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Statistical Analysis of Households' Crop Production Decisions in Jimma Rare District, Horro Guduru Wollega Zone, Ethiopia

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Abstract

Background: Crop production decision is an important for crop producers which increases the productivity of households to reduce food insecurity. This study aims at assessing the factors influencing households' crop production decision in Jimma Rare District. **Methods:** The data was generated from primary source and 196 households were selected from Jimma Rare District using Multistage sampling techniques. Both descriptive statistics and econometric model (multinomial logit) were applied in this study to analyze the data collected from the selected sample households. **Results**: The study showed that, 39.30%, 19.90%, 32.70%, and 8.10% sampled households mainly use the combination of cereal crops, pulses, and oilseeds; cereal crop alone; the combination of cereal crops and pulses; and the combination of cereal crops and oilseeds respectively. The result of MNL model showed that age of household heads, education level of household heads, total land size, availability of agricultural inputs, access to agricultural infrastructure, and agro-ecological zone had significantly influenced crop production choices of households. **Conclusion:** The result suggests that different combinations of types of crops are influenced by differing independent variables. The result of MNL model showed that education level of household heads and availability of agricultural inputs are significantly and positively associated with the choice of cereal crops alone while total land size is significantly and negatively associated. On the other hand, availability of agricultural inputs, access to agricultural infrastructure, and agro-ecological zone are significantly and positively associated with the choice of cereal crops and pulses combination whereas total land size is significantly and negatively associated. Similarly, age and education level of household heads are significantly and positively associated with the choice of cereal crops and oilseeds combination while total land size is significantly and negatively associated as compared to combination of types of crops. Therefore, the study recommends that, improving access to training, availability of agricultural inputs at planting time, and preparing experience sharing among farmers should be promoted to increase the productivity of farmers by appropriate decision of crop production in the study area.

Keywords: Crop Production Decision, jimma Rare, Multinomial logistic regression model
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Backgrounds: Most of developing countries' economy including Ethiopia is based on agricultural sector which is mostly subsistence farming. In the east African countries like Ethiopia, Kenya, Uganda and Tanzania, smallholder farming accounts for about 75% of agricultural production (Salami *et al.*, 2010). Agriculture remains by far the most important sector in the Ethiopian economy since it supports about 85% of the population in terms of employment and livelihood, contributes about 50% of the country's gross domestic product (GDP), generates about 88% of the export earnings, and supplies around 73% of the raw material requirement of agro-based domestic industries (AfDB, 2011).

Crop production decision is an important for crop producers which increases the productivity of households to reduce food insecurity. According to Abera *et al.* (2013) improved disease resistance grain, enhancing the availability of crop input and stabilizing market price during harvest time are the most important strategies to increase maize production. The availability of quality seed with necessary inputs at the right time and place with a reasonable price is crucial for households' crop production decision of crop types (Mosisa *et al*., 2001).

Jimma Rare is one of the districts in Oromiya region which has potential to grow different types of crops such as cereal crops, pulses, and oilseeds highly. The major types of cereal crops currently growing in the district are wheat, maize, *teff*, and barley. The production of cereal crop is mainly for food and sale by the rural households in local markets (CSA, 2007).

The specific objectives of the study are:

1. To identify the main factors influencing the crop production decisions of households in the study area
2. To identify the marginal effects and directions of factors affecting crop production decision in the study area

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Methods

Study Area: The study was carried out in Jimma Rare Woreda which is one of the districts in Horro Guduru Wollega Zone of Oromiya Regional State in Ethiopia. The district is bounded on the west by Jimma Horro, on the north by Guduru, on the east and south by the Guder River which separates it from the West Shewa Zone. The administrative center of the district is Wayu; other towns in Jimma Rare include Goben (JRWOA, 2014). It is located at 245 km from the capital city of the country, Addis Ababa. A survey of the land in this district shows that 73.8% is cultivable or arable, 16% is grassland, 4.6% is forest, and the remaining 5.6% is considered swampy, mountainous or otherwise unusable (CSA, 2007). The district is classified as mid- altitude which is about 78% of the area, and the rest 22% is high altitude agro ecological zones. The annual rainfall ranges 900-1400 mm per year with annual temperature ranging from 18-25^{0}C during the year. The total population for this district was 71552 people of whom 35244 (49.26%) are men and the remaining are women. Out of 71552 total populations in the study area, 7710 are household heads that live in rural areas and 86.25% are men headed households and the remaining are women headed. The primary source of income is crop production. The secondary source of livelihood for the rural people in the area is livestock production. (JRWOA, 2014).

Data Types, Sources and Method of Data Collection:

Both primary and secondary sources of data were used in this study. The primary data (both qualitative and quantitative) were collected (in January to February 2015) for the study includes the socio-economic characteristics of the households, farm characteristics, and crop production choices of households. Secondary data was collected by reviewing documents of the administration office such as list of kebeles and number of households in each kebele in Jimma Rare district. A semi-structured questionnaire was developed for the collection of necessary primary information. This questionnaire was prepared in English and translated into local language (Afan Oromo) to make the communication easier during the primary data collection from the households. In order to select a representative sample of farm households, two- stage sampling techniques were employed. In the first stage, four kebeles were selected using simple random sampling techniques (lottery method) form 18 kebeles. In the second stage, sample of households were drawn from the selected kebeles for the interview based on simple random sampling.

In the determination of sample size where there is large population, but we do not know the variability in the proportion about the households' production decision to use types of crop, p = 0.5 is considered as suggested by Kothari (2004). To determine the required sample size, 95% confidence level, and 7% acceptable error rate during sampling were used. Based on this information, the sample size was determined by using the statistical formula given below:

$$n = \frac{n_o}{1 + \frac{n_o}{N}} \quad (1)$$

Where $n_o = \frac{(Z_{\alpha/2})^2 \times p \times q}{\varepsilon^2} = \frac{(1.96)^2 \times 0.5 \times 0.5}{(0.07)^2} = 196$

n_o= the initial sample size, p is the estimated proportion of households who use all types of crops (cereal crops, pulses, and oilseeds), $q = 1 - p$, and $Z_{\alpha/2}$ is the value of standard normal distribution for a given level of significance. The sample size from each kebele is determined as:

$$n_h = \frac{N_h \times n}{N} \quad (2)$$

Where, N - is the total number of households in all selected sample kebeles, N_h- is the number of households in hth strata (kebele), and n_h - is the sample size selected from hth strata.

Method of Data Analysis

Two types of data analysis were employed, namely descriptive statistics and inferential statistics (Econometric models). Descriptive statistics include mean, standard deviation, percentages and frequency, student's t-tests and chi square test were run using SPSS version 20 and STATA 11 software packages were used to describe, compare, and contrast the data with respect to the desired characteristics. Inferential statistics (Econometric model) such as Poisson or Negative binomial model and Multinomial logistic regression model were used to identify factors influencing crop production risks due to hail or heavy rainfall and crop production decisions of households respectively.

Multinomial Logistic Regression Models

Categorical data are data on dependent variable that can fall into one of several mutually exclusive categories. The econometrics literature focus on modeling a single outcome from categories those are mutually exclusive, where the dependent variable outcome must be multinomial distributed, just as binary data must be Bernoulli or binomial distributed. Analysis is not straightforward, however because there are many different models for the probabilities of the multinomial distribution. These models vary according to whether the categories are ordered or unordered categories of dependent variable. Multinomial Logistic model works if alternative categories must be independent or mutually exclusive. In this study, multinomial logistic model was used to identify factors affecting crop production decisions of households.

Multinomial logit regression model is more appropriate and makes it possible to study the determination of the factors influencing households' crop production decisions when the explanatory variables consist of individual specific characteristics and these characteristics are the determinants of the choice. This study assumes that household's decision is generated based on utility maximization. Suppose the utility that a household i use an alternative j and k is denoted by U_{ij} and U_{ik} respectively from two crop production decisions. Then random utility models are given by:

$$U_{ij} = \beta_j' X_i + \varepsilon_j \quad and \quad U_{ik} = \beta_k' X_i + \varepsilon_k , j \neq k \tag{3}$$

Where, X_i- a vector of explanatory variable; β_j , β_k - represent parameters and $\varepsilon_j , \varepsilon_k$ - error terms.

The probability that household i, uses alternative j is given by:

$$P_{ij} = P(U_{ij}(.) > U_{ik}(.))$$
$$P_{ij} = P(\beta_j' X_i - \beta_k' X_i > \varepsilon_k - \varepsilon_j) \tag{4}$$

Following Greene (2000), the multinomial logit model for multiple decision unordered categories is specified as follows:

$$P_{ij} = \Pr(y_i = j) = \frac{\exp(x_i' \beta_j)}{\sum_{j=1}^{m} \exp(x_i' \beta_j)} \; for \quad j = 1, \dots , m \tag{5}$$

Where, P_{ij} = the probability that household i uses crop production j, X_i = is a vector of explanatory variables, and β_j = are the parameters to be estimated by maximum likelihood estimator.

For identification of the model, normalize equation (5) by assuming the first response category is equal to zero (β_1= 0) (Greene, 2000). Therefore, i^{th} probabilities for the normalized model are given by:

$$P_{i1} = \frac{1}{1 + \sum_{j=1}^{m-1} \exp(x_{ij}' \beta_j)} \; for \;\; j = 1, \dots , m-1 \tag{6}$$

Parameter Estimation of Multinomial Logit Model

Maximum likelihood estimation is the method used to calculate the logit coefficients. MLE seeks to maximize the log likelihood (LL), which reflects how likely it is (the odds) that the observed values of the dependent may be predicted from the observed values of the independents. Following Cameron and Trivedi (2005), the multinomial density for one observation is defined as:

$$P(y) = P_1^{y_1} \times \dots \times P_m^{y_m} \tag{7}$$

A model for the probability that individual *i* chooses the *j* th alternative is

$$P_{ij} = \Pr(y_i = j) = F_j(x_i, \beta), \; j = 1, \dots, m, \; i = 1, \dots, n \tag{8}$$

The functional form for $F_j(.)$ should be such that probabilities lie between 0 and 1 and sum over *j* to one. The likelihood function for a sample of *n* independent observations is given as:

$$L(\beta) = \prod_{i=1}^{n} \prod_{j=1}^{m} P_{ij}^{y_{ij}} , i = 0,1, \dots, n, \; j = 1, \dots, m \tag{9}$$

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The log-likelihood function is

$$\ln L(\beta) = \sum_{i=1}^{n} \sum_{j=1}^{m} y_{ij} \ln P_{ij} \tag{10}$$

Since, the log-likelihood function is nonlinear in parameter β, one can maximize the order conditions of the maximum likelihood by using a numerical iterative method.

Marginal Effects of Multinomial Logit Model

The coefficients in multinomial logit model only tell the direction of effect but do not tell anything about the magnitude and the margins of the effect of the explanatory variable on the response variable (production choices). Instead, the marginal effects can be an informative means for summarizing how change in a response is relative to change in an explanatory variable. The marginal effects for binary variables show how probability of a particular decision change as the binary variables changes from zero to one, holding all other variables constant. That is, for a binary variable X_k

$$\text{MarginalEffect } X_k = \Pr(Y = 1/X, X_k = 1) - \Pr(Y = 1/X, X_k = 0) \tag{11}$$

For the categorical variables with more than two possible values, the marginal effects show that the difference in the predicted probabilities for cases in one category relative to the reference category. The marginal effects for continuous variables measure the expected change in probability of a particular decision being made with respect to a unit change in explanatory variables from the mean (Greene, 2000). The marginal effect of the multinomial logistic regression model is given by taking the first order derivative of the equation (3.20) with respect to the explanatory variables as given below:

$$\delta_{ij} = \frac{\partial P_{ij}}{\partial X_i} = P_{ij}\left[\beta_j - \sum_{j=1}^{m} P_{ij}\beta_j\right] = P_{ij}\left[\beta_j - \overline{\beta}_i\right] \tag{12}$$

Where $\overline{\beta}_i = \sum_{j=1}^{m} P_{ij}\beta_j$ is a probability weighted average of the β_j. It follows that the sign of the marginal effects would be different from the sign of the coefficients due to $\overline{\beta}_i$ (Cameron and Trivedi, 2005)

Test of the Independence of Irrelevant Alternatives (IIA): Multinomial logit model is only applicable if the conditions of Independent Irrelevant Alternative assumption is fulfilled (Green, 2003). Independence of Irrelevant Alternatives assumption refers to the situation where the odds in one outcome do not depend on other outcomes that are available or odds are mutually exclusive. In this sense, these alternative outcomes are "irrelevant." This means adding or deleting outcomes does not affect the odds among the remaining outcomes. This assumption can be tested by Hausman test. The test statistic is

$$q = \left(\hat{\beta}_s - \hat{\beta}_f\right)' \left[\hat{V}_s - \hat{V}_f\right]^{-1} \left(\hat{\beta}_s - \hat{\beta}_f\right) \tag{13}$$

Where, s indicates the estimators based on the restricted subset and f denotes the estimators based on the full set of choices, $\hat{\beta}_s$ *and* $\hat{\beta}_f$ are the respective coefficients, and $\hat{V}_s$ *and* $\hat{V}_f$ are the respective estimated covariance matrices. This is asymptotically distributed as chi-square with p degrees of freedom.

Table 1. Estimated parameters of MNL for Households' crop production decisions

	Households' Production decisions								
	Cereal crops alone			Cereal crops and pulses			Cereal crops and oilseeds		
Variable	Coef.	P	dy/dx	Coef.	P	dy/dx	Coef.	P	dy/dx
AGE	-.0304975	0.410	-.0076548	.0514077	0.017	.0139475	.0836566	0.027	.0020671
SEX	-.6829474	0.416	-.0408226	-.9545013	0.237	-.1869048	.53368	0.987	.0543692
HHDS	-.0188636	0.857	-.0051984	.0065973	0.939	-.0008741	.1511852	0.230	.0099411
EDUC	.4300628	0.036	.0589678	-.4140749	0.292	-.0981531	1.518861	0.058	.1119876
TLU	-.0890754	0.228	-.0133641	-.0129416	0.814	.0022021	.0822763	0.343	.0022652
TLND	-.6648892	0.001	-.0817975	-.2781365	0.092	-.01789	-.1311333	0.009	-.0067163
IPAVA	.0027521	0.046	.0261231	.002146	0.087	.0262125	-.000182	0.300	-3.50e-06
INFRA	-.0014575	0.997	.0705428	1.290834	0.006	.2465683	-.140433	0.817	.016566
MINFO	.0120792	0.984	.0425031	-.6028338	0.253	-.1402383	-.1305763	0.882	.0020772
CDT	.8661038	0.064	.12022	-.0673778	0.889	-.0653458	.211064	0.775	.0019069
TRAIN	.3883066	0.506	.0438372	.3015433	0.580	.0491114	-.7234145	0.394	-.0239746
AEXT	-.8222727	0.227	-.1113801	-.2389877	0.732	.0281089	-.772107	0.409	-.0371167
AGECO	.0534864	0.910	-.0654585	1.250746	0.002	.2825506	-.3120057	0.641	-.0496586
WST	1.194299	0.077	.1166618	-1.044515	0.107	-.1361694	-.4022627	0.654	.0054095
_cons	2.791191	0.001		1.771309	0.022		-1.150503	0.338	
	Number of obs.	= 196			LR chi2(28) = 68.67				
	Log likelihood	= -114.49335			Prob> chi2 = 0.0000				
					Pseudo R2 = 0.2364				

Source: Computed from own survey data, 2015. Combination of cereal crops, pulses, and oilseed is the baseline category. Rebust standard errors, z-ratio and confidence intervals are not reported here because of space constraints.

Results and Discussions

The results of the Multinomial logistic regression model and marginal effect as well as their possible discussions are presented below.

Multinomial logit model was used to analyze factors affecting households' crop production decisions. The categories of crop production decisions are the combination of cereal crops, pulses, and oilseeds, cereal crops alone, the combination of cereal crops and pulses, and the combination of cereal crops and oilseeds. The multinomial logit model was tested for the reliability and validity of the independence of the irrelevant alternatives (IIA) assumption by using the Hausman test. The analysis failed to reject the null hypothesis that excluding one category of crop production decision does not affect the remaining categories of crop production decisions. The possible heteroscedasticity and Multicollinearity problems are also corrected. There is no multicollinearity problem because the variance inflation factor (VIF) is less than 10 for all continuous variables and the contingency coefficient is less than 0.75 for all dummy variables.

Overall Goodness of Fit Test: The overall goodness of fit test for multinomial model was assessed using the likelihood ratio test. The likelihood ratio test of the model as indicated by chi-square statistic is highly statistically significant at 1% level of significance, suggesting that at least one estimated coefficient is significantly different from zero (Table 1). The null hypothesis that, there is no difference between the model without independent variables and the model with independent variables was rejected. This is suggesting that the existence of a relationship between the combination of explanatory variables and the response variable was supported.

Age of Household Heads (AGE): Age of household heads (representing farmers' experience) influences the decision of crop production by farming household. Age of the household heads positively and significantly affected the production decision to use cereal crops and pulses combination and cereal crops and oilseeds combination compared to the base category (all types of crops). The marginal result shows that, holding all other variables constant, a unit increase in age of household heads increases the likelihood of mainly using the combination of cereal crops and pulses and the combination of cereal crops and oilseeds by 1.39% and 0.21% respectively (Table 1). The implication is that, aged households are expected to acquire more knowledge and experience on the production decision of crop types and that helps the households to increase their likelihood of practicing different crop production decision options. The result is confirmed with Zivanomoya and Mukarati (2013) who found that age of household head tend to increases the probability of growing new sorghum varieties.

Education level (EDU): Education level of household heads positively and significantly influenced the main decision to use cereal crops alone compared to all types of crops (cereal crops, pulses and oilseeds). The sign of the parameter estimate confirms with the expected hypothesis. Holding all other variables constant, formally educated household heads increases the probability of mainly using cereal crops alone by 5.80% relative to uneducated household heads (Table 1). The possible reason for the positive relationship is due to the fact that educated households have more knowledge and information, interpret the information received, and make crop production decision than uneducated households. This is in line with Ayuya *et al.* (2012) who found that education level of household heads had a positive and significant effect on the choice of leguminous crops.

Total Land Size (TLND): Total land size of households negatively and significantly affected the main decisions to use cereal crops alone and combination of cereal crops and oilseeds compared to the combination of all types crops. The survey result shows that, an increase in total land size of households by one hectare decreases the probability of using cereal crops alone and combination of cereal crops and oilseeds by 8.18%, and 0.67% respectively, holding all other variables constant (Table 1). The reason is that, households with large land size are more likely to use all types of crop production and allows a household to experiment new technologies on different crops than the households with less or small total land size.

Input Availability (IPAVA): Availability of agricultural input positively and significantly influenced the main decisions to use cereal crops alone compared to the combination of cereal crops, pulses and oilseeds. The sign of the parameter confirms with the expected hypothesis. The survey result shows that, households with access to agricultural inputs increases the probability of mainly using cereal crops alone by 26.13% compared to those without access to agricultural inputs, holding all other variables constant (Table 1). The availability of agricultural inputs (fertilizer, improved seed and crop protection products, chemicals) in the study area is crucial to use crop production. The reason is that, availability of agricultural crops at right place and time might increase the interest of households to use the crop production to enhance their productivity.

Infrastructure (INFRA): Access to agricultural infrastructure positively and significantly affected the main decisions to use cereal crops and pulses combination compared to all combination of types of crops. The result of marginal effect shows that, keeping all other variables constant, access to agricultural infrastructure increases the probability of mainly using the combination of cereal crops and pulses by 24.66% compared to the households without access to agricultural infrastructure (Table 1). The implication is that the households with sufficient agricultural infrastructure could participate in market and crop production than those households without infrastructure. This finding is in line with the study conducted by Jari and Fraser (2013) who found that availability of good road and market infrastructures had positively and significantly influenced market participation choices.

Agro Ecological Zone (AGECO): Households living in different agro ecological zones make use of different crop production decisions. Agro-ecological zone of households positively and significantly influenced the main decision to use cereal crops and pulses combination compared to all types of crops. The result show that, households living in highland increases the likelihood of mainly using the combination of cereal crops and pulses by 28.26% compared to households living in midland, holding all other variables constant (Table 1). The possible explanation is that households living in highland are more likely to choose and use the combination of cereal crops and pulses as compared to the households living in midland. This finding is confirmed with Aemro *et al*. (2012) who found that agro ecological setting had positively and significantly influenced improved crop variety and crop diversification.

Limitation of the study

The study would not include sources of other risks like market risk, human or personal risk, institutional risk and financial risk of households and it would not include production decisions to use livestock's. Furthermore, since Oromia has wide range of diverse agro-ecologies, institutional capacities, organizations and environmental conditions, the result of the study may have limitations to make generalizations and make them applicable to the country as a whole. However, it may be useful for areas with similar context with the study area.

Conclusions: The multinomial logistic regression model has deepened an understanding of the relations between various covariates and crop production choices commonly used in the area. The result suggests that different combinations of types of crops are influenced by differing independent variables. The result of MNL model showed that age of household heads, education level of household heads, total land size, availability of agricultural inputs, access to agricultural infrastructure, and agro-ecological zone had significantly influenced households' crop production decisions. Accordingly, education level of household heads, and availability of agricultural inputs are significantly and positively associated with the decision to use cereal crops alone while total land size is significantly and negatively associated. On the other hand, availability of agricultural inputs, access to agricultural infrastructure, and agro-ecological zone are significantly and positively associated with the choice of cereal crops and pulses combination whereas total land size is significantly and negatively associated. Similarly, age and education level of household heads are significantly and positively associated with the choice of cereal crops and oilseeds combination while total land size is significantly and negatively associated as compared to combination of types of crops.

Recommendations: The recommendations or policy implications were drawn based on the significant variables from the analysis of present study.

Households' crop production decisions were significantly affected by availability of agricultural inputs, access to agricultural infrastructure, and agro-ecological zone. The government and concerned body should improve availability of agricultural inputs at planting time, agricultural infrastructures, and give a technical advice on the crop production choices based on different agro-ecological zones. These situations help farmers to get knowledge on the choices of crop production and this leads to reduce crop production risks of households.

Empirical results showed that livestock size is significant for both production risk and crop production decisions of households. It needs to improve the existing livestock production system on the quality and quantity of livestock through upgrading the provision of animal health service and providing adequate technical support to increase crop production decisions and minimize losses of crop production in the area.

Accesses to credit service and wealth status of households are determinants affecting crop production decisions. Better credit services for households especially for landless holding and poor farmers could create ability to purchase inputs and join the new opportunity of rural non-farm like trading, and allowing others to lend in additional land.

Declarations

Ethics and consent to participate

Ethical approval was obtained from Haramaya University, college of computing and Informatics.

Consent for publication

Not applicable

Availability of data and materials

The datasets in which conclusion has taken is available on request.

Competing interests

The authors declare that they have no competing interests.

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