**Cross Current International Journal of Agriculture and Veterinary Sciences**
*Abbreviated Key Title: Cross Current Int J Agri Vet Sci*
**ISSN:** 2663-2454 (Print) & Open Access
**DOI:** https://doi.org/10.36344/ccijavs.2025.v07i02.002

Volume-7 | Issue-2 | Mar-Apr, 2025 |

Original Research Article

# Adoption of Improved Food Barley Technologies in Ethiopia

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| **Received:** 20.03.2025 | **Accepted:** 26.04.2025 | **Published:** 30.04.2025 |

**Abstract:** The study assessed adoption of improved food barley technologies and factors determining the adoption decision of smallholder barley producers. The study employed cross-sectional data collected from major barley growing regions of Ethiopia. Tobit, Double hurdle and Multivariate probit models along with descriptive statistics were used to analyze the data. According to the findings, average seed rate used was found within the rage of the national recommendation whereas inorganic fertilizers applied was lower than the recommendation. Crop rotation, inorganic fertilizers, soil and water conservation practices, herbicides, manure, improved varieties and row planting were used by 87%, 65%, 48%, 48%, 39%, 8% and 6%, of the producers respectively. The result indicated that encouraging membership of cooperatives and participation in food barley marketing, training the producers and improving access to input market helps to increase the adoption of inorganic fertilizer in food barley production. The extension system that focuses on demonstration and experience sharing helps to scale the adoption of improved food barley varieties. Improving accessibility of improved seed and fertilizer helps to increase adoption of food barley technologies. The result exhibited complementarity among adoption decision of the technologies; that suggested focusing on technology package is a favourable extension approach to enhance adoption of food barley technologies.
**Keywords:** Adoption, Double Hurdle, Technology package, Tobit.

## INTRODUCTION

Food barley is one of the most important staple food crops in the highlands of Ethiopia. It has a great importance in social and food habit of the people. It is the fifth most important cereal crop in terms of area coverage in Ethiopia next to *tef*, maize, wheat and sorghum. It is produced by more than 3.6 million households and covers more than 0.8 million hectares of land with production of more than 2 million tons annually (ESS, 2022).

The ten years development plan formulated by the government of Ethiopia in 2020 placed high priority on accelerating agricultural growth to achieve food security and poverty alleviation. The plan indicated *tef*, barley, wheat and maize are among the prioritized cereal crops. One of the major goal of this plan was to increase cereals production and productivity focusing on increasing adoption of technological packages that encompass improved seeds, fertilizers and better management practices.

In the last five decades, several interventions have been made in the area of research and extension to improve food barley production and productivity by research institutions, universities, NGOs and agriculture office. According to Ministry of Agriculture more than 41 improved food barley varieties have been released by the research system along with improved crop management practices (MoANR, 2016). These technology packages have been extensively demonstrated in major barley producing areas of the country. Despite the extensive technology generation and dissemination efforts, average barley productivity (2.59 tons/ha) (ESS, 2022) has remained below the potential yield (higher than 5 tons/ha) (Derso et al., 2018) suggesting that the county has not sufficiently benefited from developed barley technologies. Although a number of researches have been done on crop production technology adoption and the factors governing them among smallholder farmers in Ethiopia, few of such works have been devoted to barley production technologies. Adoption studies those focused on barley technology adoption are either location specific or lean towards varietal adoption (Yirga *et al.*, 2015; Yigezu *et al.*, 2015); Aman & Tewodros , 2016; Dereje, 2018).

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**Citation:** Tamirat Girma, Endeshaw Habte, Melkamu Bazie, Samuel Diro, Guta Bukero (2025). Adoption of Improved Food Barley Technologies in Ethiopia. *Cross Current Int J Agri Vet Sci, 7*(2), 43-54.

This has motivated this study to look at the level of adoption of food barley technology packages including improved varieties, inorganic fertilizers, crop rotation, row planting and soil and water conservation practices and examine factors influencing the adoption decision behavior of smallholder farmers for the technologies.

## METHODOLOGY

### Definition of Adopters

In this study adoption is defined based on existing use status of producers of food barley technologies including improved varieties, inorganic fertilizers, crop rotation, soil and water conservation practices (SWCP), and row planting. Improved variety adopters are farmers using at least one of improved verities released by the research system. Fertilizer adopters are farmers that are applying inorganic fertilizers on their food barley plots. Farmers that are using row planting method are considered as adopters of improved planting method. Producers that are using at least one of soil and water conservation methods like terracing, stone or soil bund, counter ploughing etc. are adopters of soil and water conservation practices.

Each of the dependent variable took dichotomous value depending on the farm households' decision either to adopt or not. As a result, for each one of the technology, when the farm households adopt the technology, the household is called adopter and represented by one (1); otherwise, non-adopter and represented by zero (0).

### Data and Method of Collection

The sampling and data collection were done in collaboration with Ethiopian Statistical Service (ESS). The study employed multistage sampling technique to select regions, *kebeles (Enumeration Areas (EAs))* and households. Major barley producing regions were purposively selected and the sample size proportionally allocated to regions in the first stage. Barley producing *kebeles/EAs* were identified in the second stage and then random sampling technique was employed to select study *kebeles/EAs* and interview households. A total of 604 households were randomly selected from 33 *kebeles/EAs*. Four more sample households were included in cases of missing or non-responses of selected samples. Out of 604 sample households, 49 households were producing only malt barley and thus excluded from the analysis. The required sample size was determined using Kothari (Kothari, 2004) as follow:

$$N = \frac{Z^2pq}{e^2} = \frac{(1.96)^2\,(0.5)(0.5)}{(0.04)^2} = 600 \quad (1)$$

Where, N is the sample size, Z is the inverse of the standard cumulative distribution, *e* is the desired level of precision, *p* is the estimated proportion of an attribute that present in the population, and *q* = 1-*p*

**Table 1: Sample distribution along the study regions**

| Regions | Number of sample households | Percent (%) |
|---|---|---|
| Amhara | 198 | 33 |
| Oromia | 334 | 55 |
| SNNPR | 72 | 12 |
| **Total** | **604** | **100** |

### Data Analysis

The study employed both descriptive and econometric analysis. Description of socio-economic, and farm characteristics of households was made for better illustration of variables. Econometric models were also used to analyse adoption decision and intensity of improved varieties and inorganic fertilizer in food barley production.

### Model Specification

Different econometric models has been used by researchers to analyse adoption decision and intensity of adoption of agricultural technologies. Probit and logit model is appropriate to estimate the effects of one or more independent variables on a binomial dependent variable (Laduber et al., 2016). However Tobit model is superior to Probit and logit (Tobin, 1958) when the dependent variable is truncated and thus continuous between a certain lower and upper limit. The advantage of this model compared to Probit and Logit models is that it reveals the probability of adoption and the intensity of use after adoption decision and assumes determinants of adoption decision and intensity of adoption are similar. On the other hand, double hurdle model is better in explaining determinants of adoption and intensity of adoption of the technology in two separate decision stages. Double hurdle model examines technology adoption and intensity of adoption using separate equations. For this study a log-likelihood ratio (LR) test was used to choose the appropriate model between Tobit and double hurdle specifications. Based on log-likelihood ratio (LR) test, the study adopted double hurdle model to study the factors influencing adoption and intensity of use of inorganic fertilizer as the factors influencing adoption decision and use intensity differs. Tobit model that better fits the data was used to analyse adoption and intensity of adoption of improved variety in food barley production.

Variance inflation factor (VIF) analysis was conducted to tests existence of multicollinearity problem among predictors and did not find serious correlation (average VIF= 1.41 for Tobit model and 1.43 for double hurdle). Linktest was used to test model adequacy and specification error for Tobit model specification. Linktest performs a link test for model specification after any single-equation estimation command and the test justified the specification was good enough.

In addition to Double hurdle and Tobit model, the study used multivariate probit model to investigate the interdependency of adoption decision among food barley technologies. An expansion of a single probit model, multivariate probit model, use to estimate a bunch of coinciding probit equations together, that means these correlated choices often occur in a technology package adoption decision as adoption of one technology may dependent on the other whether the relationship is positive or negative. Major food barley technologies including improved varieties (VAR), inorganic fertilizers (FER), crop rotation (ROT), and soil and water conservation practices (SWC) were the technology packages (dependent variables) used in the model. Wald test (Wald chi2 (72) =250.12; Prob > chi2 =0.0000) indicate that the model is adequately described the relationship among the dependent and independent variables. Likelihood ratio test of ρ/rho also rejected (p=0.000) the null hypothesis that states there is zero correlation among the error terms or the adoption decision of the considered technologies.

Latent adoption decision can be specified using Tobit model as follow:

$$y_{i1}^{*} = x_{i1}\beta_1 + \mu i = \begin{cases} 1 \ if \ y_{i1}^{*} > 0 \\ 0 \ if \ y_{i1}^{*} \leq 0 \end{cases} \quad (2)$$

Yi = $y_{i1}^{*}$ if $y_{i1}^{*} > 0$ or 0 if $y_{i1}^{*} \leq 0$ (3)

Where:

Yi = the observed dependent variable, in our case proportion of area allocated to improved variety of food barley

$y_{i1}^{*}$ = the latent variable which is not observable

$x_{i1}$ = vector of factors affecting adoption and intensity of the technology use

$\beta$ = vector of unknown parameters

$\mu i$ = residuals that follow normal distribution [$\mu i \sim N(0,\sigma^2)$]

The Double hurdle postulates that households must pass two separate hurdles (participation decision and decision to apply fertilizer) before they are observed with a positive level of adoption (Yen & Huang, 1996).

Participation decision:

$y^{*}_{1j} = x_{1j}\beta + u_j$ (4)

Decision to apply fertilizer:

$y^{*}_{2j} = x_{2j}\gamma + v_j$ (5)

$Z_i = x_j\gamma + v_j$ if $y^{*}_{1j} > 0$ and $y^{*}_{2j} > 0$ or $Z_i = 0$ otherwise (6)

$u_j \sim N(0, 1)$

$v_j \sim N(0, \sigma^2)$

corr $(u_j, v_j) = \rho$; $\rho \neq 0$,

Where:

$y^{*}_{1j}$ is a latent participation,

$y^{*}_{2j}$ is latent consumption

Zi is the observed consumption (intensity);

$x_j$ are independent variables;

$\beta$ and $\gamma$ are coefficients of regression and

$u_j$ and $v_j$ are error terms.

Following Arun & Yeo, (2020) the general specification for the multivariate probit model (MVP) is given as follows

$y_m^{*} = x'_{m\beta_m} + \varepsilon_m$ , $y_m$ =1 if $y_m^{*} > 0, 0 \ otherwise, m = 1, \ldots \ldots M$ (7)

$E[\varepsilon_m | x_1, \ldots, x_m] = 0$

$Var[\varepsilon_m | x_1, \ldots, x_m] = 1$

$cov[\varepsilon_j \varepsilon_m | x_1, \ldots, x_m] = \rho_{jm}$

$\varepsilon_1 \ldots \ldots \ldots, \varepsilon_m \sim N_M(0, \Omega)$

Where $x$ is a matrix of covariates, consisting of any independent variables, β is a matrix of unknown regression coefficients and $\varepsilon_m$ is residual error. $\Omega$ is the variance-covariance matrix. The off-diagonal elements in the correlation matrix $\rho_{jm}$ represent the unobserved correlation between the stochastic component of the j^th^ and m^th^ options. $y$ is the dependent variable (VAR: improved food barley varieties; FER: inorganic fertilizer; ROT: crop rotation; SWCP: soil and water conservation practices).

## RESULTS AND DISCUSSION

### Inputs Uses in Barley Production

The average area allocated for food barley was 0.45 hectare. Out of average cultivated area owned (1.21 ha) by the producers 37% was allocated for food barley production. Producers on average used 151 kg of food barley seed per hectare. The seed rate used was within the range of the national recommendations (100-150 kg/ha). The amount of inorganic fertilizer used was found lower than the national recommendation. Average application rate of NPS and Urea was found 60.65 kg $ha^{-1}$ and 33.72 kg $ha^{-1}$ respectively. According to ESS, (2021) data average application rate of NPS and Urea was found 43 kg $ha^{-1}$ and 3 kg $ha^{-1}$ respectively. Even if the value found in this study was higher than what was found in the data of ESS, (2021), it was consistent in indicating that the rate was below the national recommendation. The study revealed that improved variety adopters applied more fertilizer compared to non-adopters.

**Table 2: Description of input use practices in food barley production**

| Inputs | Type of seed | | Total [N=555] |
|---|---|---|---|
| | Local seed [N=511] | Improved seed [N=44] | |
| Food barley area (ha) | 0.45 | 0.45 | 0.45 |
| Seed (kg/ha) | 149.89 | 159.64 | 150.67 |
| NPS (kg /ha) | 57.79 | 93.96 | 60.65*** |
| Urea (kg /ha) | 30.87 | 66.90 | 33.72*** |

| | | | |
|---|---|---|---|
| Labor (Man day/ha) | 62.92 | 73.26 | 63.75 |
| Herbicide (lit/ha) | 0.90 | 1.10 | 1.00 |
| Fungicide(lit/ha) | 0.90 | 1.40 | 1.20 |

***** p<0.01; N: Number of sample households**

Among food barley producers only 8% of them used improved varieties. Adoption of improved varieties of food barley was found higher in Southern Nation Nationalities and Peoples regional state compared to other regions. Manure, crop rotation, row planting, SWCP and herbicides were applied by 39%, 87%, 6%, 48% and 48% of the producers respectively. Row planting was practiced by the lowest number of producers compared to other food barley technologies. Crop rotation was widely adopted technology and followed by inorganic fertilizer (65%). Crop rotation, inorganic fertilizer, SWCP and herbicides employed more in Oromia regional state compared to other regions. Recommended rate of fertilizer package (total of NPS and Urea), NPS and Urea were adopted by 10%, 21% and 25% of the producers respectively. Among food barley producers 54% of them applied both NPS and Urea below the rate of national recommendation whereas 72% of them used at least either of the NPS and Urea below the national recommendation. Only 5% of the producers used NPS or Urea above the rate of national recommendation (Table 3).

**Table 3: Proportion (%) of farmers using a particular food barley technologies across regions**

| Technologies used | Regional states | | | Total [N=555] |
|---|---|---|---|---|
| | Amhara [N=189] | Oromia [N=295] | SNNPR [N=71] | |
| Improved Variety | 2 | 6 | 31 | 8*** |
| Manure | 68 | 17 | 52 | 39*** |
| Crop rotation | 76 | 95 | 83 | 87*** |
| Row planting | 1 | 1 | 38 | 6*** |
| SWCP | 46 | 55 | 24 | 48*** |
| Apply pesticides | 14 | 73 | 42 | 49*** |
| Herbicide | 14 | 72 | 42 | 48*** |
| Apply inorganic fertilizer | 43 | 79 | 68 | 65*** |
| Recommended rate of NPS | 9 | 28 | 23 | 21*** |
| Recommended rate of Urea | 22 | 25 | 30 | 25 |
| Recommended fertilizer rate | 4 | 12 | 17 | 10*** |
| Recommended seed rate | 33 | 38 | 34 | 36 |

***** p<0.01; SWCP: soil and water conservation practices**

**Table 4: Adoption of combination of food barley technologies by respondents**

| Combination of technology packages | Frequency (N=555) | Percent |
|---|---|---|
| $VAR_0$, $FER_1$, $ROT_1$ & $SWC_0$ | 152 | 27 |
| $VAR_0$, $FER_1$, $ROT_1$ & $SWC_1$ | 147 | 26 |
| $VAR_0$, $FER_0$, $ROT_1$ & $SWC_1$ | 72 | 13 |
| $VAR_0$, $FER_0$, $ROT_1$ & $SWC_0$ | 68 | 12 |
| $VAR_0$, $FER_0$, $ROT_0$ & $SWC_0$ | 43 | 8 |
| $VAR_1$, $FER_1$, $ROT_1$ & $SWC_1$ | 29 | 5 |
| $VAR_0$, $FER_1$, $ROT_0$ & $SWC_0$ | 14 | 3 |
| $VAR_1$, $FER_1$, $ROT_1$ & $SWC_0$ | 12 | 2 |
| $VAR_0$, $FER_0$, $ROT_0$ & $SWC_1$ | 8 | 1 |
| $VAR_0$, $FER_1$, $ROT_0$ & $SWC_1$ | 7 | 1 |
| $VAR_1$, $FER_1$, $ROT_0$ & $SWC_0$ | 1 | 0 |
| $VAR_1$, $FER_0$, $ROT_1$ & $SWC_0$ | 1 | 0 |
| $VAR_1$, $FER_1$, $ROT_0$ & $SWC_1$ | 1 | 0 |
| $VAR_1$, $FER_0$, $ROT_0$ & $SWC_0$ | 0 | 0 |
| $VAR_1$, $FER_0$, $ROT_0$ & $SWC_1$ | 0 | 0 |
| $VAR_1$, $FER_0$, $ROT_1$ & $SWC_1$ | 0 | 0 |
| **Total** | **555** | **100** |

***VAR: improved food barley varieties; FER: inorganic fertilizer; ROT: crop rotation; SWCP: soil and water conservation practices; 1: is availability or adoption and 0: is non availability or non-adoption of the technology***

The result (Table 4) indicated that 76% food barley producers adopted two or more combination of food barley technologies and 16% of them adopted only one of technologies. Among the sample producers 8% of them were adopted none of the considered food barley technology packages. About 27% of them adopted the combination of fertilizer and crop rotation, 26% adopted the combination of fertilizer, crop rotation and soil and water conservation practices. The proportion of producers that adopted the combination of all considered food barley technologies were only 5% whereas producers that did not adopt all considered food barley technologies together is 8% from the sample.

**Constraints in Food Barley Production**

Producers reported that crop damage was occurred on 81% of barley plots. Higher number of food barley plots were affected in Oromia regional state by different production constraints compared to other regional states. The major causes of the damage identified were diseases (27%), insect pests (24%), shortage of rain (22%) and frost (17%). Diseases, insect pests and frost was identified as a major production constraint in SNNPR and Oromia regional states whereas shortage of rain and frost are major production constraints Amhara regional states.

The focus group discussion and previous studies on food barley production also identified major production challenges in the country. Accordingly, low productivity, diseases, frost, waterlogging in heavy rainfall conditions and lack of supply of improved varieties were among the production constraints (Zewdie & Adamu, 2020). Shifting to market oriented and cash crops like wheat, declining the fertility of the soil; declining the productivity of landraces from time to time are also among the challenges (Tadesse & Derso, 2019**).** Lack of quality seed and inorganic fertilizers in the required amounts and time, high price of fertilizer, and infestation of weeds are major limiting factors in barley production (Tigabie *et al.*, 2017).

**Table 5: Rate of barley plots damaged and the causes of damage across regions**

| Particulars | Amhara | Oromia | SNNPR | Total |
|---|---|---|---|---|
| Plots affected by damage [% plots] | 78 | 90 | 53 | 81 |
| Causes of damage [ % respondents] | | | | |
| Disease | 12 | 34 | 46 | 27 |
| Insects/pests | 5 | 35 | 41 | 24 |
| Shortage of rain | 44 | 11 | 0 | 22 |
| Frost | 22 | 14 | 11 | 17 |
| Hailstorm | 9 | 0 | 0 | 3 |
| Others/unknown | 1 | 5 | 2 | 3 |
| Water logging | 4 | 0 | 0 | 2 |
| Animal trampling | 3 | 1 | 0 | 1 |

**Description of Independent Variables**

Non-adopters of improved food barley varieties had to travel 4.35 km to get extension office which is longer compared to adopters (3km). Adopters were found to have better access to extension compared to non-adopters. On average, adopters had met extension personnel three times more than non-adopters in a year. Improved food barley variety adopters found to have higher access to input market (57%) and credit (66%), have more networks with farmers using improved varieties (82%), participate on field days (32%), participate in community leadership (43%), perceived as food secured (68%) and trained (82%) on food barley production. The result indicated more number of non-adopters (81%) of improved food barley varieties used food barley as staple food compared to adopters (48%).

**Table 6: Description of independent variables across improved food barley adoption**

| Variables | Improved food barley variety | | |
|---|---|---|---|
| | **Non adopters [N=511]** | **Adopters [N=44]** | **Total [N=555]** |
| **Demographic characteristics** | | | |
| Age of head [years] | 47.18 | 48.84 | 47.31 |
| Education of Head [years] | 2.19 | 2.48 | 2.22 |
| Sex of head [% male] | 89 | 93 | 90 |
| **Wealth related factors** | | | |
| Cultivated land (ha) | 1.19 | 1.16 | 1.19 |
| Livestock owned (TLU) | 5.17 | 5.32 | 5.18 |
| Oxen owned [Number] | 1.35 | 1.40 | 1.350 |
| Use barley as staple food [% yes] | 81 | 48 | 79*** |
| Perception on food security [% secure] | 45 | 68 | 47*** |
| Improved livestock [% yes] | 20 | 20 | 20 |
| **Institutional factors** | | | |
| Distance to extension [km] | 4.35 | 2.59 | 4.21** |
| Distance to cooperative [km] | 6.38 | 3.30 | 6.14 |
| Number of extension contact [frequency] | 2.43 | 6.98 | 2.79*** |

| | | | |
|---|---|---|---|
| Access to input market [% Yes] | 30 | 57 | 32*** |
| Credit access [%Yes] | 28 | 66 | 31*** |
| Cooperative membership [% yes] | 33 | 39 | 34 |
| **Information and communication factors** | | | |
| Know farmers using improved seed [% Yes] | 44 | 82 | 47*** |
| Participation on field day [% yes] | 16 | 32 | 17*** |
| Participation in cluster [% yes] | 47 | 67 | 48 |
| Community leadership [% yes] | 25 | 43 | 26*** |
| Trained on food barley [% yes] | 51 | 82 | 53*** |

***** p<0.01, ** p<0.05 for $\chi^2$ or t-test**

**Factors Affecting Adoption of Improved Varieties in Food Barley Production**

The result of Tobit model indicated that adoption and intensity of adoption of improved varieties in food barley production is influenced by number of oxen owned, knowing improved variety users, access to credit, participation on field days, and perceived food security of producers positively and significantly. Adoption of improved varieties negatively and significantly influenced by cooperative membership and using barley as staple food in the household.

Land preparation is one of the major agricultural activities for crop production that mostly done traditionally using bullock power in Ethiopia. The study confirmed that producers with more number of oxen are more likely to adopt improved variety and increase intensity of adoption of improved food barley area. As the number of oxen that producers own increased by one, the area of improved food barley increases by 0.024 ha for adopters keeping other factors constant. Aman & Tewodros, (2016) also found positive association between oxen and intensity of adoption of improved varieties.

We found that producers were more likely to adopt improved food barley varieties if they had a network with farmers planting improved varieties of food barley. Knowing improved variety users increase the probability of adoption by 2.4% and the area of improved seed by 4.3% for adopters. The research done by Jaleta et al., (2018) similarly indicated that the social network of the household enhances the adoption of improved maize varieties.

Access to credit influenced adoption of improved food barley varieties positively and significantly. Producers that had access to credit (3.2%) more likely to adopt improved food barley varieties compared to their non-adopter counter parts. Producers that have access to credit can afford the increasing price of improved seed and more likely to adopt improved varieties. Similar result was reported by Dereje, (2018) in his study of barley technology adoption and its contribution to farm income and food availability in North Shewa zone of Amhara region.

Field days are used to demonstrate technological improvements for farmers and believed to raise awareness. The study revealed participation on barley based field days influenced adoption of improved food barley varieties positively and significantly at 5% level of significance. Farmers that participate on field day are 4.6% more likely to adopt improved food barley varieties and participation on field day increases the area of improved varieties by 8% for adopters.

Perceived food security influenced intensity of adoption of improved food barley varieties positively and significantly at 5% level of significance. Food security was taken as indicator variable for risk aversion behaviour or poverty level of the producers and it is assumed that producers with better perceived food security status are more confident to try new technologies. Farmers that perceived themselves food secure are 2.9% more likely to adopt improved food barley varieties and it increases the area of improved seed by 5.1% for adopters. The result is in agreement with the result of Dereje, (2018) that indicated positive association of food availability and adoption of fertilizer.

Cooperative membership affected adoption and intensity of adoption of improved food barley varieties negatively and significantly, which was unexpected. This might be due to cooperative involved in supply of rather more competitive crop seeds like wheat than improved seed of food barley that might have hindered adoption and intensity of adoption of improved food barley varieties.

The study indicated using food barley as staple food in the household negatively and significantly influenced adoption of improved varieties in food barley production. Using food barley as staple food reduce the probability of adoption by 6% for barley producers and the area of improved seed by 10% for improved food barley variety adopters. Producers that used food barley as staple food in the household were producers that had less access to input market (30%), output market (23%), less adopters of improved technology like fertilizer and pessimistic to the future price of food barley compared to those not used food barley as staple food and thus stick to traditional practices.

**Table 7: Estimates of the Tobit model for factors influencing adoption of food barley varieties**

| Variables | Coefficient | Std.err | Marginal Effect on censored observation | | Marginal Effect on truncated observation | |
|---|---|---|---|---|---|---|
| | | | dy/dx | Std. | dy/dx | Std. |
| Age of head [years] | 0.006 | 0.006 | 0.000 | 0.001 | 0.001 | 0.001 |
| Sex of head [% male] | 0.025 | 0.279 | 0.002 | 0.022 | 0.004 | 0.040 |
| Education of head [years] | 0.017 | 0.022 | 0.001 | 0.002 | 0.002 | 0.003 |
| Cultivated land (ha) | 0.004 | 0.180 | 0.000 | 0.014 | 0.001 | 0.025 |
| Access to input market [% Yes] | -0.185 | 0.167 | -0.015 | 0.014 | -0.026 | 0.024 |
| Livestock owned [TLU] | -0.054 | 0.034 | -0.004 | 0.003 | -0.008 | 0.005 |
| Oxen owned [Number] | 0.169* | 0.093 | 0.014* | 0.008 | 0.024* | 0.013 |
| Uses barley as staple food [% yes] | -0.692*** | 0.166 | -0.055*** | 0.015 | -0.098*** | 0.023 |
| Improved livestock [% yes] | -0.041 | 0.205 | -0.003 | 0.016 | -0.006 | 0.029 |
| Future food barley price [% increase] | -0.032 | 0.183 | -0.003 | 0.015 | -0.004 | 0.026 |
| Know farmers planting improved seed [% Yes] | 0.302* | 0.174 | 0.024* | 0.014 | 0.043* | 0.025 |
| Access to credit [%Yes] | 0.403* | 0.243 | 0.032* | 0.020 | 0.057 | 0.035 |
| Distance to extension [km] | -0.001 | 0.022 | 0.000 | 0.002 | 0.000 | 0.003 |
| Distance to cooperative [km] | -0.028 | 0.026 | -0.002 | 0.002 | -0.004 | 0.004 |
| Participation on field day [% yes] | 0.569** | 0.236 | 0.046** | 0.021 | 0.080** | 0.034 |
| Extension contact [frequency] | 0.014 | 0.012 | 0.001 | 0.001 | 0.002 | 0.002 |
| Participation in cluster [% yes] | -0.296 | 0.281 | -0.024 | 0.023 | -0.042 | 0.040 |
| Cooperative membership [% yes] | -0.412** | 0.191 | -0.033** | 0.016 | -0.058** | 0.028 |
| Community leadership [% yes] | 0.299 | 0.192 | 0.024 | 0.016 | 0.042 | 0.027 |
| Perceived food security [% secure] | 0.360** | 0.173 | 0.029** | 0.014 | 0.051** | 0.024 |
| Trained on food barley [% yes] | 0.272 | 0.196 | 0.022 | 0.016 | 0.039 | 0.028 |
| Constant | -1.643*** | 0.492 | | | | |

***** p<0.01, ** p<0.05, * p<0.1**

**Factors Influencing Adoption of Inorganic Fertilizer in Food Barley Production**

We used Double hurdle model to identify socio economic factors that determine adoption of inorganic fertilizer in food barley production. Accordingly age of the household head, access to input market, using improved food barley variety, membership to cooperative, training on food barley production and market orientation of the household influenced adoption of inorganic fertilizer in food barley production positively and significantly whereas using barley as staple food and frequency of extension contact influenced it negatively and significantly.

The positive relationship between age of household head and adoption of inorganic fertilizer implied that farmers with increased age (experience) are more likely to adopt inorganic fertilizer in food barley production. Farmers that have access to input market (for fertilizer, chemicals, seed and labour) (13.4%) are more likely to adopt inorganic fertilizer in food barley production.

Using improved food barley variety influenced the probability of adoption of inorganic fertilizer positively and significantly at 1% level of significance. Improved variety adopters were found trained on food barley production (82%) and have better network with other improved food barley variety users (82%) and thus assumed to have better knowledge about importance of using inorganic fertilizer in food barley production.

Membership to cooperative was found to have positive influence on the likelihood of adoption of inorganic fertilizer and members are 25% more likely to adopt inorganic fertilizer. Agricultural cooperatives are one of the major agricultural input suppliers in the country and thus membership to cooperatives improve access to inputs including fertilizers. On the other side cooperatives usually provide fertilizers in credit and improves accessibility of the fertilizer.

Training on food barley production influenced probability of adoption of inorganic fertilizer positively and significantly at 1% level of significance. Producers that are trained on barley production more likely to apply inorganic fertilizer on food barley plots. Training increases the likelihood of applying inorganic fertilizer by 17.9% in food barley production.

Market orientation of the household influenced adoption of inorganic fertilizer significantly and positively at 1 % level of significance. If the amount of food barley sold increases by 1%, the likelihood of adoption of inorganic fertilizer in food barley production increases by 51.8% for barley producers. The result is consistent with the study of Dereje, (2018) that found positive association between participation in selling options and fertilizer adoption. This might be due to producers that sell their barley grain develops more financial capacity to purchase inorganic fertilizers and tend to produce surplus for market. In addition to this, commercial farmers tend to hunt technologies that improves their crop productivity to produce surplus.

Subsistence farming / using food barley as staple food/ negatively and significantly affected adoption of inorganic fertilizer in food barley production. It reduces the probability of adoption of inorganic fertilizer by 16.7%. Producers that used food barley as staple food in the household were producers that had less access to input market, output market and pessimistic to the future price of food barley and thus produce food barley for subsistence have less tendency to adopt new technologies. Asfaw, (2000) also reported as barley was the predominant subsistence crop in the highlands of Ethiopia.

Frequency of extension contact influenced adoption of inorganic fertilizer negatively and different to what was expected. This might be due to the extension agents meet producers for advices on other crops rather than on food barley technologies. That is, this might be related to the focus given to competitive crops like wheat which may negatively affects the likelihood of technology adoption in food barley production.

**Table 8: Estimate of Double-hurdle model for factors affecting decision to apply inorganic fertilizers (1st hurdle)**

| Variables | Coefficient | Std.err | Marginal Effect | |
|---|---|---|---|---|
| | | | dy/dx | std.err. |
| Oromia | 1.535*** | 0.221 | 0.389*** | 0.049 |
| SNNPR | -0.141 | 0.298 | -0.036 | 0.076 |
| Age of head [years] | 0.012* | 0.007 | 0.003* | 0.002 |
| Sex of head [male] | -0.318 | 0.256 | -0.078 | 0.063 |
| Education of head [years] | 0.023 | 0.026 | 0.006 | 0.006 |
| Family size [No] | 0.008 | 0.030 | 0.002 | 0.007 |
| Cultivated land [ha] | -0.040 | 0.084 | -0.010 | 0.021 |
| Access to input market [yes] | 0.546*** | 0.210 | 0.134*** | 0.050 |
| Livestock [TLU] | 0.008 | 0.028 | 0.002 | 0.007 |
| Uses barley as staple food [yes] | -0.680*** | 0.214 | -0.167*** | 0.051 |
| Improved livestock [yes] | -0.113 | 0.213 | -0.028 | 0.052 |
| Food barley variety [improved] | 1.929*** | 0.612 | 0.475*** | 0.146 |
| Credit access [yes] | 0.284 | 0.204 | 0.070 | 0.050 |
| Distance to extension [km] | 0.015 | 0.017 | 0.004 | 0.004 |
| Distance to cooperative [km] | 0.002 | 0.006 | 0.001 | 0.001 |
| Participation on field day [yes] | -0.369 | 0.231 | -0.091 | 0.056 |
| Extension contact [frequency] | -0.042** | 0.016 | -0.010** | 0.004 |
| Cooperative membership [yes] | 1.015*** | 0.206 | 0.250*** | 0.047 |
| Perceived food security [secure] | 0.170 | 0.178 | 0.042 | 0.044 |
| Trained on barley production [yes] | 0.728*** | 0.186 | 0.179*** | 0.044 |
| Market orientation [% sold] | 2.103*** | 0.427 | 0.518*** | 0.096 |
| Constant | -1.378*** | 0.469 | | |

***** p<0.01, ** p<0.05, * p<0.1**

**Factors Influencing Adoption Intensity of Inorganic Fertilizer in Food Barley Production**

Table 9 presents the second part of Double hurdle model that revealed factors influencing adoption intensity of inorganic fertilizer in food barley production. Intensity of adoption of inorganic fertilizer in food barley production was found to be determined by area of cultivated land, using barley as staple food, owning improved livestock, distance to extension and distance to cooperative.

Area of cultivated land was found to significantly and negatively affect the level of inorganic fertilizer applied at 1% level of significance. As the area of cultivated land increase by 1 hectare the amount of inorganic fertilizer applied for food barley production reduces by 13 kgha$^{-1}$ for those who have positive fertilizer application. (Yu et al., 2011) also found negative association between number of plots and fertilizer application. This might be related to the amount of money required for purchase of fertilizer to cover larger area might not be affordable by the producers.

Subsistence farming /using food barley as staple food/ found to negatively influence adoption decision of inorganic fertilizer in food barley production. However, once they have understood the benefit and decided to apply fertilizer, using food barley as staple food in the household increases the amount of fertilizer used for food barley production. Amount of fertilizer applied increases by 23.5 kgha$^{-1}$ if producers were using food barley as staple food and decided to apply inorganic fertilizer for food barley production.

As number of livestock owned increases by one unit of TLU, the level of inorganic fertilizer applied on food barley increases by 2.3 $kgha^{-1}$ (significant at $p<0.1$). The more number of livestock in the household the more that household applied inorganic fertilizer to his barley plots. This might be related to possible income that could be obtained from animal sale which could be used for fertilizer purchase.

Distance to extension and cooperative office negatively and significantly affected the level of inorganic fertilizer applied on food barley plots. This indicated as the households reside far away from extension and cooperative office they tend to apply less inorganic fertilizer to their food barley plots. This might be related to the lack of information that could be obtained from the extension offices. Cooperatives are the major supplier of fertilizers to producers in the country and thus as the distance to cooperative increases it is difficult and costly for farmers to transport fertilizer to their farm area.

**Table 9: Estimate of Double-hurdle model for factors affecting intensity of inorganic fertilizer adoption (2nd hurdle)**

| Variables | Coefficient | Std. err. | Marginal Effect | |
|---|---|---|---|---|
| | | | dy/dx | Std. err. |
| Oromia | -27.662 | 17.180 | -21.035 | 13.500 |
| SNNPR | 7.592 | 26.012 | 6.117 | 21.029 |
| Age of head [years] | 0.131 | 0.530 | 0.098 | 0.398 |
| Sex of head [male] | -34.403 | 23.231 | -25.885 | 17.239 |
| Education of head [years] | 2.866 | 2.280 | 2.157 | 1.704 |
| Family size [no] | -0.884 | 2.588 | -0.665 | 1.950 |
| Cultivated land [ha] | -16.935*** | 5.811 | -12.742*** | 4.262 |
| Access to input market [yes] | -20.338 | 15.657 | -15.302 | 11.763 |
| Livestock [TLU] | 2.990* | 1.817 | 2.250* | 1.366 |
| Barley as staple food [yes] | 31.238** | 15.490 | 23.504** | 11.444 |
| Improved livestock [yes] | 47.490*** | 16.384 | 35.731*** | 12.135 |
| Food barley variety [improved] | 29.425 | 22.628 | 22.139 | 16.700 |
| Credit access [yes] | 12.153 | 14.998 | 9.144 | 11.255 |
| Distance to extension [km] | -4.221*** | 1.483 | -3.176*** | 1.103 |
| Distance to cooperative [km] | -2.084** | 0.875 | -1.568** | 0.643 |
| Participation on field day [yes] | -13.044 | 15.589 | -9.814 | 11.630 |
| Number of extension contact [frequency] | 0.611 | 1.074 | 0.460 | 0.807 |
| Cooperative membership [yes] | 3.774 | 12.789 | 2.840 | 9.602 |
| Perceived food security [secure] | 8.405 | 14.863 | 6.324 | 11.203 |
| Trained on barley [yes] | -42.364 | 14.809 | -31.875 | 10.822 |
| Market orientation [% sold] | -42.239 | 25.865 | -31.781 | 19.467 |
| Constant | 197.962 | 39.835 | | |

***** p<0.01, ** p<0.05, * p<0.1**

The correlation between the decisions to adopt any one of food barley technologies (VAR, FER, ROT and SWC) with the other technologies after the factors that govern the adoption decision have been accounted for are correlations between the error terms from the multivariate probit model (Table 10). The result exhibited positive interdependency (complementarity) of adoption decision of food barley technologies. Only one among the six combination of adoption decision of food barley technologies statistically not significant indicating the food barley producers adoption decision is interdependent among food barley technologies. Adoption decision of improved food barley varieties has positive and statistically significant association with inorganic fertilizer and crop rotation adoption. Adoption decision of inorganic fertilizers has positive and statistically significant association with adoption of improved food barley varieties, crop rotation and soil and water conservation practices.

The result of multivariate probit model revealed that participation on field days, number of livestock owned by the household, cooperative membership, perceived food security of the households and training on food barley production positively and significantly influenced the adoption decision of more than one food barley technologies (Annex 1).

**Table 10: Correlation matrix of food barley technologies adoption from multivariate probit model**

| Combination | Coefficient | Std. err. | z | p-value (P>\|z\|) |
|---|---|---|---|---|
| ρ21 | 0.532 | 0.161 | 3.32 | 0.001 |
| ρ31 | 0.431 | 0.213 | 2.02 | 0.043 |
| ρ41 | 0.207 | 0.134 | 1.55 | 0.122 |

| | | | | |
|---|---|---|---|---|
| ρ32 | 0.737 | 0.073 | 10.08 | 0.000 |
| ρ42 | 0.384 | 0.083 | 4.65 | 0.000 |
| ρ43 | 0.569 | 0.090 | 6.33 | 0.000 |

**ρ =Rho/** *Greek alphabet;* 1=VAR, 2=FER, 3=ROT and 4= SWC

Likelihood ratio test of rho21 = rho31 = rho41= rho32=rho42 = rho43 = 0; chi2 (6) = 92.163, Prob >chi2 =0.0000

## CONCLUSION

The study employed cross-sectional data collected from major barley growing regions of Ethiopia to examine the adoption of food barley production technologies and practices. Both descriptive statistics and econometric analysis was utilized to analyze the collected primary data. From cultivated area owned by the producers, 38% was allocated for food barley production. The average area allocated for barley was 0.5 hectare and producers used 151 kg of food barley seed per hectare. Inorganic fertilizers that were used for food barley production was found lower than the national recommendation. On average producers were using 33.72kg $ha^{-1}$ and 60.65kg $ha^{-1}$ of Urea and NPS respectively.

Row planting was found to have the smallest number of adopters followed by improved varieties in food barley production. Row planting and improved varieties was used by 6% and 8% of the producers respectively. Crop rotation and inorganic fertilizer had better adoption rate compared to the other food barley technologies. Most of food barley technologies were adopted by less than half of the producers and the rate of adoption of the technologies varied across regional states.

Inorganic fertilizer was adopted by 65% of producers. The amount of inorganic fertilizer used by adopters of improved varieties was found significantly higher than the amount used by non-adopters. Access to input market positively influences the adoption of inorganic fertilizer and the adopters found to have higher access to input market (35%) compared to non-adopters. Using improved varieties, cooperative membership, training, market orientation of the household positively influences the adoption of fertilizer in food barley production. The intensity of fertilizer use was found to be influenced by owning improved livestock and number of livestock positively and distance to extension and cooperative negatively. This indicates that producers that have better wealth and closer to input distribution centres tend to apply more amount of fertilizer in food barley production. Encouraging farmers to be member of cooperatives and to participate in food barley marketing (producing surplus) could boost the amount of fertilizer applied for food barley production.

Though most (65%) of food barley producers apply inorganic fertilizer to their food barley plots, only 10% of them applied recommended amount of fertilizer. This has to be improved through intensive awareness creation, improving access to fertilizer as long as the rate of fertilizer critically determine the productivity of the crop.

The number of oxen owned, networking with other improved variety adopters, access to credit, and participation on field days, perceived food security of producers were found to be a driver of adoption of improved food barley varieties. Development and distribution of improved varieties which are high yielding, drought, frost and disease tolerant need to be given higher priority to alleviate production constraints faced by the producers. Ministry of agriculture also need to focus on supply of improved seed and fertilizer with affordable price to increase adoption of the technologies. The study suggested improving access to markets, cooperative, extension office and training the producers would help to increase adoption of inorganic fertilizer in food barley production.

The study unveiled that food barley producers tend to adopt multiple technologies simultaneously where adoption of one technology enhances the adoption of the other. Cooperatives, field days and trainings were found crucial leverage points that could facilitate adoption of multiple technologies. Therefore focusing on food barley technology package demonstration is a wise and cost effective approach to speed up the uptake of the technologies.

**Acknowledgement**

The authors are grateful to Ethiopian Institute of Agricultural Research (EIAR) for the financial support given. We cordially appreciate the support given by EIAR and Ethiopian Statistical Service (ESS) staffs during the survey data collection.

**Conflict of Interest:** The authors has not conflict of interests to declare.

**Author's Contribution**

Tamirat Girma and Endeshaw Habte performed the research design, data collection, data analysis, interpretation, and manuscript writing. Melkamu Bazie, Samuel Diro and Guta Bukero contributed to the design, data collection, write up and revision of the manuscript.

## REFERENCES

1. Aman,Tufa Tewodros, A. (2016). Determinants of Improved Barley Adoption Intensity in Malga District of Sidama Zone , Ethiopia. *International Journal of Agricultural Economics*, *1*(3), 78–83. https://doi.org/10.11648/j.ijae.20160103.15
2. Arun, G., & Yeo, J. H. (2020). Perception to Adaptation of Climate Change in Nepal: An

Empirical Analysis Using Multivariate Probit Model. *Sci*, *2*(4). https://doi.org/10.3390/sci2040087

3. Asfaw, Z. (2000). GENES in the. In S. B. Brush (Ed.), *GENES in the FIELD Bon-farm Conservation of Crop Diversity* (pp. 77–107). Lewis Publishers copublished by International Plant Genetic Resources Institute. https://idrc-crdi.ca/en/book/genes-field-farm-conservation-crop-diversity
4. Dereje, H. (2018). *Barley technologies adoption and its contribution to farm households'income and food availability in semen shewa zone, Amhara region, central Ethiopia*. Addis Ababa University.
5. Derso, E., Alemayehu, N., & Tadesse, T. (2018). *Results of Crop Research 2018, Proceedings of the National Conference on Completed Crop Research, 9 - 14 October 2017, Addis Ababa, Ethiopia, pp. 706*.
6. ESS (Ethiopian Statistical Service). (2022). Area and Production of Major Crops. Ethiopian Statistics Servce, Agricultural Sample Surver. In *Survey Report: Vol. I*.
7. ESS (Ethiopian Statistical Service). (2021). *Agricultural sample survey report on farm management practices (private peasant holdings, Meher season) statistical bulletin: Vol. III*.
8. Jaleta, M., Kassie, M., Marenya, P., Yirga, C., & Erenstein, O. (2018). Impact of improved maize adoption on household food security of maize producing smallholder farmers in Ethiopia. *Food Security*, *10*(1), 81–93. https://doi.org/10.1007/s12571-017-0759-y
9. Kothari, C. (2004). *Research Methodology Methods and Techniques* (second Edi). New Age International Publishers.
10. Laduber, W., Dessalegn, M., & Daniel, T. (2016). Logit analysis of factors affecting adoption of improved bread wheat (Triticum aestivum L.) variety: The case of Yilmana Densa District, West Gojam, Ethiopia. *Journal of Agricultural Extension and Rural Development*, *8*(12), 258–268. https://doi.org/10.5897/jaerd2016.0768
11. MoANR. (2016). *Crop Variety Register* (Issue 19). Ministry Of Agriculture And Natural Resources Plant Variety Release. Protection And Seed 0ual1ty Control Directorate Crop.
12. Tadesse, D., & Derso, B. (2019). The status and constraints of food barley production in the North Gondar highlands , North Western Ethiopia. *Agriculture & Food Security*, 1–7. https://doi.org/10.1186/s40066-018-0248-3
13. Tigabie, A., Yirga, C., & Jema, H. (2017). *Determinants Of Malt Barley Technology Adoption In The Case Of Determinants Of Malt Barley Technology Adoption M . Sc . Thesis*. *December*, 2010–2013.
14. Tobin, J. (1958). Estimation of Relationships for Limited Dependent Variables. *Econometrica*, *26*(1), 24. https://doi.org/10.2307/1907382
15. Yen, S. T., & Huang, C. L. (1996). Household demand for finfish: A generalized double-hurdle model. *Journal of Agricultural and Resource Economics*, *21*(2), 220–234.
16. Yigezu, Y. A., Tizale, C. Y., & Aw-Hassan, A. (2015). Modeling Farmers' Adoption Decisions of Multiple Crop Technologies: The Case of Barley and Potatoes in Ethiopia. In 2015 Conference, August 9-14, 2015, Milan, Italy (No. 211867). *International Association of Agricultural Economists.*
17. Yirga, C., Atnafe, Y., & Awhassan, A. (2015). A Multivariate Analysis of Factors Affecting Adoption of Improved Varieties of Multiple Crops : A Case Study from Ethiopian Highlands. *Ethiop. J. Agric. Sci.*, *25*(2), 29–45.
18. Yu, B., Nin-Pratt, A., Funes, J., & Asrat, S. (2011). Cereal Production and Technology in Ethiopia. In *IFPRI–ESSP II Discussion Paper*.
19. Zewdie, B., & Adamu, M. (2020). Deployment of Malt Barley Technologies in Ethiopia: Achievements and Lessons Learned. International Center for Agricultural Research in the Dry Areas. In *International Center for Agricultural Research in the Dry Areas*, (Issue August).

## ANNEXES

**Annex I. Multivariate probit model for adoption of food barley technologies**

**Table 11: Result of multivariate probit model for adoption of food barley technologies**

| VARIABLES | VAR (1) | FER (2) | ROT (3) | SWC (4) |
|---|---|---|---|---|
| Age of head [years] | 0.011 | 0.004 | 0.009 | -0.003 |
| | (0.009) | (0.006) | (0.007) | (0.005) |
| Sex of head [% male] | 0.473 | -0.317 | 0.379 | 0.084 |
| | (0.482) | (0.229) | (0.278) | (0.232) |
| Education of head [years] | 0.063* | 0.019 | -0.008 | 0.016 |
| | (0.036) | (0.024) | (0.028) | (0.022) |
| Family size [No] | -0.075 | 0.041 | 0.069 | 0.040 |
| | (0.047) | (0.028) | (0.044) | (0.028) |
| Cultivated land (ha) | -0.173 | 0.047 | 0.048 | -0.035 |
| | (0.116) | (0.078) | (0.113) | (0.066) |

| | | | | |
|---|---|---|---|---|
| Access to input market [% Yes] | -0.211 | 0.138 | -0.020 | -0.508*** |
| | (0.272) | (0.178) | (0.214) | (0.164) |
| Livestock owned [TLU] | 0.002 | 0.049* | 0.099** | -0.018 |
| | (0.038) | (0.025) | (0.041) | (0.023) |
| Use barley as staple food [% yes] | -1.063*** | -0.600*** | -0.008 | 0.042 |
| | (0.223) | (0.181) | (0.214) | (0.157) |
| Improved livestock [% yes] | -0.248 | -0.078 | -0.068 | 0.117 |
| | (0.301) | (0.193) | (0.259) | (0.178) |
| Access to credit [%Yes] | 0.469* | 0.528*** | -0.375* | -0.071 |
| | (0.252) | (0.178) | (0.222) | (0.165) |
| Distance to extension [km] | -0.038 | -0.006 | -0.016 | 0.011 |
| | (0.036) | (0.016) | (0.019) | (0.016) |
| Distance to cooperative [km] | -0.016 | 0.014 | 0.015 | -0.088*** |
| | (0.029) | (0.006) | (0.011) | (0.018) |
| Participation on field day [% yes] | 0.751*** | -0.046 | 0.524* | 0.582*** |
| | (0.287) | (0.203) | (0.295) | (0.198) |
| Extension contact [frequency] | 0.016 | -0.015 | 0.029 | 0.017 |
| | (0.014) | (0.014) | (0.034) | (0.013) |
| Cooperative membership [% yes] | -0.244 | 0.595*** | -0.413** | 0.263* |
| | (0.247) | (0.169) | (0.194) | (0.149) |
| Perceived food security [% secure] | 0.643** | 0.416*** | 0.455** | 0.381** |
| | (0.255) | (0.159) | (0.207) | (0.148) |
| Trained on food barley [% yes] | 0.573** | 0.296* | 0.005 | -0.111 |
| | (0.270) | (0.154) | (0.200) | (0.147) |
| Proportion of food barley sold [%] | -0.047 | 1.658*** | 0.306 | -1.431*** |
| | (0.488) | (0.299) | (0.327) | (0.285) |
| Constant | -1.988*** | -0.549 | -0.450 | 0.388 |
| | (0.726) | (0.405) | (0.500) | (0.392) |
| Observations | 458 | 458 | 458 | 458 |

**Standard errors in parentheses**
***** p<0.01, ** p<0.05, * p<0.1**