adopt and widely disseminate new technologies. Therefore, it can be difficult to establish broadly defined standards to restrict or encourage technology adoption.

The purpose of this study was to identify the variables that affect Kindo Koyisha district's adoption of improved haricot bean varieties and associated agronomic practices. In light of this, the study findings are expected to provide crucial information for the continued development of this crucial crop in the study area. The criteria for rating farmer-developed technologies would also help researchers create technologies that are compatible with the regional environment and satisfy farmer expectations. The main findings of the study could help to fine-tune the extension to meet the socioeconomic and technical limits of the haricot bean production. This information may suggest initiatives that could help increase the effectiveness of agricultural research and extension.

Various extension agencies, including the Agriculture Ministry and nongovernmental organizations (NGOs), have distributed improved haricot bean varieties to farmers in the research region of the Kindo Koyisha district. For market sales, intercropping (with maize, coffee, enset, and barley) and monocropping (as an alternative food source), farmers grow Haricot beans. To advance Haricot bean technology, the MoA is working with a non-governmental organization. However, the adoption and extent of the use of improved agricultural technology in the study area have not yet been investigated [19,20]. Farmers adopt technologies that are tailored to their specific demands and no attempt has been made to investigate the intensity and factors influencing the adoption of improved haricot bean technology in the research area. Haricot beans are a significant and commercially important commodity crop grown on a small scale in the southern region, mainly for subsistence and commercial purposes. According to the CSA [19] average production statistics (2005–2012), the southern area represented the competence rank, accounting for more than 25% of the country's total haricot bean production. At the small-scale level, the Hadiya zone is the main haricot bean producing area in this region.

Farmers in the study area did not follow all the recommendations of the investigation. Several factors that influenced the farmers' choice to adopt the enhanced Haricot bean production package can be blamed for their inability to fully recognize and implement the recommended production package. However, the factors that influence the adoption and intensity of the expansion of Haricot bean varieties and the suggested agronomic techniques are not empirically documented in the study region. The findings of this study will be useful to stakeholders, including policymakers, developers, and academics. The main objectives of the study were to pinpoint the traits that affect both the level of acceptability of the Haricot bean production technology package and the adoption of enhanced Haricot bean varieties and related agronomic practices. What is the current level of use of the Haricot bean production package? What factors could affect the adoption of improved Haricot bean production? Both these and other questions could be answered in this study.

Low productivity and production were major problems, primarily as a result of a lack of acceptance of new technology and a poor marketing strategy. One of the most promising solutions to Ethiopia's food insecurity is the use of new technology. However, a number of issues prevent the use and adoption of these technologies. Practical knowledge and observations of reality have demonstrated that a particular factor can temporarily increase the adoption of a technology in one area while acting as a barrier in anotherfinding [21–25]. These characteristics make it difficult to develop a solitary and comprehensive adoption model for all unique settings in the technology adoption process. As a result, the conceptual framework depicted in Fig. 1, demonstrates the key factors expected to affect the adoption of improved Haricot bean varieties in the study area.

2. Materials and methods

2.1. Description of the study area

The study area, Kindo Koysha district, is one of 12 rural districts in the Wolaita zone, southern nations, nationalities and regional state of peoples. It is one of the most food-insecure districts in the zone. The Kindo Koyisha district of the Wolaita zone is located in the Southern Nations, Nationalities, and regional state of peoples. The district's capital city is Bele, located at a distance of 45 km to the south-west of the zonal capital Sodo. It is found at 6°33′43; 34″N and 37°76′27; 34″E and 1180 m above sea level. It has a minimum and maximum temperatures of 21.2 and 30.7 °C, respectively. It is bounded by the Dawro zone in the south, Offa district in the east, Damot Sore in the north, and Kindo Didaye in the west (Fig. 2).

The district encompasses 23 rural Kebeles and 2 urban Kebeles. Concerning population, the district has a total population of 118,850, of which 58,140 are men and 60,710 are women. According to the Zonal Socioeconomic Profile 2011, the total number of households in the district is 22,495 of which 18356 are male, 4139 households are female, and the average size of the household is 6 [26].

The district covers 50,093 ha of land mass, where 36,366 ha of arable, 4957 ha of forest, 1184 ha of grazing land, 6529 ha of bush land and 1057 ha are used for different purposes. The district study has three agro-ecological zones: *Dega* 8%, *Woina Dega* 20% and *kola* 72% and characterized by mountains, rugged and hilly terrain with large plain valleys and gorges. According to Fig. 3, from the district agriculture office, the type of land comprises inclined/sloppy/40%, Gorges/sloping 25%, mountains 20%, flat land 10%, and shallow/valley 5%. The altitude of the district ranges from 700 to 2280 m above sea level and its mean annual rainfall is 400–1400 mm. Rainfall in the district is bimodal and begins around March and ends in May, which is known as '*Belg*', and again begins in June and continues until September, which is known as '*Meher*'.

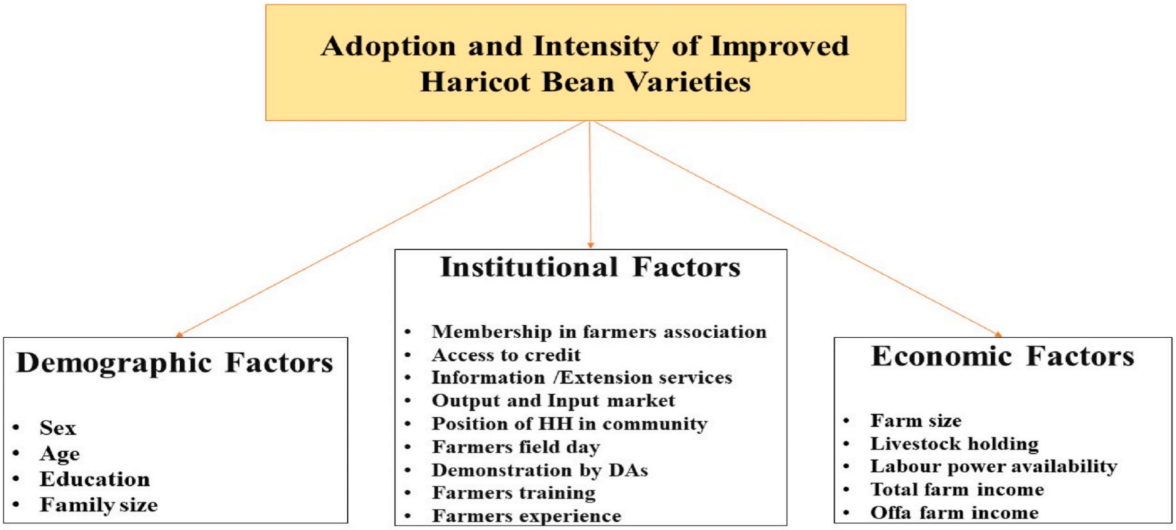

Fig. 1. The conceptual framework of the study.

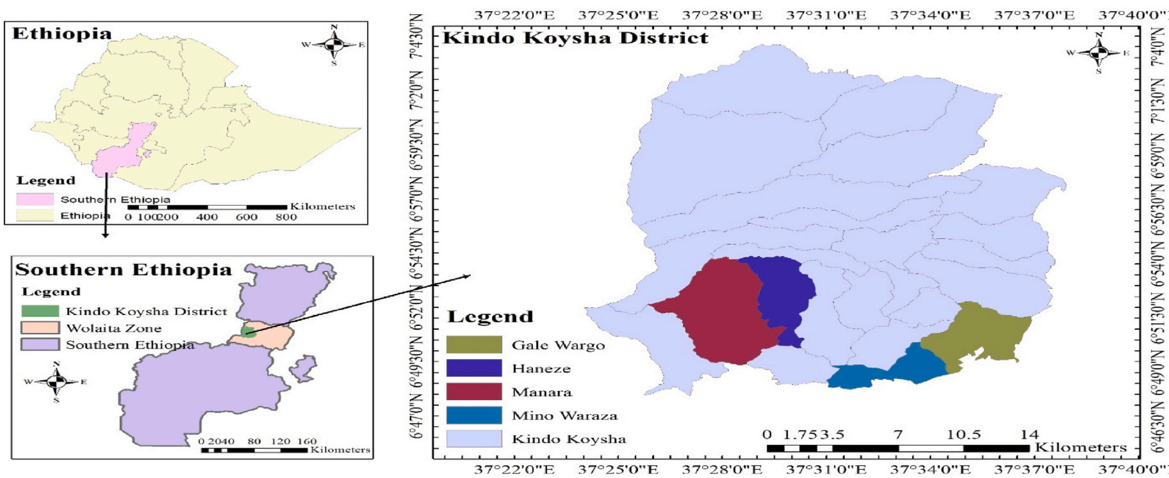

Fig. 2. Map of the study area.

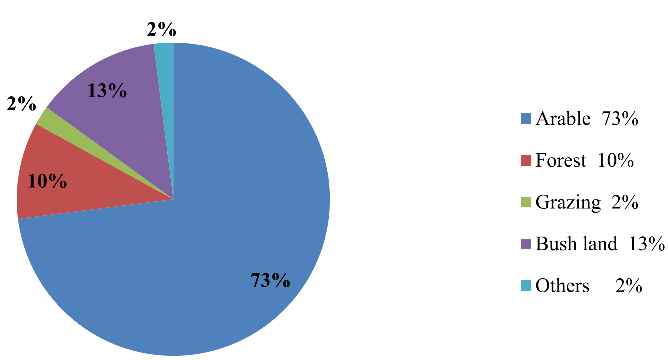

Fig. 3. Land use distribution of Kindo Koysha district.

According to IPMS [27], Kindo Koyisha district has two basic farming practices. First, the coffee Enset and livestock system in the garden (also known as the coffee/livestock system) is located east of the main road that runs through Kindo Koyisha from north to south; the topography is mountainous red soil (Nitosols). Rainfall is more abundant and consistent than in the previous Haricot bean/livestock system. The agricultural system comprises garden, coffee, Enset, and cattle tied and kept for manure and dairy production. Haricot beans (as an intercrop), yam, cereals, and fruits, particularly avocados and bananas, are also part of the system. The Cereals, Enset, Haricot beans, garden, coffee, and livestock system (also known as the Haricot bean/livestock system) is the second agricultural system. This system is located west of the road that runs from north to south through Kindo Koyisha. The terrain is varied, ranging from flat to hilly. Black soils (*Pellic Vertisols*) are common in the plains, while red soils are standard on slopes. In the coffee/livestock system, rainfall is lower and more erratic. In this system, cereals (Maize, Teff) prevail and are alternated with Haricot beans. The Enset is grown close to the farm. The average farm size is estimated to be 0.5 ha. Farmers use oxen to cultivate their land [27].

2.2. *Research design*

2.2.1. *Sampling procedure*

In this investigation, a two-stage sampling approach was adopted. The first stage involves a deliberately selection of haricot bean producing kebeles in the district, then a selection of sample houses. Through secondary data analysis of Haricot bean distribution and production in the region using various techniques, including the use of inoculants, kebeles were found. Total of the 23 kebeles in the district, four kebeles that produce Haricot beans were carefully chosen as the focus area. The leaders, key informants, and development agents of the relevant rural kebeles helped identify the heads of households that produce Haricot beans before they were included in the sample. Using a systematic random selection method that took into account the amount of haricot bean production in each of the four rural kebeles, the second phase involved choosing 100 farm household heads from the identified kebeles that produced the crop.

To determine the sample size, a mathematical formula was used. Yamane [28], has suggested the following mathematical formula for determining the sample size.

$$n = \frac{N}{1 + Ne^2}$$

$$n = \frac{1742}{1 + 1742\,(0.08)^2} = 143$$

where;

n is the sample size,

N is the total number of Haricot bean growers in 1742 selected sites 1742, and

e is the level of precision (0.08).

As a result of the topographic unsuitability of the location for data collection, 100 respondents were chosen for the survey and information was acquired and reviewed. Table 1 shows the total number of responders in each rural kebele as a consequence.

2.3. Methods of data collection

To address the study questions and fulfill the study objectives, primary and secondary data were gathered. In 10 randomly chosen farm households, the interview was tested at the farm level. We tested the farmers' knowledge of the interview schedule beforehand to make sure that they understood it clearly. Because of this, many pointless inquiries were cut from the final interview schedule while some crucial ones were added. A preplanned and pretested interview schedule was used to conduct in person and face-to-face interviews with participants. Under the close supervision of the researcher, the interviewees who had been hired and trained carried out the interviews. Based on their adoption of improved Haricot bean types, the survey included 100 randomly chosen household heads. The qualitative use of biofertilizer was evaluated in each rural kebele using in-depth interviews, key informant interviews, and focus groups.

The reports of the administrative office of the district from various levels of the agriculture department, nongovernmental organizations (NGOs), CSA, earlier findings, the Internet and other published and unpublished materials that were deemed pertinent for the study were among the sources from which secondary data was gathered. Depending on their proficiency in the regional language "*Wolaitegna*" and level of education, three enumerators were hired in collaboration with the researcher to complete the data collection on time. Two development specialists from the Catholic development program also offered to act as enumerators. Enumerators were taught how to apply the data collection method, approach, respondents regulate the interview setting, and correctly record information.

Table 1
Name of Kebele and HH size for research.

S. No.	Name of the Kebeles	Total HHs	Total number of Haricot Bean growing households	PPS
1	Hanaze	795	274	19
2	Manara	1423	487	27
3	Gale Wargo	1787	608	34
4	Mino Waraza	1091	373	20
	Total HH	5096	1742	100

2.4. Definition of variables used for analysis

In this study, the explanatory variables influence the intensity of the adoption of haricot beans. These include personal and demographic variables from economic and institutional variables of households (Table 2). The following are the explanatory variables.

2.4.1. Dependent variables of the model

The dependent variable in the Tobit model has a value between 1 and 0. This variable can be expressed as a ratio, an actual number, or a logarithmic form depending on the study's objectives, as seen in many empirical studies. For instance, in their study on increased adoption of chickpea varieties, Kassa et al. [29] examined the percentage of area covered by various chickpea varieties. Similarly to this, Idrisa et al. [30] used fertilizer used per hectare as the dependent variable of the Tobit model in their analysis of factors influencing fertilizer adoption. The superior packaging of the Haricot bean cultivar was adopted by the Tobit model in this study using the dependent variable as a basis. Adopters in our study are farmers who preferred higher yield, earlier maturation, and disease resistant white haricot beans over those available locally. The intensity (degree) of adoption was determined by the degree to which the white haricot bean production package (fertilizer rate, seed rate and area allotted) was implemented compared to the rate advised during the survey year.

2.4.2. The independent variables of the study

Several independent variables could influence the farmer's decision to adopt. The definitions and explanations for the 17 hypothesized explanatory variables are shown in Table 2. Among the independent variables are economic factors (farm size, livestock holding, farm income, and labor availability); demographic factors (household head's education level, farmer's age, and farmer's sex); institutional factors (position of the head of household in the community, demonstration participation, farmers' association membership, access to extension services, output and input markets, field day participation, access to credit, participation in off-farm.

Table 2
Units of measurement definition and expected effect of hypothesized variables.

Variables Code	Variable Type	Definition of Variables	Expected Sign
EDULEVEL	Years	Education level of the household	+
AGEHH	Years	Age of household	±
SEXHH	Dummy	Sex of house Hold	±
PHHHC	Dummy	Position of farmer in the community	+
FARMSIZ	Continuous	Total farm size of the household	+
FARMINC	Birr	Total farm income of the household	+
PARTDEMO	Number	Participation in on-farm demonstration	+
MEMSHIP	Score	Membership of Farmers' Association	+
CONEXE	Dummy	Contact to Extension agent	+
MARKACE	Kilometers	Distance to output and Input Markets	−
PARTIFIDA	Number	Attendance in field days	+
ACCESCRE	Dummy	Access to Credit	+
PARTOFAR	Dummy	Participation in off-farm activities	+
NUMLISTO	TLU	Number of Livestock	+
FAREXEP	Years	Farming experience of the household	+
PARTRAI	Number	Participation in training	+
Labor	Man Equivalent	Labor Availability	+

2.5. Analytical techniques

For descriptive data, SPSS version 16.0 software was. The significance of the relationship between the adoption groups was determined using Chi-square and F tests. The chi-square test was used for categorical variables and the F test for continuous data after dividing the respondents into different adoption groups.

2.5.1. Estimation of the adoption index

Before delving into the adoption aspects, each farm home's level of adoption must be determined. Farmers who did not cultivate an improved cultivar of Haricot beans were labeled nonadopters, whereas farmers who did cultivate an improved cultivar while utilizing some of the proposed technology packages were labeled adopters. In the study area, only three improved agronomic strategies (better cultivar, seed rate, and fertilizer application rate) are being investigated. The other two procedures (cm spacing and chemical application) were abandoned due to a lack of precise information and the difficulty in obtaining it. The adoption index score was calculated by adding the adoption quotient of each practice and dividing it by the number of practices adopted by each respondent. The adoption quotient for each practice was calculated by dividing the actual rate used by the indicated rate. Arega [31] calculated the intensity of adoption of old coffee stumping technology packages using weight. Mihretie [32] provide a proportion score to calculate the intensity of Malt-barley adoption.

In this study, the adoption index was used to measure the amount of adoption of various practices (packages) in the survey, indicating how far the farmer in question has embraced the most set of a package. Each respondent's farmer's index was calculated as follows:

$$AI_i = \frac{\varepsilon\left[\frac{AH}{AT} + \frac{SRA}{SRR} + \frac{FA}{FR}\right]}{NP}$$

where: AI_i = adoption index of the ith farmer.

AH = area under improved Haricot bean cultivar of the ith farmer.

AT = total area allocated for Haricot bean (improved cultivar + local, if any).

SRA = seeding Rate applied per unit of area in haricot bean production.

SRR = seeding rate recommended for application per unit of area,

FA = amount of fertilizer applied per unit of area in the cultivation of Haricot bean.

FR = amount of fertilizer recommended for application per unit of area in the cultivation of Haricot bean.

NP = number of practices.

As a result, in the algorithm discussed above, the adoption index is a continuous dependent variable with a value ranging from 0 to 1. A zero value indicates that there has been no adoption, while a value of one indicates total adoption. Once the adoption index was developed, the farmer's responses were classified as low, intermediate, or high adopters.

Haricot bean production requires the use of a packaging process cultivar. Among these are the use of bio-fertilizers, cultivar selection, plantation rate, fertilizer rate, spacing, and other characteristics. Significant improvements in production and productivity are determined by the household's adherence to the recommended Haricot bean production procedures. The adoption of Haricot bean by farmers can vary depending on demographic and socioeconomic factors, but institutional and economic circumstances that affect family functions are also important.

The actual adoption index score is between 0 and 1. The sample houses' index scores were divided into four groups of adopters; non-adopter, low, medium, and high adopters. A score of zero indicates that total Haricot bean production has not been adopted. More significant than zero (>0 and 1) indicates adopters in three categories; low adopters, medium adopters, and high adopters. The mean adoption index scores of the non-adopter, low, medium, and high adopter groups were 0.00, 0.30, 0.58, and 0.84, respectively (Table 3).

2.5.2. Econometric analysis (Tobit model)

To determine the relative significance of several explanatory variables in the dependent variable, the Tobit model was used. The Tobit model was used to investigate the factors influencing the acceptance and level of adoption of an improved Haricot bean cultivar and the agronomic approaches associated with it. This model was selected because it predicts both the likelihood and the extent of technological adoption [29]. Farm household production and productivity are determined not only by technology adoption, but also by its application. The Tobit model, which combines both discrete and continuous components, is ideal because it addresses both the likelihood and intensity of adoption at the same time [33]. The farmer can use just a portion of the recommended package, or he or she can use it on all or a part of his or her property. As a result, for both discrete and continuous variable combinations, the Tobit model yields more consistent results. Several researchers have used the Tobit model in empirical studies to identify factors that influence technology adoption and intensity. The various studies [30,34,35], for example, used the Tobit model to assess the likelihood of adoption and the intensity of fertilizer application. The Tobit model, benefits from quantifying the likelihood and intensity of technological adoption.

2.5.2.1. Specification of the Tobit model

The Tobit model [36,37], which tests factors affecting the incidence and intensity of determinants of adoption, can be specified as follows:

$$AI_i{}^* = B_0 + B_iX_i + U_i$$

$$AI_i = AI_i{}^*$$

$$if\ B_0 + B_iX_i + U_i > 0 \quad (1)$$

$$AI_i = 0, \text{ if } B_0 + B_iX_i + Ui, 0$$

Where:

$AI_i{}^*$ = is the latent variable and the solution to the utility maximization problem of the intensity of adoption subject to a set of constraints per household and conditional on being above a certain limit,

AI_i = is the adoption index for the i^{-th} farmer.

X_i = vector of factors that affect adoption and intensity of adoption,

B_i = vector of unknown parameters, and.

U_i = is the error term that is normally distributed with mean 0 and variance $\sigma.^2$

The Tobit model illustrated above is sometimes known as a censored regression model, since the issue can be seen as one in which observations of Y^*at or below zero are suppressed [38].

Before running the Tobit model, all hypothesized explanatory variables were checked for the possibility of multicollinearity. Two measures are commonly used to test the existence of multicollinearity. The variance inflation factor (VIF) links continuous explanatory factors, whereas the contingency coefficients link dummy variables. In this study, the variance inflation factor (VIF) and contingency coefficients were used to examine multicollinearity in continuous and dummy variables, respectively. The higher the difficulty level, the higher the value of VIF. A variable is considered very collinear if its VIF exceeds 10 (which will happen if R_i reaches 0.95) [39]. Similarly, the contingency coefficients were calculated for the dummy variables. Again, the variable is considered collinear if the value of the contingency coefficient is more significant than 0.75 [40].

2.6. Description of improved production practices

The production process includes the selection of plant materials, soil preparation, planting, weeding, cultivation, protection of plants,

Table 3
Adoption of Haricot bean technology package by components.

Adoption category	Adoption index score range	Mean of adoption index	% of farmers	Average proportion of land (Haricot bean/total land)	Average seeding rate/ recommended	Chemical fertilizer application rate in g/ha
Non-adopters	0	–	17	–	–	–
Low	0.10–0.33	0.30 (0.02)	4	0.14 (0.08)	55.33 (38.40)	50.00 (30.00)
Medium	0.34–0.66	0.58 (0.08)	54	0.20 (0.07)	61.31 (21.66)	67.38 (32.22)
High	0.66–1.00	0.84 (0.21)	25	0.30 (0.13)	67.68 (20.30)	71.06 (23.48)
Total or Mean	0.00–1.00	0.54 (0.30)	100	0.22 (0.10)	54.27 (29.54)	57.28 (36.13)
F-value		244.891***		16.012***	39.304***	26.418***

Note: STD in parentheses, *** indicates at < 1% significance level of 1%.

harvesting, threshing, cleaning, and grading. The procedures mentioned above can be improved or recommended with the help of research. This study was designed to catalog farmers' practices. The production processes for which better and/or suggested packages are available are described in the following section. Improved Haricot Bean refers to a previously known group of Haricot Bean that can be consistently distinguished from any other similar group of Bean, generation after generation, in this study. These new Haricot Beans were not found in the wild, but were created through human plant breeding efforts.

2.6.1. *Improved varieties*

To increase Haricot bean yield and productivity, researchers have made various attempts to develop superior cultivars using appropriate agronomic practices. Farmers in the study area were first introduced to Haricot bean cultivars Ibado, Dimtu, Nasir, Awasa dume and Omo 95 in 2004 by the non-governmental organization Improving Productivity and Market Success of Ethiopian Farmers (IPMS) and Kindo Koysha District Office of Agriculture (KKDOA). By dividing the area planted with improved Haricot bean varieties by the total land ratio, the adoption index (AI) was calculated. To determine whether there was a significant mean difference in the amount of acreage covered with higher Haricot bean rates applied between the three adopter categories, a one-way analysis of variance was performed in Appendix I.

2.6.2. *Seeding rate*

Proper plant pace is one of the key factors in raising Haricot bean yield. Inadequate or excessive seed application will have a negative impact on crop performance. For a given cultivar or crop with a particular range of seed viability and spacing, research typically suggests a specific seeding rate. Inadequate production is the end result of delayed and stunted development caused by overcrowding. According to RABEPM [41], the recommended seed rate for Haricot beans is 70–100 kg for row planting and 90–120 kg for transmission, depending on the size of the seed. In rows, plants are spaced 10 cm apart and 40 cm apart. The adoption index was calculated using 100 kgh^{-1} improved Haricot bean seed (AI). A one-way analysis of variance was conducted to determine whether there was a significant mean difference in the seeding rate used in the three adopter groups.

2.6.3. *Fertilizer*

Haricot bean farming requires the use of a cultivar of inputs, just as growing any other crop. One of the most important processes is the application of fertilizer. To produce high yields, fertilizers must be used, both phosphoric and nitrogen. The recommended fertilizer rates are 100 kg/ha DAP at planting, 50 kg/ha urea before flowering, or 0.5 kg ha^{-1} inoculant (Rhizobia bacteria) in the planting [41]. Farmers in the study area only used diammonium phosphate (DAP) fertilizer to grow Haricot Beans. Using 100 kgh^{-1} DAP fertilizer, the Adoption Index (AI) was determined. A one-way analysis of variance was used to evaluate whether there was a significant mean difference in the fertilizer rate applied between the three adopter groups.

2.6.4. *Weeding practice*

Crop loss evaluation trials show that unchecked weed growth reduces haricot bean production by more than 36% and soybean production by more than 50% [42]. Haricot bean cultivation required 2–3 weeding to ensure sufficient yield. Two weeks after the plant emerges, the first weeding is done, and another is done 21–25 days later. Despite frequently being discussed in the findings, production techniques such as spacing, intercropping, weeding, etc., were not taken into account in the calculation of the Adoption Index (AI) or the econometric analysis.

2.6.5. *Bio fertilizer*

This preparation contains active or dormant cells from efficient microorganism strains that help plants absorb nutrients through interactions in the rhizosphere when applied to seed or soil. Nodules are circular, irregular, or cylindrical root outgrowths that support symbiotic rhizobia that fix nitrogen dioxide in the atmosphere. Leguminous plant roots or stem nodules are penetrated and promoted by rhizobia, symbiotic bacteria that convert atmospheric nitrogen (N_2) to ammonia (NH_3) in plant roots. Rhizobia can enter legume roots symbiotically and fix atmospheric nitrogen [43]. Most of the technologies envisioned to increase nitrogen fixation in various cropping systems are well within the study budgets of developing countries, and it is important to emphasize. Using the genetic diversity and symbiotic effectiveness of hosts (leguminous plants) and their corresponding endosymbionts (rhizobia), technologies have the potential to offer significant benefits, according to Kebede [44]. Responses indicate that biofermenters or inoculants keep the soil moist during and immediately after harvest and make it fertile. Farmers have, however, also claimed that biofertilizer results in soil darkening.

3. Results and discussion

3.1. *Adoption of haricot bean technology package by components*

3.1.1. *Overall adoption of haricot bean technology package*

In this study, farmers who did not grow an improved cultivar of Haricot beans were classified as non-adopters. Farmers who cultivated an improved cultivar while adhering to some of the suggested agronomic methods for the cultivation of Haricot beans (improved cultivar, seed rate, and fertilizer application rate) were classified as adopters [45]. The adoption index of the sample households showed that (17%) respondents had a score of 0, indicating that they are nonadopters, (4%) respondents had a score between 0.1 and 0.33, indicating low adopters, (54%) respondents had a score between 0.34 and 0.66, indicating medium adopters, and (25%) respondents had a score between 0.67 and 1.0, indicating high adopters (Table 3).

3.1.2. *Improved haricot bean varieties*

By dividing the percentage of the expanded coverage of the Haricot bean cultivar by the entire area, the intensity of cultivar adoption is determined. There were variations in the amount of cover in the home samples where Haricot beans were grown. The graph reveals that 0.22 ha on average were covered by every household in the sample (Table 4).

Table 4
Characteristics of farmers by adoption levels of the Haricot bean production package (categorical variables, % of farmers).

Indicators	Category of Responses	Adoption Category					Chi-Square Test value
		Non Adopter	Low Adopter	Medium Adopter	High Adopter	Total	
Sex	Male	7.6	2.3	61.1	29	87.3	73.27***
	Female	78.9	15.8	5.3	0	12.7	
Education status	Illiterate	31.9	8.5	42.6	17	31.3	18.32***
	Literate	14.6	0	56.1	29.3	27.4	
	Formal education	6.5	3.2	61.3	29.0	41.3	
Off-farm activity	Yes	2.7	10.8	59.5	27	24.7	0.67
Membership in Farmers' Association	Yes	0	3.8	65.4	30.8	34.6	16.11***
Access to Credit	Yes	0	7.7	61.5	30.8	34.7	10.39***
Contact with Extension agent	Yes	3.5	1.2	67.1	28.2	56.7	30.88***
Participation in training	Yes	0	3.2	66.1	30.6	41.3	21.83***
Participation in Field Day	Yes	1.7	3.4	67.8	27.1	39.3	16.72***
Conducting Demonstration	Yes			53.1	46.9	21.3	15.86***

*** indicates significance level <1%.

The adopter sample homes were spread over an area ranging from 0.06 to 0.50 ha. The variation in the area covered by the improved Haricot bean cultivar may be related to different land holdings and the level of adoption of an individual [11]. This finding is consistent with [11,46], who discovered that during the cropping year, (44.77%) adopters and seven (12.50%) nonadopters received training on improved haricot bean varieties and agronomic practices, while (55.43%) adopters and (87.5%) nonadopters received no training.

3.1.3. Seeding rate

Various amounts of an improved Haricot bean cultivar were seeded by farmers in the study area. Low, medium and high adopters, respectively, used 55.3, 61.31, and 67.38 kg/ha (Table 4). All adopter groups are used at levels below those advised. With a minimum seed rate per hectare of 43.5 kg and a maximum seed rate per hectare of 75.4 kg, the seed rates of the sample homes per unit of area varied significantly. This finding is consistent with the study by Degaga et al. [46], who discovered that farmers used an average of 29.40 kg/ha of improved haricot bean varieties, with a minimum and maximum of 5.33 and 35.00 kg/ha, respectively, while the required seed rate was 100 kg/ha. A one-way analysis of variance revealed a significant mean difference in the seeding rate applied between the three adopter categories, low, medium and high, $F = 39.304$, $P \leq 0.001$) at a level of significance of 1%.

3.1.4. Fertilizer application rate

Farmers in the area apply fertilizer at rates lower than demands [47]. The typical fertilizer application rate for Haricot bean production by sample farmers in the production year 2009–10 was 57.28 kg/ha^{-1}. On the other hand, the respective mean fertilizer rates of the nonadopters, low, medium and high adopters were 0 kg, 50 kg, 67.38 kg, and 71.06 kg per hectare (Table 3). Depending on the adoption category, the survey respondents apply fertilizer at varying rates. The variance analysis indicated a significant mean difference between the adoption categories ($F = 26.418$, $P \leq 0.01$) in relation to the adoption index of the fertilizer application rate of 1% significance (Table 3). This average is much lower than the recommended rate of 200 kg/ha or more for gypsum (i.e. calcium topdressing) [48], but Senegal's average NPK (nitrogen, phosphorus and potassium) guideline is 150 kg/ha [49]. Again, this average rate is much lower than the 200 kg/ha NPK needed for millet production systems in Sudano-Sahelian agro ecological zones [50].

3.2. Haricot bean production practices by adoption level

3.2.1. Spacing

Only 23% of the respondents used row planting, and only 11% followed the recommended spacing guidelines (20 cm between plants and 40 cm between rows), with the remaining respondents doing whatever they liked. Farmers who responded gave explanations for why they did not follow the suggested spacing guidelines. Most of the respondents said that they frequently intercropped Haricot beans with other crops, but also said that it takes more time and skill, so they claimed that sticking to the recommended spacing is challenging for them [51]. They required a larger crop to compensate for some species that went extinct. They also believe that planting more closely together will produce a higher yield [52].

3.2.2. Intercropping

For small-scale farmers with resource limitations experiencing a food shortage, intercropping is essential [53]. By boosting long-term revenue, lowering the chance of crop failure, and increasing the amount of protein in their diet, smallholders can benefit from cereal/leg intercropping [54]. Fig. 4 reveals that in the study area, 19% of the 100 respondents used monoculture as a mode of production, 50% used intercultural and 31% combined the two in the same or different plots of land during the same or different production seasons. During a group discussion, a respondent noted that most people intercrop due to the scarcity of agricultural land and the possibility of crop failure [55].

According to the findings, 21% of the respondents intercropped Haricot beans with maize and coffee, 21% with maize and barley, 20% with only maize, 13% with maize and Enset, 5% with Enset, 2% with barely and 2% with barley. In times of food scarcity, intercropping is essential for small-scale farmers with limited resources [52] (Fig. 5). This finding supports the findings of Degaga et al. [46], who found that 76% of farmers in the study region grow Haricot beans, only 11% grow Haricot beans together with other crops, and 13% grow Haricot beans in intercropping and single cultivation (Fig. 5). Because the land is limited and they want to reduce crop failure, respondents suggested intercropping during group discussions [56]. Essential crops such as maize, sorghum, khat, and coffee are often interpolated with Haricot beans Degaga et al. [46].

3.2.3. Weed control practices

In the study area, 42% of households do not weed their Haricot bean farm, 55% weed once, and only 3% weed twice (Fig. 6). As a result, extension agencies must work hard to improve weed control techniques. Failure to do so results in production loss and lower grain quality for sale. To provide an appropriate yield, common bean cultivation takes 2–3 weeding sessions. According to Amanuel and Girma [57], the first weeding occurs two weeks after the emergence of the plant, and the second occurs 21–25 days later. According to Merga et al. [58], insecticides and hand weeding may have led to stronger leaves under low weed infestation, increasing the photosynthetic efficiency of the chickpea (*Cicer arietinum* L.) and allowing a significant number of pods to survive. Weeds drastically decrease crop yield by competing for light, nutrients, and space with crops. Weed competition has caused haricot bean yield losses ranging from 35 to 90% across the country [59].

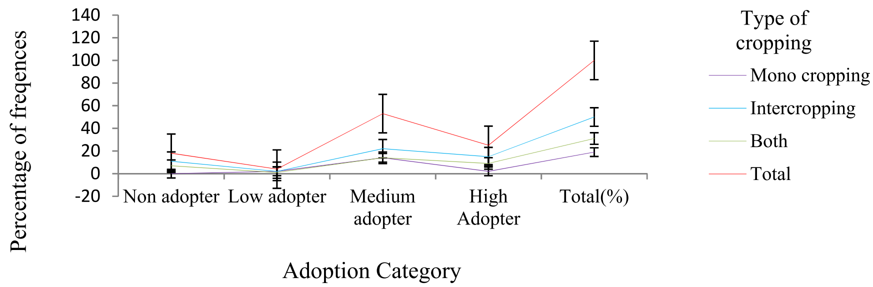

Fig. 4. Types of cultivation techniques in Haricot bean production with adoption level.

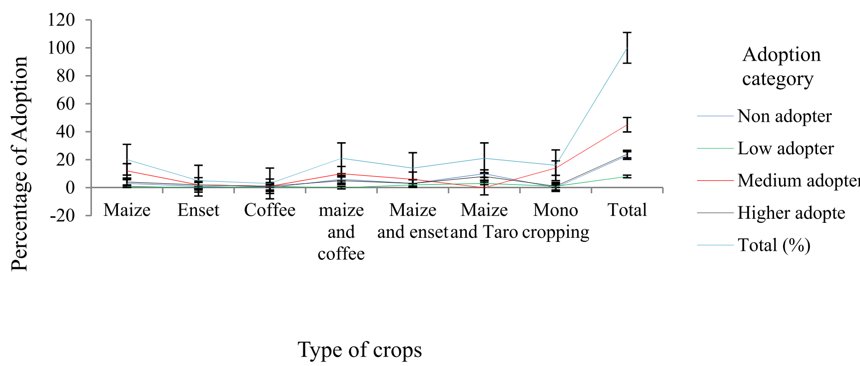

Fig. 5. Types of crops used to intercrop with Haricot beans.

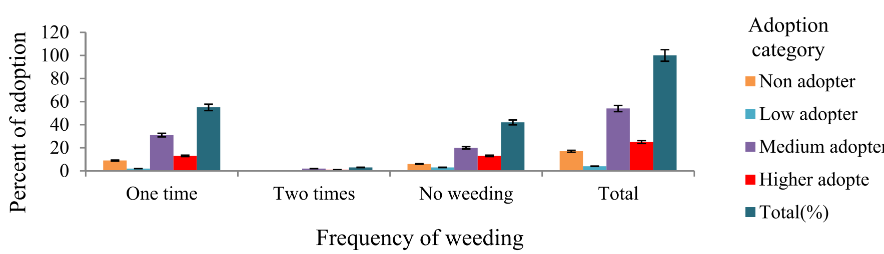

Fig. 6. Frequency of weeding in Haricot Bean production.

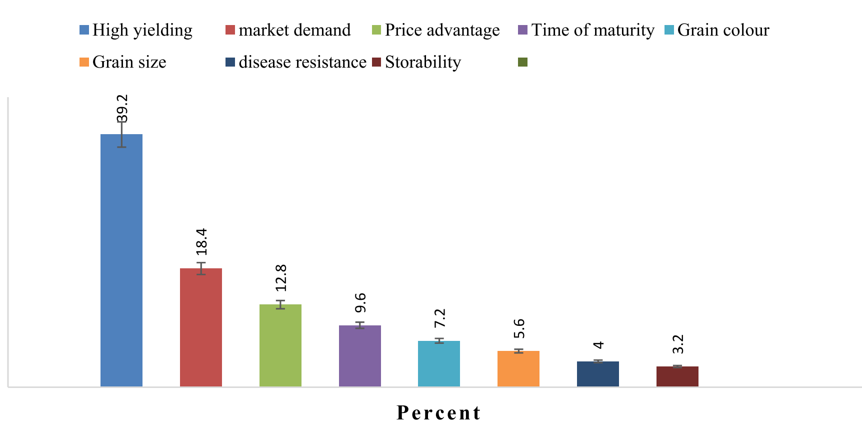

Fig. 7. Farmers' evaluation criteria of improved haricot bean varieties.

3.3. Farmers' selection criteria for improved haricot bean varieties

Farmers have adoption requirements for released varieties that are rarely taken into account by researchers and extension. As a result, many innovations are simply rejected by farmers due to a mismatch in preference criteria between the technology disseminator and the farmers. The most attractive characteristics of the improved Haricot bean varieties, according to the results of the survey and the discussions of focus groups in the study field, include high yield, market demand, price advantage, maturity duration, grain color, grain size, disease resistance, and storage (Fig. 7). According to survey statistics, the majority of respondents cultivate Nasir varieties of the total sample [60]. Nasir Cultivar was chosen for its high production, high market demand, inexpensive price, and brilliant color. As a result of these occurrences, the number of sample families growing Nasir increased; however, seeds for this enhanced cultivar are scarce in the study region.

3.4. Sociodemographic characterization of haricot bean production by adoption levels

3.4.1. Sex

Men comprised 81% of the 100 respondents, while women comprised 19% (Table 4). Most of the female adopters in the household were in the low adoption group, showing that they are less adept at adopting haricot bean production than their male counterparts. At the 1% level, a Chi-square analysis ($\chi^2 = 73.274$, $P \leq 0.01$), Cramer's V = 0.501 revealed a significant link between sex and the adoption of Haricot bean production. The findings of this study (Table 4) are consistent with previous studies that have found a strong relationship between sex and the adoption of agricultural technology [31].

3.4.2. Educational status of sample household heads

In the sample, approximately 31.3% of the families were illiterate, 27.3% were literate, and 41.4 were enrolled in formal schooling (Table 4). The result of the chi-square test ($\chi^2 = 18.315$, $P = 0.005$) indicated a significant relationship between education and the adoption of Haricot beans. Farmers with a higher education level are better able to assimilate knowledge and identify applicable ways to reduce production restrictions. The findings of this study are consistent with those of Arega [31] who discovered a substantial relationship between education and the adoption of a better maize production package.

3.4.3. Off-farm activities

Many farmers can supplement their income by working in a non-farm cultivation. This is expected to improve their financial situation and provide more information. 24.7% of the total number of households interviewed engaged in activities other than agriculture, while 75.3% did not (Table 4). Unlike predictions, engagement in off-farm activities ($\chi^2 = 0.613$, df = 3) demonstrated a negligible connection with acceptance of Haricot bean introduction. There was no association between off-farm activities and haricot bean adoption, according to Cramer's V = 0.179. The outcomes of this study support the finding of VanWey [61], who found that off-farm activities in which the sample households participated in the study area included trading, daily labor occupations, and civil servants.

3.4.4. Membership in the farmers' association

Farmers' adoption decisions are likely to be influenced indirectly by their social group membership. As a result of this interaction, they are exposed to new ideas and behaviors [62]. The farmers association's seed multiplication group is anticipated to have a significant impact on adoption. Table 4 shows that 54 (34.6%) of the total sampled households participate in seed multiplication, while 96 (65.3%) do not ($\chi^2 = 16.109$, $P \leq 0.01$). The findings demonstrated a significant association between membership and the adoption of Haricot bean production at the 1% level, this finding in line with [60].

3.4.5. Access to a credit service

Loan increases are one technique for increasing farmers' access to new agricultural equipment. It strengthens farmers' ability to obtain higher-quality seeds, fertilizers, and other inputs [2]. As a result, access to credit is expected to increase the likelihood of adopting introduced haricot bean production; however, no cash credit is available in the study location, but fertilizer credit is available in kind [63]. At a probability level of less than 1% ($p \leq 0.01$), the results of this study demonstrate a statistically significant difference between the adoption categories depending on the availability of fertilizer credit ($\chi^2 = 10.395$, $p \leq 0.01$). Throughout the planting season, farmers could obtain numerous enhanced seeds with credit from the agricultural administration and non-governmental organizations (NGOs). In terms of fertilizer credit availability, 35.7% of the respondents reported having access to it, while the remaining 64.3% reported not having access to it (Table 4). Farmers' adoption decisions were likely to be influenced by institutional seed financing. Access to institutional seed loans will enable resource-constrained farmers to obtain improved seed varieties, while also encouraging them to apply fertilizer at the appropriate pace [64]. Farmers who lack money and credit will find it difficult to adopt modern technology. Previous writers backed up this claim about loan availability [65], the availability of credit is projected to increase Haricot bean consumption. Credit availability enables farmers to use higher quality agricultural inputs, increasing agricultural output.

3.4.6. Contact with the extension agent

The data found that 27.50% of nonadopters, 72.8% of low adopters, 72.8% of medium adopters, and 92.1% of high adopters had contact with an extension agent, respectively (Table 4). Nonadopters, low, medium and high ads, did not interact with development agents, but 72%, 50%, 27.2% and 7.9% of nonadopters, low, medium and high ads, respectively, did. This implies that a larger proportion (69.3%) has had interaction with a development agent, whereas a smaller proportion (30.7) has not. According to studies, most farmers have contact with an extension agent, and most farmers are adopters in various adoption categories. Regarding farmer contact with extension agents, the chi-square result ($\chi^2 = 30.879$, $P \leq 0.01$) reveals a statistically significant difference between adoption categories [31] observed comparable findings.

3.4.7. Participation in training

Of the 100 farmers interviewed, 41.3% had received Haricot bean production instruction, while 58.7% had not (Table 4). The chi-square result ($\chi^2 = 21.878$ and $P \leq 0.01$) There is a statistically significant difference between the groups of nonadopter and adopter in participation in training that helps people perform new activities successfully. The findings of this study support those of [66], who investigated the factors influencing the adoption of improved maize technology in the Yelma Dansa district, Ethiopia. Training is an important component that improves farmer performance, while also providing farmers with new information and skills.

3.4.8. Participation in the farmers field day visit

39.3% of the farmers in the entire sample household attended field days regularly, while most farmers (60.7%) did not participate in field day programs (Table 4). Respondent participation in field days can be observed with varied frequency levels of low, medium, and high adopters. Chi-square analysis ($\chi^2 = 16.721$, $P \leq 0.01$) demonstrates a substantial difference between the non-adoptive and adoptive groups to investigate the relationship between field day attendance and adoption status. The Cramer study V = 0.255 also indicated a link between field day and Haricot bean adoption. The findings of this study are consistent [60]. During field days, neighboring farmers will see how the new technology is used. This scenario may make the adoption process more accessible.

3.4.9. Conduct a demonstration

Demonstration is an important tool for increasing farmers' concrete awareness. It also acts as an efficient method of communicating information to adjacent farms. Accepting the new techniques, putting them into practice in the field under the careful supervision of extension agents, and then requesting others to see how they accomplish it, it is what the demonstration implies in this study. This circumstance may facilitate the adoption process, and it is hypothesized that adoption and these circumstances have a positive relationship.

According to the study, only 21.3% of the total sampled households participated in field demonstrations on improved haricot bean production and associated agronomic practices, while 79.7% did not (Table 4). At the 5% probability level, the Chi-square test revealed a significant (χ^2 = 15.864, P ≤ 0.01) participation in demonstrations and adoption are related. Participation in demonstrations has a large and positive impact on the adoption of the Haricot bean production method; this finding is in line with [67,68] discovered comparable results.

3.4.10. Age of the household head

The age of the farmers sampled ranged from 25 to 85 years (Table 5). The mean test determined that there were no significant mean differences (F = 1.29, P = 0.31) between the adoption categories, showing that there was no connection between age and the adoption of newly introduced Haricot bean crops. This is evident in the nonsignificant mean difference in the median age of the adoption groups. The average ages of nonadopters, low, medium, and high adopters were 43.40, 45.33, 40.00, and 41.50, respectively. Amare [69] found no statistically significant mean age difference between adopters and nonadopter groups in their study on the adoption of seed and fertilizer packages.

3.4.11. Experience of the household head

Farmers with greater skill in various operations of haricot beans appear to have more information and better knowledge and are expected to evaluate the benefit of technology. A one-way analysis of variance (F = 1.394, P = 0.247) did not reveal statistically significant mean differences between adoption categories.

3.4.12. Family size

In the survey, family size is defined as the number of people living in the respondent's household. The large size of the family is said to indicate the availability of labor in the household. As a result, this variable was projected to have a strong and significant relationship with the adoption of the newly developed Haricot bean m production technique. The availability of labor is likely to have an impact on the gross margin of innovation.

The average family size among the respondents was 5.43 people. There was a minimum family size of one person and a maximum family size of ten persons in the sample houses (Table 5). According to the findings, there is a considerable disparity between the categories of adoption of households. The mean difference between adoption categories is statistically significant, according to a one-way analysis of variance (F = 0.5.424, P ≤ 0.01). Tesfay [70] observed a positive and significant link between family size and adoption in his study on factors influencing the adoption of new wheat and maize varieties in Tigray.

3.4.13. Total land holding

Land is unquestionably an important resource because it is the foundation of all economic activity, particularly in the rural and agricultural sectors. Furthermore, the size of the farm determines whether a household adopts or rejects new technologies. As a result, land ownership was expected to have a positive and significant relationship with adoption and its intensity of adoptions of Haricot Bean [71].

The average land holding of the households studied was 0.5 ha. The total land holdings of the respondents ranged from 0.25 to 1.75 ha (Table 5). The nonadopters owned 0.84 ha of total land, while the low, medium, and high adopters each owned 0.74, 1.25, and 1.50 ha. A one-way analysis of variance revealed that the mean difference between adoption categories is statistically insignificant (F = 2.240, P = 0.086). The findings of this analysis support Million and Belay's (2004) findings. The total land holdings of the respondents ranged from 0.25 to 1.75 ha (Table 5). The nonadopters owned 0.84 ha of total land, while the low, medium, and high adopters each owned 0.74, 1.25, and 1.50 ha. A one-way analysis of variance revealed that the mean difference between adoption categories is statistically insignificant (F = 2.240, P = 0.086), this finding in line with kassa [29].

3.4.14. Animal holding

In the rural context, livestock ownership is an important indicator of a household's wealth situation. The number of animals owned by a farmer was expected to influence the adoption of the newly introduced Haricot bean production method. In Ethiopian agriculture, livestock is a key source of income, food, and draught power for crop cultivation. As a result, a family with a large livestock holding can benefit from improved draught, which is one of the most important cash sources for purchasing inputs. According to Table 5, the average number of animals owned by TLU sample families was 1.29. The total number of responses ranged from one to five animals, with a minimum of one and a maximum of five. To investigate if there is a difference in average livestock ownership between adopters and nonadopters, an analysis of variance was done. There are no significant differences in average cattle ownership between adopter groups, according to the analysis of variance (F = 1.986, P = 0.119). The findings of this study contradict previous adoption research. Groher [72], discovered that cattle ownership has a positive influence on the adoption of agricultural advances in their research.

3.4.15. Labor availability

It may not be essential to hire additional workers when a family has a notable workforce. Money saved by using one's own labor force can be used to purchase additional crop production inputs. This increases the possibility that the production of Haricot beans introduced will be

Table 5
Characteristics of farmers by adoption levels of the Haricot Bean production package (*Continuous variables*).

Explanatory Variables	Adoption Category								Total		F-value
	Non Adopter		Low Adopter		Medium Adopter		High Adopter				
	Mean	STD	Mean	STD	Mean	STD	Mean	STD	Mean	STD	
Age of HH	43.40	11.78	45.33	11.57	40.00	41.50	8.55	10.06	41.16	9.67	1.23
Experience of HH	10.6	3.73	7.33	2.58	10.26	5.7	12.11	8.32	10.67	6.18	1.39
Family size of the HH	4.48	1.15	6.67	2.65	5.63	1.15	5.42	1.44	5.43	1.53	5.43***
Total land HH	0.84	.33	1.74	.48	1.35	.67	1.60	2.17	1.34	1.23	2.24*
Livestock TLU	2.97	2.06	3.1	1.10	3.01	0.74	4.12	2.91	4.29	3.29	1.99
Availability of Labor	3.57	1.25	3.10	1.1	3.01	.74	3.00	.95	3.11	.93	4.39***
Farm Income	3289.8	1803.2	5728.6	4694.6	6073.0	4834.2	6871.5	5196.1	5797.7	4680.4	5.29***
Output/Input Market	6.07	1.813	6.39	1.597	5.82	1.687	5.48	2.325	5.80	1.880	0.72

*** indicates significance level at 1% and * significance at 10%.

accepted by the household. As a result, a favorable association was predicted between haricot bean production, adoption, and intensity [72]. The average availability of labor in the sample household with an equivalent mean was 3.10, with a standard deviation of 0.93. The average number of available labor force in terms of equivalent men for non-adopters, low, medium, and high adopters was 3.57, 3.10, 3.01, and 3.00, respectively (Table 5).

3.4.16. Farm income

Farm income is the primary capital used to purchase farm and household input. This study calculated household agricultural income based on sales of crops, livestock and animal products. Coffee sales account for the majority of cash revenue for households in the study sample (dry berry and red berry coffee). The average annual farm income of the study household was 5797.70, but nonadopters earned Birr 3289.80, while low, medium and high adopters earned 5728.66, 6073.09, and 6871.51, respectively (Table 5). The minimum and maximum agricultural income of the sample household range from 1545 Birr to 23410 Birr. An analysis of variance was performed to evaluate the association between farm income and the adoption of haricot bean production. The results ($F = 5.285$ and $p \leq 0.01$) demonstrated a significant mean difference between adoption categories, this study supports the findings of Kassa [73].

3.4.17. Distance to output/input market

In this study, it is assumed that the distance (in kilometers) between the respondent's residence and the nearest marketplace is negatively correlated with the decision to adopt newly introduced crop varieties and associated agronomic practices. There were no statistically significant mean differences between the adoption groups, according to a one-way ANOVA ($F = 1.410$, $P = 0.242$). There are no statistically significant mean differences between the adoption groups for the input market.

3.5. Determinants of adopting haricot bean production technology

In this section, estimates of the factors that influence the adoption of the Haricot bean production technology package in the Tobit econometric model are presented. Using the Variance Inflation Factor (VIF) for continuous explanatory variables and contingency coefficients for dummy explanatory variables, it was determined whether there was significant multicollinearity among independent variables for all continuous and discrete variables prior to performing the model analysis. The acceptance and intensity of the Haricot bean are investigated according to individual, demographic, economic, and institutional factors. Eight out of a total of 16 explanatory factors that were thought to have an impact on the likelihood and intensity of adoption were found to be significantly related (Table 6).

Table 6
Maximum likelihood estimates of the Tobit model.

Variables	Estimated Coefficient.	Std. Err.	T	P
SEXHH	0.5675765	0.0533227	4.90***	P ≤ 0.01
PAOFA	−0.0199447	0.05165	−0.39	0.7005
SEECRED	0 .0336503	0.0473561	2.13**	0.0325
PAFILD	0.081008	0.223211	3.16**	P ≤ 0.01
FAREXP	−0.0013123	0.045314	−0.03	0.9770
MEMSEM	0.1072141	0.1532016	1.76 *	0.0804
PATRAIN	0.088732	0.0530616	1.29 **	0.0216
AGEHH	−0.4567856	0.375619	−0.33	0.7405
TLU	−0.000214	0.02985	−0.01	0.9941
MANEQ	−0.0242109	0.0817001	−0.30	0.7670
TOTLAN	0 .0662677	0.040857	1.62	0.1072
TOTINCO	0.0317772	0.0308668	1.03	0.3050
CONDEM	0.093043	0.0592687	3.36*	0.0911
MARKDIS	-0.0600924	0.0161347	−3.23**	P ≤ 0.01
Constant	0 .0932834	0.3708259	0.25	0.8021
Sigma	0.238506	0.055337	12.35***.	P ≤ 0.01

Logarithmic likelihood = −16.70931; Pseudo $R^2 = 0.7764$; Prob = 0.0000; ***, represents a level of significance of 1%, **, 5% and * 10%, respectively.

3.5.1. Sex of the household head

One of the indicators of technology adoption is the gender of the head of the household. According to the Tobit model, at the 1% significance level, the gender of the head of household had a favorable and significant impact on the adoption of better Haricot bean production technology (Table 6). This reveals that male families are more likely than female households to accept new technology and boost haricot bean production because they have more access to information on improved haricot bean production techniques. On the other hand, women-headed households are more likely to adopt new technologies than men-headed households and do not have better access to upgraded technology. This finding is congruent with [74], who revealed that female-headed households have less access to enhanced technical knowledge.

3.5.2. Access to credit

One method of improving farmers' access to contemporary production technology is to increase financing availability. At the 5% significance level, the Tobit model shows that the availability of finance has a positive and significant impact on implementing the newly introduced Haricot bean production technology (Table 6). Boost farmer income so that they can purchase superior seeds, inoculants, fertilizers, and other inputs [75]. There is no access to cash credit in the study area, but there is access to credit in kind, which is anticipated to increase the likelihood that a better Haricot bean production technology will be adopted. During the cropping season, farmers can borrow a cultivar of input from the agriculture office and nongovernmental organizations.

3.5.3. Participation in field day

Participating in a field day is one method of educating and learning about new technology. The Tobit model findings for this variable demonstrate that training attendance was positively and significantly associated with the adoption of the Haricot bean production method at a level of significance of 5%. (Table 6). Farmers are more likely to use improved Haricot bean production technology than farmers who do not have the same opportunity to attend an upgraded field day of Haricot bean production. In other words, the results show that farmers are more likely than nonfarmers to employ formal extension information. This demonstrates that having access to field-day participation boosted the yield of Haricot beans and that farmers can become more knowledgeable about the numerous factors affecting crop productivity and production. This finding is in line with those made by Abayneh et al. [76], who found that having access to field day participation boosted the production of Haricot beans and that farmers might know more about the numerous factors affecting crop yield.

3.5.4. Membership in the association

At the 10% significance level, participation in seed multiplication had a beneficial impact on the acceptance and level of adoption of the introduced haricot bean production (Table 6). Farmers who join a seed multiplication group will also have access to market access, extension information, and basic seed study for multiplication (20kg/farmer). This demonstrates that increasing and expanding seed multiplication is essential to improve the area's capacity to provide a sustainable seed supply system and increase the acceptability of improved haricot bean varieties [77].

3.5.5. Participation in training

A training event is a type of extension activity in which farmers can acquire technical knowledge about new technologies as well as practical skills. The study's findings showed that training received had a favorable and significant impact on participation in training at a level of significance of 5% (Table 6). This could be explained by the fact that trained farmers have a better understanding of production methods and technology than untrained farmers, which contributes to improved haricot bean production and productivity. Farmers' expanded technology packages must be given priority through training to increase the adoption of updated Haricot bean production packages; these results support those [76,77].

3.5.6. Conducting a demonstration

Farmers can increase agricultural production and productivity by learning new skills through demonstration. According to Tobit's results, the demonstration had a positive and significant impact on the chance of adopting the Haricot bean production package at a significant level of 10% (Table 6). Therefore, the demonstration method is essential to provide farmers with advances in agricultural productivity in real-world settings. To properly adopt and employ new practices, farmers must assess the advantages and disadvantages of the new technology. These findings imply that farmers who participate in protests are more likely than other farmers to adopt new and improved technologies. This suggests that expanding the demonstration coverage would speed up the adoption of new packages, requiring the expansion of the currently constrained demonstration techniques [65] found similar findings.

3.5.7. Output/input market distance

The adoption of the Haricot bean production package was adversely correlated with the distance between the farmer's home and the input and output markets. At a level of significance of 10%, the distance from the market considerably affects the probability of package acceptance (Table 6). The results of market access indicated that household adoption increased as the market distance decreased. This suggests that farmers located closer to the input and output markets have better access to the input, technology, and product markets, as well as better access to information about new technologies than those who are farther away and cannot quickly decide how to adapt. Similar results were shown by Addison [78], adoption and intensity of adoption both increase with market distance.

3.6. Effects of changes in significant explanatory variables on the probability and intensity of adoption of improved haricot bean production

All elements driving the adoption and intensity of Haricot bean production technology may not have the same impact on farm family decisions. The results of the Tobit model analysis (marginal effect) of the effects of changes in explanatory factors on adoption and intensity of usage are shown in Table 7.

The marginal effect shows that having a male-headed household in the area improves the likelihood of adoption and the intensity of use of an upgraded Haricot bean production package by 47 and 56%, respectively. Women in many developing nations have less access to family resources and new farming practices due to long-standing cultural and social concerns. Access to enhanced seed credit boosted the likelihood and intensity of application of the upgraded Haricot bean production process by 3.1 and 7.3%, respectively, according to the computed data. Participating in field day visit programs for the improved Haricot bean production package resulted in an estimated 5.4% and 8.1% increase in the probability and intensity of usage of the better Haricot bean production package, respectively, according to the marginal effect. Field days are also an important tool for convincing farmers to accept technology solutions. Farmers can gain hands-on experience with technology through the field day visit program. The marginal effect also demonstrates that involvement in the seed multiplication group improves the frequency and intensity of use of the upgraded Haricot bean production package by 10.7 and 15.3%, respectively. This suggests that increasing the multiplication of seeds in the farming community will improve the acceptance of new technologies, such as a more advanced Haricot bean production package [79]. Improved Haricot bean production training increases the likelihood and intensity of application of the improved Haricot bean production package by 3.1 and 7.3%, respectively. The likelihood of acceptance and the intensity of use of the upgraded Haricot bean production package increase by 5.2% and 9.3%, respectively, as the demonstration stage progresses. As a result, to increase the adoption of technology, the extension service must consider presenting a cultivar of extension events as a substantial component of the extension [80,81]. A unit increase in an explanatory variable in this study will be a specific percentage increase in the probability and intensity of using improved Haricot bean production and associated agronomic practices. As a result, the present extension service must place greater emphasis on improving the variables that influence the adoption of improved Haricot beans.

Table 7
Effects of changes in explanatory variables.

Variables	Change in the probability of Adoption	Change in the intensity of Adoption	Total change
SEXHH	0.478765	0.567527	0.567528
ASECRED	0 .031650	0 .073650	0 073650
PAFILD	0.054763	0.081068	0.081069
MEMSEM	0.107235	0.153214	0.157214
PATRAIN	0.068193	0.083761	0.083762
CONDEM	0.052843	0.093068	0.093069
Constant	0 .093283	0.370825	0.370824

4. Conclusions

This study was carried out in the Kindo Koyisha district, which is located in the Wolaita zone in southern Ethiopia. Haricot bean cultivation is a key crop that provides both food and income. The primary goal of this study was to evaluate the current level of acceptance and identify factors that influence the adoption of improved varieties of haricot bean production and associated agronomic practices. A standardized schedule was used to interview 100 sample families (81 males and 19 females) from four kebeles in the district. The improved Haricot bean production package in this study includes a better cultivation rate, planting, and fertilizer. These were discovered to be used by Haricot bean farmers, who use improved cultivars at a lower rate than previously thought. The variation in adoption between sample families was explored using multiple criteria such as personal and demographic, economic, and institutional factors of the household. The adoption and intensity of the improved Haricot bean were substantially related to most of the characteristics that are thought to influence the adoption behavior. The educational status and gender of the head of the household were found to be highly associated with the level of adoption of the improved Haricot bean among the personal and demographic criteria studied. The 100 houses sampled included 19 female houses, 15 of these female households were nonadopter, three were early adopters, and one was a late adopter.

In the economic and wealth-related variables that were expected to influence the adoption of improved Haricot bean production technology, labor availability and farm income revealed a positive and significant connection. Furthermore, receiving an extension agent advisory service, attending a field day training, showing, having access to improved seed credit, and being a seed multiplication group all had a positive and significant relationship with the intensity of adoption of improved adoption Haricot bean production. Farmers prioritized high yield, market demand, price advantage, maturation time, grain color, grain size, disease resistance, and storability in this perspective. According to these selection criteria, the Nasir cultivars are cultivated by most Haricot bean growers in the study region because they match the above qualities and have high seed demand. The findings of the econometric model also indicated the relative impact of several variables on the likelihood and intensity of adoption of expanded haricot bean production. Therefore, access to seed credit, attendance at extension training, field day programs, demonstrations, participation in seed multiplication, and market distance were found to have a substantial influence on the probability and intensity of adopting an upgraded Haricot bean production package.

5. Recommendations

Based on the results of the study, the following recommendations are made to boost farmers' adoption of improved Haricot bean production packages to increase production and productivity.

- The extension service for improved Haricot bean production was found to have a substantial link with the adoption of the Haricot bean production package because it improves the ability to collect and use product information. As a result, farmers' awareness of greater haricot bean production should be increased through training, field visits, and demonstrations.
- In addition, domestic chefs should be prioritize the cultivation of Haricot beans. As a result, to increase crop uptake and production, development interventions should prioritize the establishment of such institutional support networks.
- In this regard, more demonstration sites of improved agronomic practices should be constructed to increase awareness of improved Haricot bean production varieties and related agronomic practices in the study area.
- Farmers deviated from the recommended package procedures, according to the recommendations, due to a lack of extension assistance and the farmers' inability to apply fertilizer. As a result, the supply of extension services must be improved to increase farmers' access to information and extension counsel.
- It is also critical to increase loan availability. According to the producing region, a collection of approaches to the bean cropping system can be analyzed and recommended to farmers. Additionally, advice on the appropriate fertilizer and seed rate is required for bean/medium intercropping systems.
- Women household leaders should be empowered and encouraged to participate in increased haricot bean production activities through the provision of agricultural input credits to increase production and productivity and, as a result, improve their livelihoods. Farmers also have their own adoption criteria for newly released varieties, which study and extension do not always take into account. As a result, the research and extension system should prioritize participatory study that takes into account farmers' goals and needs.
- Particular attention should be paid to the prescribed inoculants, which were found to be underutilized due to a lack of extension services and insufficient experience among Development Agents to administer bio-fertilizer as suggested. As a result, the delivery of extension services should be improved to provide farmers with more information and guidance.

Authors' contribution statement

The inception and design of the study were contributed by all authors. Mr. Moges Cholo, who helped develop the proposal, collected data, supervised the analysis and wrote the manuscript; Dr. M. Senapathy, who helped with data supervision, clerking, discussion, writing, and manuscript preparation, as well as editorial issues; and Mr. Elias Bojago; Mrs. Divya,R.K and Mr. Dawit Leja, who revised and prepared the manuscript, edited the text, and helped with data cleaning and analysis. The final manuscript was read and approved by all authors.

Limitations

The study is limited to investigating the parameters that influence the adoption and intensity of improved haricot bean varieties and associated agronomic practices in the study area. A systematic interview schedule was used to interview 100 sample homes (81 males and 19 females) from four kebeles in the district; therefore, the sample size was very small. The interaction effect of the intensity of the improved haricot bean varieties on the associated agronomic practices was not evaluated due to the cross-sectional nature of the study. Other similar studies are suggested in different parts of the country.

Consent to publication

All authors agreed to make this original study work available to the public.

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Availability of data and materials

The data from the current study were generated and evaluated and are presented in this article, as well as on request from the contributing authors.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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List of abbreviations

^{0}C	Degree Celsius
ANOVA	Analysis of variance
CSA	Central Statistical Authority
EIAR	Ethiopian Agricultural Research Institute
FDRE	Federal Democratic Republic of Ethiopia
Ha	Hectare
HH	Household Head
IPMS	Improving Productivity and Market Success
Kg	Kilogram
KKDAO	Kindo Koyisha District Agriculture Office.
Km	Kilometer
Masl	Meters above sea level
MoA	Ministry of Agriculture of the MoA
NGOs	Non-Governmental Organizations
PA	Peasant Association
SARI	Southern Agricultural Research Institute
SD	Standard Deviation
SNNPRS	Southern Nations Nationalities and Peoples Regional State
SPSS	Statistical Package for Social Sciences
TLU	Total livestock unit
VIF	Variance Inflation Factor

Appendix A. Supplementary data

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