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A double hurdle estimation of crop diversification decisions by smallholder wheat farmers in Sinana District, Bale Zone, Ethiopia

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Abstract

Background: Ethiopia is heterogeneous in agro-ecological, social, and economic conditions. In such heterogeneous environment, crop production needs to be diversified to meet household consumption and market needs. This study analyzed determinants of crop diversification in wheat dominant producer rural households in Ethiopia's Sinana District of the Oromia Regional State. The study utilized a structured survey of 384 households, and both inferential and descriptive statistics were employed to analyze the data. A Cragg's double hurdle model was applied to identify factors influencing decision and the extent of crop diversification.

Results: We found that decision to crop diversification was positively associated with household size, access to fertile farm plots, and access to extension services and negatively associated with age of household head, and participation in off/non-farm activities. The extent of crop diversification is positively associated with access to extension services, labor availability, membership to farmers cooperatives, and distance to market.

Conclusions: These findings support the need for resources to strengthen available extension packages, support existing farmers' cooperatives, and develop rural infrastructures in order to improve the smallholder farmers' extent of crop diversifications.

Keywords: Crop diversification, Double hurdle, Determinants, Sinana District, Bale Zone

Background

In sub-Saharan Africa, the agricultural sector is key for spurring economic growth, overcoming poverty, and enhancing food security (Michler and Josephson 2017). However, in this region, agriculture is often characterized by low productivity (Kassie et al. 2011). This is due to several factors, including limited natural resources, socio-economic, technological, and infrastructure problems (FAO et al. 2017).

Block and Timmer (1994) and Pellegrini and Tasciotti (2014) noted that crop-diversification increases farm income, creates employment opportunities, reduces poverty, and enhances soil health and water retention. Through crop diversification, farm families can spread production and economic risk over a wider range of crops, thereby reducing financial risks associated with adverse weather conditions or market shocks. Growing diverse products can also help financially by expanding market potential (Truscott et al. 2009). Further, diverse cropping systems generally provide more varied and healthier food for humans and livestock. As mentioned through FAO (2017) and Acharya et al. (2011) crop diversification is used as one of the fundamental instruments for ensuring food security, poverty reduction, and

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nutritional adequacy and is a source of overall agricultural development in most developing countries.

Theoretically, there are two main pathways through which crop diversification affects farm household poverty. (i) It can enhance access to a wide variety of food products necessary for a balanced diet for the households. As diversified production improves dietary diversity, it can enhance the nutritional balance of people's diet and, in doing so, help improve their health and earning capacity, (ii) Farming diversified crops including marketable higher-value crops can lead to increased income for farm families (Mazunda et al. 2018).

The increasing risks of crop failure due to erratic rainfall and crop disease usually force farmers to diversify their portfolio as a hedge against these risks (Asante et al. 2017; Khanal and Mishra 2017). Concurrently, Winters et al. (2006) have identified three key factors that derive farmers' 'demand' for crop diversity: managing risk, adapting to heterogeneous agro-ecological production conditions, and meeting market demands and food and nutritional security. Likewise, studies (FAO 2012; Feliciano 2019) indicated that crop diversification has beneficial effects for the soil. This is mainly because crop diversification usually associated with reduced weed and insect pressures, reduced need for nitrogen fertilizers (especially if the crop mix include leguminous crops), and reduced erosion (because of cover crops inclusion). It also potentially reduces pests and diseases as well as increases food security by offering farmers access to sufficient, nutritious and diverse foods in areas where markets are not available (Mukherjee 2015; Van den Broeck and Maertens 2016). Furthermore, it has also argued that diversifying by growing more enterprises may lead to farm income stability (Mazunda et al. 2018). Indeed, Habte and Krawinkel (2012) found that pulses are more profitable than most cereals. In addition, the FAO (FAO 2016) reported that the economic benefit of faba bean production is 70% greater than that of wheat.

In Ethiopia, agriculture continues to be the dominant economic sector in terms of share in the gross domestic product (GDP) (34.9%), employment generation (80%), and share of export (70%), and it provide about 70% of raw materials for the country industries during the 2015/2016 fiscal year (UNDP 2016). Major Ethiopian policy documents related to economic growth and poverty reduction strategies, place emphasis on the importance of agricultural diversification. Specifically, the Agricultural Development Led Industrialization (ADLI) and the Growth and Transformation Plans (GTPs) I and II embodied all aspects of diversification (Ministry of Finance and Economic Development [MoFED] 2015).

Even though it has been emphasized in public policy, crop diversification in Ethiopia is not well practiced (Mesfin et al. 2011; Sibhatu et al. 2015; Mussema et al. 2015). In the Sinana District, agriculture is traditional, and dominated by monoculture cropping system. Productivity is constrained by several factors such as technology, resources availability, environmental factors, socio-economic conditions, poor infrastructure, low soil fertility, and crop pests and insects (Bale Zone Finance and Economic Development [BZFED] 2018). Farmers in this monocropping region are therefore vulnerable to marketing risks, income instability, and hunger. Crop diversification is believed to be a solution, and an effective strategy for the improvement of subsistence farming practice. Nevertheless, the importance and potential of crop diversification has not yet been fully exploited in the study areas. The determinants were also not studied. Thus, this study was designed to examine the determinants of crop diversification in the study area.

Different studies (including Fetien et al. 2009; Degye et al. 2012; Mandal and Bezbaruah 2013; Kanyua et al. 2013; Veljanoska 2014; Ainembabazi and Mugisha 2014; Rehima et al. 2013, 2015; Hitayezu et al. 2016; Eisenhauer 2016; World Bank 2018) have identified that crop diversification is shaped by various factors within the farming households. These include available inputs such as labor, farm experience, availability of seed, prices, government policy, land availability, market access, extension service, household characteristics as well as environmental factors such as climatic and soil conditions. However there has been limited research examining determinants of crop diversification at the household level in study area. As part of our contribution to the poverty reduction in the study area, this study was intended to identify and analyze the factors affecting the decision and extent of crop diversification by rural households in the Sinana District for the first time. The findings of this study contribute to the growing body of crop diversification literature. It can also be used as an input to improve production income, food and nutrition security, and poverty reduction for most rural households elsewhere in monocroping areas of Ethiopia.

Theoretical framework of the study

Agricultural production is subject to complex socio-economic and environmental constraints. As stated by Singh et al. (1986) households' decision is to ensure a balance between production, consumption and labor input. Farmers' production decision objectives go beyond profit maximization, comprising multiple objectives, namely profit, risk and crop complexity (Van Dusen and Taylor 2005). The objective of smallholder agriculture households is to maximize utility as consumers, unlike the traditional theory of profit maximization (Singh et al. 1986).

The analytical model used for this study was drawn from the theory of the farm household model (De Janvry et al. 1991). The household[1] combines farm resources and family labor to maximize utility over consumption goods produced on the farm or purchased on the market. Household decisions are constrained by a production technology, farm physical environment and land area, family labor time allocated to labor and leisure and income constraint.

A farm household's expected utility is dependent on its attitude toward risk. Even in a one-season model, a farm household's utility is subject to uncertainty in, levels of rainfall, output prices, and consumption prices. A farmer's production decisions, including optimal crop allocation, are therefore dependent on that farmer's attitude toward risk (Fafchamps 1992; Van Dusen and Taylor 2005) as well as the presence of markets problems (De Janvry et al. 1991; Hitayezu et al. 2016); . For example, markets for price information or crop insurance would decrease a farmer's perceived level of risk, affecting crop allocation decisions. The literature (Hitayezu et al. 2016) suggests that farmers in developing countries tend to be risk averse and crop diversification may be a strategy to insure against production and price risk.

These conditions pose risks to farm production and make farmers cautious in their farming decisions. Hence, farmers are assumed to use the risk-aversion strategy and maximize utility in their decision-making process. As a mechanism for incorporating risk aversion into a farmer's decision-making process, crop diversification played a vital role (Davis et al. 1987).

The analytical framework used for this study was drawn from both risk-averse and utility-maximizing theories of farm household production behavior. The fundamental assumption is that the farmer's decision on whether to minimize risks (diversify crops) or not is based upon the utility- maximization theory (Ellis 1993; Rahm and Huffman 1984).

The expression $U\left(CD_{ji}*P_{ji}\right)$ is a non-observable underlying utility function, which ranks the preference of the ith farmer for the jth diversification process or status of diversification ($j = 0$, 1; where $0 =$ no diversification and $1 =$ diversification). Thus, the utility derived from crop diversification depends on *CD,* which is a vector of demographic, socio-economic, farm specific, marketing and institutional attributes of the diversifier and *P,* which is a vector of the attributes associated with crop diversification. Although the utility function is unobserved, the

relation between the utility derivable from the jth diversification process is postulated to be a function of the vector of explanatory variables and a disturbance term having a zero mean:

$$U_{ji} = \alpha_j F(CD_i P_i + \varepsilon_{ji}) \tag{1}$$

Since the utilities U_{ji} are random, the ith farmer will select the alternative $j = 1$ if $U_{1i} > U_{0i}$ or if the non-observable (latent) random variable $Y^* = U_{1i} - U_{0i} > 0$. The probability that Y_i equals one (i.e., that the farmer practices crop diversification) is a function of the explanatory variables:

$$
\begin{aligned}
P_i &= \Pr\left(p_i = 1\right) = \Pr\left(U_{1i} > U_{0i}\right) \\
&= Pr\left(\alpha_1 F_1\left(CD_i^* \, P_i\right) + \varepsilon_{1i}\right) > Pr\left(\alpha_0 F_1\left(CD_i^* \, P_i\right) + \varepsilon_{0i}\right) \\
&= Pr\left[(\varepsilon_{1i} - \varepsilon_{0i}) > F_i\left(CD_i^* \, P_i\right)(\alpha_1 - \alpha_0)\right] \\
&= \Pr\left(\upsilon_i > -F_i\left(CD_i^* \, P_i\right)\beta\right) \\
&= F_i\left(X_i, \, \beta\right)
\end{aligned}
\tag{2}
$$

where X *is the* $n \times k$ matrix of the explanatory variables and β is a $k \times 1$ vector of parameters to be estimated, *Pr(.)* is the probability function, υ_i is the random error term, and *Fi (X*i *β)* is the cumulative distribution function for υ_i evaluated at $X_i\beta$. The probability that a farmer will diversify in crop production is a function of the vector of explanatory variables and of the unknown parameters and error term. Equation 2 cannot be estimated directly without knowing the form of *F.* It is the distribution of υ_i that determines the distribution of *F.* The functional form of *F* is specified with double hurdle model. It is used to assess the determinants of crop diversification as well as the factors influencing the extent of crop diversification by rural households.

Material and methods
Description of the study area
The study was conducted in Sinana District, Bale Zone, Oromia Regional State of Ethiopia. The District is located in the southwest of Ethiopia and is 412 km from Addis Ababa, capital city of the country. Robe Town is the major town of the District and of the center of the Zone. In the District, agriculture (crop and livestock production) is dominant livelihood strategies of rural households. Farmers in the District utilize mixed farming system of both crops and livestock. The major crops produced in the District are cereals (wheat, barley, maize, and teff), pulses (bean, field pea), and oil crops (Bale Zone Agriculture Development Organization [BZADO] 2017).

In addition to farming activities, off-farm and non-farm activities were also practiced in small scale. Off-farm activities such as wage employment, participation in crop production on someone else 's land for harvest

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[1] A small group of persons who share the same living accommodation, who pool some, or all, of their income and wealth and who consume certain types of goods and services collectively, mainly housing and food.
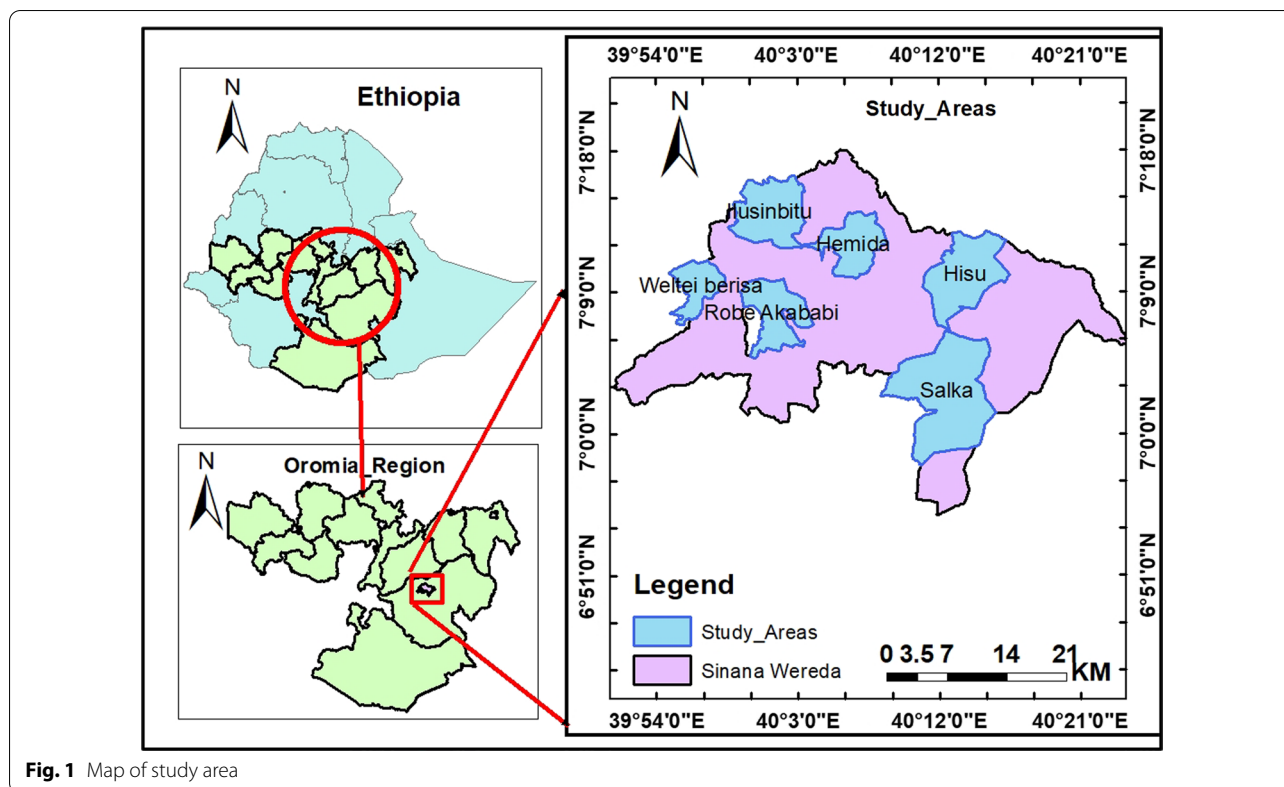
Fig. 1 Map of study area

share (especially very small land size holders) were commonly practiced. In the study site, two *Kebeles (the lowest administrative unit)* out of six were identified as food insecure (BZADO 2017). In response to this level of food insecurity in the District, the Productive Safety Net Program (a livelihoods supporting scheme) was the major food insecurity intervention (BZADO 2017) (Fig. 1).

Data collection

A combination of quantitative and qualitative data were collected from primary and secondary sources. Primary data was collected from rural households through structured and semi-structured survey. To complement this primary data, secondary data was collected from records of government officials, published and unpublished reports, journals, books, and websites. The survey interview guide, which consists of structured and semi-structured questions, was prepared in English and translated into the local language (Afan Oromo) to collect information on socio-economic, demographic, and characteristics of households. Furthermore, it was pretested in *Kebele*, different from sampled *Kebeles*, and necessary adjustments were made before the actual survey.

Sampling design

To select the sampled respondents, a multistage sampling procedure was employed. In the first stage, the Sinana District was purposely selected from ten districts of the Bale Zone due to dominance of wheat production. In the second stage, six *kebeles*, namely Ilu-sanbitu, Hamida, Hisu, Salka, Robe-Akababi and Weltei-berisa were selected based on a simple random sampling method. In the third stage, 384 sampled households were selected by using a simple random sampling technique following a scientific sample size determination formula developed by Yamane (1967).

$$\text{n} = N/\left(1 + N\text{e}^2\right) 9768/\left(1 + 9768 * 0.05^2\right) = 384 \tag{3}$$

where **n** is sample size to be included in this study, **N** is population size and **e** level of precision and the size of our population (wheat producers) is 9768 (BZSP 2015).

Data analysis

In this study STATA software version 14.2 was used to analyze data. The *t* test was used to assess mean differences between crop diversifier and non-diversifier as well

as continuous explanatory variables. Chi-square test was also used to assess the association of households and farm-related characteristics between groups (diversifier vs. non-diversifier). Moreover, to investigate the determinants of rural household decisions and extent of crop diversification, double hurdle model was used.

Empirical model specification

There are various methods to measure crop diversification (Magurran 1988; Malik and Singh 2002). The current study used Herfindahl Index (HI[2]) as measures of crop diversification to represent relative land sizes of farming activities operated by a given farm, widely used in crop diversification literature (Magurran 1988; Malik and Singh 2002; Sichoongwe et al. 2014). This study employs Herfindahl index because it is widely used in the literature of agricultural diversification (Malik and Singh 2002; Kanyua et al. 2013; Ojo et al. 2014; Sichoongwe et al. 2014; Asante et al. 2017). Besides, the index is easy to compute. The CDI (Crop Diversification Index) has a direct relationship with crop diversification, such that a zero value implies specialization and a value greater than zero means crop diversification. The CDI is obtained by subtracting the Herfindahl index (HI) from one $(1 - HI)$. Precisely, the CDI is calculated as follows:

$$p_i = \frac{A_i}{\sum_{i=1}^{n} A_i} \tag{4}$$

where, P_i = proportion of ith crop, A_i = Area under ith crop (ha), $\sum_{i=1}^{n} A_i$ total crop land(ha) and $i = 1, 2, 3 \ldots, n$) (number of crop)

$$\text{Herfindahl Index} = \text{HI} = \sum_{i=1}^{n} p_i{}^2 \tag{5}$$

$$\textit{Crop diversification index} = CDI = 1 - HI \tag{6}$$

The analysis of crop diversification entails a situation where at each observation the event may or may not occur. An occurrence (crop diversification) is associated with a continuous non-negative random variable, while a non-occurrence (not diversifying) yields a variable with zero value (Cragg 1971). Such a scenario presents a limited dependent-variable (Engel et al. 2014) modeling problem where the lower bound of the variable, zero value, occurs in a considerable number of observations. The occurrence of the event allows a continuous

distribution over positive values, but an "accumulation" at zero exists (due to non-occurrence), which is a corner solution for the diversification problem (García 2013). Such common cases in the social sciences invalidate the use of the usual regression model and require models capable of handling binary endogenous variables.

The common approaches of modeling such situations include the Tobit, Heckman and double-hurdle models (Komarek 2010). Several studies have applied the Tobit model to approach this type of study (Bellemare and Barrett 2006; Gebremedhin and Jaleta 2010; Martey et al. 2012; Gani and Adeoti 2011), but the major drawback of this approach is that it imposes a restriction that both diversification decisions are simultaneously influenced by the same set of explanatory variables (Ground and Koch 2008). Since we assume, in this study, that the decisions on crop diversification and level of diversification are influenced by different sets of independent variables, the Tobit model is not recognized. It is also argued that the model yields biased parameter estimates (Wanyoike et al. 2015) and recent studies have stressed the inadequacy of the Tobit, proposing the use of less restrictive alternative approaches to Heckman's model (Heckman 1979) and Cragg's double obstacle model (Cragg 1971). These two-step alternative models are relevant for our study because separate vectors of independent variables influence the farmer's crop diversification decision.

The double hurdle is a less restrictive variant of the Heckman and is best suited for samples drawn through random probabilistic sampling procedures (Komarek 2010). Therefore, the double hurdle was adopted for the analysis of our randomly selected sample data. The model is a generalization of Tobit, where two distinct stochastic processes determine participation and quantitative decisions. The remarkable difference between the two-step models is based on the contribution of the Heckman, which non-participants will not participate under any circumstance (Kiwanuka and Machethe 2016). Contrary, the double hurdle assumes that the decision not to participate is a deliberate choice (Tura et al. 2016), then the zeros of the non-participants are considered as the solution of the angles in the utility maximization model (Yami et al. 2013). The model is also flexible, assuming that there are no restrictions on the components of the independent variables in each phase of estimation.

The double hurdle model is more flexible than the Tobit and allows the participation and extent of crop diversification to be determined separately (Burke 2009). The model requires a joint application of the probit and truncated regression models, sequentially or simultaneously (Yami et al. 2013). The theoretical basis of the double-hurdle estimation framework by Cragg (1971) is

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[2] Herfindahl Index (HI): As proposed by Orris C. Herfindahl and Albert O. Hirschman (1964) "to quantify the amount of competition in a given industry where the market shares are expressed as fractions between 0 and 1". The method was applied to measure the extent of crop diversification for those farmers who diversified their crops. i.e., a measure of the crop concentration of the farm.

grounded on the probit model where the probability of crop diversification at observation *t*, $p(E_t)$, is given by:

$$P(E_t) = \int_{-\infty}^{x'\beta} (2\pi)^{-\frac{1}{2}} \exp\left\{-z^2/2\right\} dz \qquad (7)$$

where X_t is a K* 1 vector of exogenous variables at observation t and β represents a vector of parameter estimates. Then the cumulative unit normal distribution is designated as

$$C(z) = \int_{-\infty}^{z} (2\pi)^{-\frac{1}{2}} \exp\left\{-t^2/2\right\} dt \qquad (8)$$

The probit model estimates the probability of a farmer to participate in crop diversification (first diversification decision). The second quantity of diversification occurs when favorable circumstances (search, information and transaction costs) prevail to allow the diversification to be completed (Moffatt 2005). This non-negative quantity decision can only be measured for non-zero values in the first decision, thus estimated by the truncated regression (Ground and Koch 2008). Therefore, the double-hurdle two-equation framework (Matshe and Young 2004; Kefyalew 2012) is presented as:

$$CD_i^* = z_i^*\alpha + \varepsilon_i \; Diversification\; decision \quad Q^{CD**} = X_I'\beta + \mu_i \; Quantity\; diversified \begin{pmatrix} \varepsilon_i \\ \mu_i \end{pmatrix} \sim N\left[\begin{pmatrix} 0 \\ 0 \end{pmatrix} \begin{pmatrix} 1 & 0 \\ 1 & \partial^2 \end{pmatrix}\right] \qquad (9)$$

where CD_i^* is the latent variable for the binary dependent variable taking a value of one for crop diversification and zero indicates otherwise. Q^{CD**} is the latent variable reflecting the number of crop diversified. z_i^*, α *and* ε_i represent vectors of explanatory variables, parameter estimates and the error term for the crop diversification decision. Likewise, X_I', β and μ_i represent vectors of explanatory variables, parameter estimates and the error term for the level of crop diversification. Since an individual farmer is involved in both sales decisions, the error terms are assumed to be independently and normally distributed, thus the first hurdle corresponds to a probit model (Kefyalew 2012).

The binary dependent variable of the diversification decision in Eq. (9) is defined by

$$CD_i^* = 1 \; if \; CD_i^* > 0, CD_i^* = 0 \; if \; CD_i^* \leq 0 \qquad (10)$$

and decisions on the level of crop diversification is defined by

$$Q^{CD*} = max\left(Q^{**}, 0\right) \qquad (11)$$

The observed variable, Q^{CD*} (normally presented as y_i in literature) is determined as

$$Q_i^{CD*} = CD_i Q_i^{CD*} \qquad (12)$$

and log-likelihood function for the double hurdle is:

$$LogL = \sum_0 ln\left[1 - \Phi\left(z_i'\right)\Phi\left(\frac{X_i'\beta}{\sigma}\right)\right]$$
$$+ \sum_+ ln\left[\Phi\left(z_i'\right)\frac{1}{\sigma}\Phi\left(\frac{y_i - X_i'\beta}{\sigma}\right)\right] \qquad (13)$$

Variables definition

There are a number of studies that identify level and determinants of crop diversification at different level. Reviewed literature indicates that the decision and extent of crop diversification practices depend on demographic, socioeconomic, farm attributes, and institutional factors. These factors include sex, age, family size, education level, size of livestock holding, amount of off/non-farm-income, farm experience, farm size, land fragmentation, plot fertility, access to credit, extension services, distance to nearest market and cooperative membership. The list of explanatory variables used in the Cragg's double hurdle model and their expected signs are summarized in Table 1.

Result and discussions

Household characteristics and status of crop diversification

The finding indicates that 58.72% of rural households in study area did not diversify cropping systems. Further, using the Hirschman and Albert (1964) formula, the study found that the average CDI of sampled households is 41.28%. This implies that the cropping system is less diverse. The mean index in this study was less than the national crop diversification index which was 0.83 (CSA 2020). Further, it was less than the findings of Dessie et al. (2019) and Mekuria and Mekonnen (2018) who found 0.77, and 0.57 in other rural areas of Ethiopia. Table 2 shows descriptive analyses that aim to give a picture of demographic and socio-economic characteristics of the diversifier and non-diversifier farmers in the study area.

The survey result shows that two third of the respondents were male-headed households while the remaining one third were female-headed households. The average family size of household was 7.06 with standard deviation of 2.24. A closer look at the economically active family members (15 to 64 years old) shows that crop diversifiers

Table 1 Summary of the explanatory variables used in double hurdle model

Variables	Measurement	Expected sign
Dependent variable		
Crop Diversification Indices	Index	
Explanatory variables		
Gender	Sex of household head (Male = 1, female = 0)	+
Age of household head	Age of household head (years)	−+
Family size	Persons in the household (number)	+
Labor availability	Access to labor for farming (yes = 1, No = 0)	+
Education level of household	In year of schooling	+
Farm experiences	Number of year engaged in farming activities	+
Extension visit	Frequency of extension contact (frequency)	+
Membership to cooperatives	Membership to farmers' cooperative (Yes = 1, No = 0)	−+
Total livestock unit/TLU	Size of Livestock owned (TLU)	−+
Farm land size	Land operated for farming by the household (ha)	+
Plot fertility	Plot fertility (Yes = 1, No = 0)	−+
Number of plots	Number of plot operated for farming (number)	+
Distance to market	Distance from homestead to nearest market (km)	−+
Distance to farmers training center	Distance from homestead to FTC (km)	−+
Distance to farm	Distance from homestead to farm (km)	−
Income (annual income)	Total income (birr)	+
Number of oxen	Number of oxen used for farming (Number)	+
Participation on off/non-farm income	Participation on off/nonfarm activities (yes = 1, No = 0)	−/+
Access to remittance	Access to remittance (Yes = 1, No = 0)	−+

−+indicates listed variables were expected to affect crop diversification negatively or positively

Table 2 Descriptive result of factors affecting crop diversification

Characteristics	Non-diversified % or mean ($n_1 = 71$)	Diversified % or mean ($n_2 = 311$)	Total	χ^2 or *t-test*
Gender of household head (% female)	12.86	14.57	11.54	0.006
Age of HH	44.47	44.23	44.33	− 0.003**
Dependency Ratio	2.34	1.4	1.98	0.0325
Family size in number	6.69	7.13	7.06	0.010
Labor availability (%yes)	47.25	75.56	63.34	.0405**
Education level of household head	0.34	0.37	0.362	0.002**
Farm Experience in year	35.61	24.72	24.74	0.011***
Access to credit (% yes)	18.57	11.22	12.50	0.024
Total livestock unit/TLU	7.24	7.57	7.48	− 0.002
Farm land size	2.67	3.06	2.99	− 0.007***
Number of plot	2.64	3.22	3.13	0.001**
Plot fertility	97.14	61.22	49.87	0.092*
Extension visit (frequency)	94.29	95.51	95.05	0.097**
Access to remittance	43.12	56.88	41.34	0.004
Membership to coops (% yes)	74.29	66.67	67.97	− 0.016**
Distance to market	26.29	30.03	29.33	0.003
Distance to farmers training centers	15.66	15.93	15.87	0.003
Distance to farm	15.96	15.73	15.77	− 0.004
Total income/AE in birr	5214.29	7370.19	6943.18	2.76e−06
Number of oxen	2.39	2.37	2.68	0.061

*, ** and *** significant at 1%, 5% and 10% significance, level respectively

had larger economically active members (3.6 persons) than non-diversifiers (2.1 persons).This implies that crop diversifiers had relatively more labor resource than non-diversifiers. However, non- diversifiers had higher average dependency ratio (2.34) than that of diversifiers (1.4). The dependency ratios indicate that every economically active person in a household had to support more than one economically inactive person in both diversifiers and non-diversifiers cases.

The results of the survey showed that 82.77% of household heads have no education. The remaining 17.23% attend different educational levels, i.e. primary school at 15.44%, secondary school at 1.57%, and university or college at 0.52%. The average years of farm experience of household head is 24.74 years with standard deviation of 8.68. Education level and farm experience of household head determine crop diversification because educated and farmers with more farm experience easily understand agricultural instructions provided by the extension workers (Gauchan et al. 2005; Ibrahim et al. 2009). The finding also indicates that most of rural households (66.67% of crop diversifiers and 74.29% of non-diversifier) were members of farmers' cooperatives.

Findings of the study showed that almost all sampled households own livestock though the number of livestock varies. The mean livestock holding in Tropical Livestock Unit (TLU) for the sample households is 7.48. Non-diversifier households have a better livestock holding than the diversifier households. The mean livestock holding in TLU for crop diversifier households is 7.57 and 7.24 for non-diversifiers.

Regardless of the size, all respondents have ensured that they own land they operate. The landholding of the sample households ranges from 0.5 to 9 ha. The average land holding is 2.99 ha. The mean landholding for crop diversifiers is 3.06 ha, and the corresponding figure for non-diversifiers is 2.67 ha. The survey results indicate that the mean number of farm plots that farmers own is 3.13. The mean farm plots for crop diversifiers are 3.22; the corresponding figure for non-diversifiers is 2.64 farm plots. Findings of the survey results indicates that 49.87% of households have fertile plots. The comparison between crop diversifiers and non-diversifiers showed that 97.14 and 61.22% of the households perceived that they have infertile land (Table 2).

Factors influencing smallholder farmers decision to crop diversification

This result presented in Table 3 shows that overall, the model is statistically significant at the <0.1 with Wald test Wald χ^2 (18)=231.19, Pseudo R^2=1.0294 and log likelihood=3.3021182, which indicates that the model fulfilled the condition of good fit. Multicollinearity was checked using variance inflation factor (VIF) and the calculated VIF values are all less than ten (the cut-off point), which indicated that multicollinearity is not a problem. A test for normality of CDI was made using Kernel density plot residuals. Was

Table 3 Probit regression estimates for determinants of crop diversifications

Variables	Coeff	Std. err	Marginal effect
Gender	− 0.022	0.026	0.002
Age of household head	− 0.003***	0.001	− 0.003
Family size	0.004	0.004	0.008
labor availability	− 0.003	0.017	0.050
Education level of household head	0.001	0.011	− 0.007
Total livestock unit/TLU	− 0.002	0.002	− 0.005
Farm land size	− 0.442*	0.104	0.254
Number of plots	− 0.007	0.005	0.005
Plot fertility	− 0.119*	0.009	− 0.046
Extension visit	0.086**	0.041	0.081
Access to remittance	0.011	0.018	0.089
Distance to nearest market	− 0.001	0.001	0.006
Distance farmers training center	0.003	0.003	0.006
Distance to farm	0.002	0.003	− 0.012
Number of oxen	0.012	0.008	0.002
Participation in off/non-farm activities	− 0.037**	0.018	− 2.070
_cons	0.856	0.137	− 1.220

LR Chi (18) = 231.19
Number of observations = 383
Prob > Chi^2 = 0.0000
Pseudo R^2 = 1.0294

Significance levels: ***p < 0.01, **p < 0.05, *p < 0.1
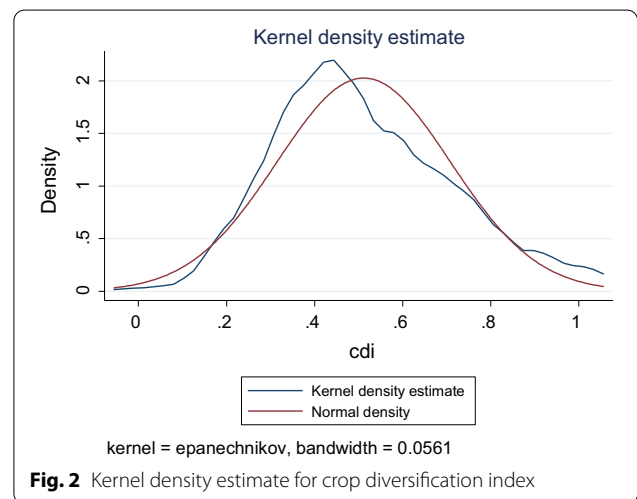
Fig. 2 Kernel density estimate for crop diversification index

completed the usage of the kernel density plot of residuals. The kernel density plot supplied a reasonably clean curve that closely resembles a normally distributed curve, indicating that the normality assumption was not violated (Fig. 2).

The coefficient of age of household head is negative and significant at 1%, indicating an inverse relationship between age of household head and decision to crop diversification. The result indicates that a 1-year increase in age of household reduces the probability of crop diversification by 0.3%. Elderly farmers were less likely to participate in crop diversification and probably are engaging only in food crop production. The reason is that older farmers cannot manage the farm properly and usually rely on old farming systems. This agrees with the findings of Ojo et al. (2014) and Lighton et al. (2016), who also found that a farmer's risk-bearing ability reduces as his/her age increases.

Farm size has a negative significant effect on probability of crop diversification at 10% level of significance. The negative impact of farm size suggests that farmers with relatively small farm practice crop diversification than large farms. This is in agreement with our hypothesis formulated regarding the relationship between crop diversification and land holding size of the household. This implies that probably because sizable farm land demands more management skill, inputs and draft power, households may not be able to produce multiple crops. On average, each additional hectare of land decreases the probability of farmer crop diversification by 25.4%. Similar to this, studies by Assefa and Gezahegn (2010) found a similar result.

Plot fertility is negative and significant at $p < 0.1$, reflecting that holding of infertile plot decrease probability of crop diversification. The study further revealed farmers with access to fertile farm plots are 4.60% less likely to diversify their agricultural production than farmers who have access to fertile agricultural land. The negative coefficient for the fertile plots owned and operated by a household indicates that households with fertile farm plots are less likely to diversify by growing different crops. We surmise that if the soils are productive, the farmer will have more cropping options and is probably to participate in more than one crop enterprise on the farm. Farmers with low soil fertility farms are more likely to adopt diversified crop rotations as they have been shown to contribute to higher and more stable net farm income when compared to traditional monoculture, which over extended periods of time, has shown evidence of degradation of soil quality and reduced crop productivity (Clark 2004).

It appears a positive and significant relationship between frequency of extension contacts per year and crop diversification and the coefficient is significant at < 0.05. This might be associated with the extension system, which is focused on enhancing farmers' productivity and profitability. Extension service providers favor crop diversification at the micro level and are generally aware

Table 4 Truncated regression estimates for determinants of level of crop diversification

Variables	Coeff	Std. err	Marginal effect
Gender	0.009	0.256	− 0.019
Age of household head	− 0.011	0.009	− 0.003
Household size	0.033	0.042	0.008
labor availability	0.217	0.152	0.025
Education level of household head	− 0.029	0.107	− 0.004
Total livestock unit/TLU	− 0.023*	0.024	− 0.004
Farm land size	1.097***	0.637	0.209
Number of plots	0.022	0.050	− 0.002
Plot fertility	− 0.200**	0.102	0.073
Extension visit	0.385**	0.184	0.048
Distance to nearest market	0.024*	0.009	0.002
Distance FTC	0.026	0.030	0.005
Distance to farm	− 0.053**	0.028	− 0.005
Total annual income	0.013*	0.07	0.010
Number of oxen	0.007	0.081	0.010
Access to remittance	0.343***	0.183	0.048
_cons	− 1.249	1.025	

Significance levels: ***p < 0.01, **p < 0.05, *p < 0.1

of the role of crop diversification in risk minimization. We found that access to extension services increases the probability of a farmer's participation in crop diversification by 50.36%. The result is consistent with the findings of Mesfin et al. (2011), Rehima et al. (2013), Sisay (2016) and Asante et al. (2017), where a positive relationship was found between probability of crop diversification of the household and their access to extension services.

Participation in off/non-farm activities negatively and significantly affects probability of crop diversification at 5% probability level. In those households that participated in off/non-farm activities, the likelihoods of farmers participating in crop diversification decreases by 200.70%. The plausible explanation is that if a household receives income from off-farm work, it is less likely to pursue crop diversification as a method of reducing financial risk associated with farming (Sandretto et al. 2004). This finding is similar with findings of Lighton and Emmanuel (2016) and Dessie et al. (2019), who also found out that off-farm income had a significant and negative effect on crop diversification.

Factors influencing the extent of crop diversification

Ceteris paribus, the statistically significant variables allude to an increase or decrease in the extent of crop diversification, subject to the sign of the relevant parameter estimate (see Table 4). The key factors affecting the level of crop

diversification that reveal statistical significance at $p < 0.01$ include farm land size, plot fertility, extension visits, distance to nearest market, distance to farm, and total annual income.

As expected, gender of household head affected the level of crop diversification positively and but insignificantly. The finding indicates that households headed by women grow more diverse varieties of crops than household headed by male. These study results is in agreement with findings by Assefa et al. (2022) in which they reported a positive relationship between higher crop diversity on women-managed farmlands than men-managed farmlands.

The coefficient of livestock ownership is negative and significant at 10% indicating an inverse relationship between livestock ownership and extent of crop diversification. The results indicate that a one unit increase in TLU among rural households decreased the level of crop diversification by 0.4%. The explanation for the result is that livestock as a measure of wealth may act as insurance against crop production risk, bearing a negative relationship with crop diversification. So, households with large number of livestock are less likely to grow more crops. The result is consistent with the findings of Benin et al. (2004), but in contrast to that of Fetien et al. (2009).

The amount of land owned by the farmer has a positive and significant effect on the extent of crop diversification at 1% level of significance. This indicates that an addition of one hectare of land increases the extent of diversification by 20.9%. This implies that large farm size may enable households to allot their land for multiple crops, thereby, minimize income, production and price risks than small land holders. The result supports the finding of Benin et al. (2004), Fetien et al. (2009), Rehima et al. (2013). They found a positive relationship between the level of crop diversification and total farm size in their respective studies.

The coefficient of fertile plot/plot fertility has significantly and negatively affected extent of crop diversification at 5% level of significance. Households that had access to fertile farm plots decreased their levels of diversification by 7.30%. This implies that fertile land is promising to increase production and yield, and the households might have motivated to produce a more profitable crop because they can easily increase production and yield levels. This is consistent with the findings of Rehima et al. (2013) and Lighton and Emmanuel (2016), who also found that a fertile plot had a significant and negative effect on crop diversification.

Extension service (frequency of contacts) has positively and significantly affected the extent of crop diversification practice at 5% level of significance. This implies that extension workers have an important role to play in creating awareness among farmers as well as educating them on the importance of diversification. A household who had more frequency of extension contact during the cropping period increased probability of being engaged in crop diversification practice by 4.80%. This finding is consistent with the research results of Ibrahim et al. (2009) and Rehima et al. (2013).

The coefficient of walking distance from residence to the nearest market significantly and positively affected extent of crop diversification at less than 5% significance level. An increase in one minute to walk to the nearest market increased the extent of crop diversification of households by 0.2%. The possible explanation is that the households that have poor market access are more likely to rely on diversification to meet their consumption needs and to avoid transaction costs. The finding concurs with Alpízar (2007), Rehima et al. (2013) and Dessie et al. (2019) indicating a household far from a market was positively related to crop and variety diversification.

Walking distance from residence to the farm plot significantly and negatively affected extent of crop diversification at less than 5% level of significance. As walking to the farm plot increases by a minute, the extent of crop diversification of households decreased by 0.50%. This justifies that in terms of time, labor, safety and management, households may prefer to diversify their crop on the nearest farm. This finding is similar with the finding of Benin et al. (2004) and Sichoongwe et al. (2014), who indicated households living farther from their farms manage fewer crop diversity.

The coefficient of total annual income positively and significantly affected extent of crop diversification at less than 10% level of significance. We found out that a 1 Birr increase in income increased the extent of crop diversification by 1.00%. This implies that higher incomes allow farmers to have access to critical productive resources such farm assets, inputs, and land, which increase the extent of crop diversification. The extra income earned by farmers from one crop is also important in providing financial resources that are used for diversification into other crops. Similar studies by Bonham et al. (2012), Rehima et al. (2015) and Basantaray and Nancharaiah (2017) indicated that crop diversification is strongly associated with higher farm income.

Conclusion and recommendations

The objective of this study was to analyze crop diversification among wheat-dominant producer rural households. Crop diversification was measured by Herfindahl–Hirschman Index, while double hurdle model was used to identify probability and extent of crop diversification in study area. The study found that the average CDI of sampled households was 41.28%. The results also revealed that age of household

head and participation in off/non-farm activities negatively influence probability of crop diversification, while household size, access to fertile plots of land, and access to extension services positively influence probability of crop diversification in study area. The results further showed that farm land size, extension visit, distance to nearest market, total annual income, and access to remittance positively influence extent of crop diversification. In contrast, distance to farm plots, access to fertile plots of land, and TLU negatively affect extent of crop diversification in study area. In this study it can be synthesized that wheat farming households asserted that they hope with the incomes from wheat they can procure pulses and other food items. However, one critical factor which needs further reflection relates to the over exploitation of the environment to support preserving wheat farming and access to market in such a remote area. Mitigation of this risk requires the improvement of market and other infrastructure among other strategies to enhance crop diversification.

Access to extension services significantly and positively affect likelihoods of crop diversification practices. Given the positive effects of access to extension services on crop diversification, there is now a strong need to strengthening available extension packages to help smallholder farmers improve probability of crop diversifications. Hence, the local government should arrange experience-sharing and short-term training programs so as to share the rich knowledge to inexperienced farmers.

Membership to farmers' cooperatives significantly and positively affect extent of crop diversification practices. Thus, we recommend that efforts must be made to strengthen the role of farmers' cooperatives in information dissemination, farmer-to-farmer extension, and smallholder farmers' access to markets and their bargaining power for higher producer prices.

Labor availability positively and significantly affects likelihoods of crop diversification. The results also indicated that the availability of labor positively and significantly affects the probability of crop diversification in the study area. The results suggested that policy and strategy makers should consider availability of labor force before introducing labor-intensive technology in other similar agro-ecology areas of the country. As the same time, regional and local governments should encourage the use of labor-saving technologies in diversified farming systems.

To this end, the findings suggest that policies that target achieving food and nutritional gains should focus on promoting crop diversification to improve the quality and variety of the products from own farming. These needs supporting farmers through subsidy and providing access to reliable price information and inputs. Integrating diversification strategies into the extension system of the country could also

help promote diverse production systems that feature cereals, cash crops, and legumes.

The study did not consider crop production efficiency nor the role of PSNP in crop diversification. Future research should focus on understanding the association that exists between crop diversification and household crop production efficiency that could impede productivity. To address this knowledge gap, further research is needed to determine the optimum number and combination of crops and income that the household can efficiently manage without compromising the benefits of crop diversification. Further, we would like to acknowledge that this study did not collect the role of PSNP on household crop diversification. This limit our analysis and inference cannot be made about contribution of PSNP to household crop diversification. Given the importance of crop diversification, it is crucial to examine how PSNP helped to transform livelihoods through crop diversification and make beneficiaries resilient in the face of shocks. In this case, it is important to analyze whether the transfer of resources in the form of food, cash, or both has a role on the crop diversification of households, which in turn relates to their ability to improve their food security status.

Appendix

See Table 5.

Table 5 Collinearity statistics for variables in the double hurdle model

Variable	VIF	1/VIF
Oxen	2.31	0.433
TLU	2.27	0.440
Land size	2.26	0.443
Access to remittance	1.82	0.551
Total annual income	1.76	0.569
Number of plots	1.72	0.582
Participation in non/off farm	1.64	0.608
Household size	1.50	0.666
Member to farmer cooperatives	1.50	0.667
Distance to nearest market	1.49	0.671
Age of household head	1.45	0.692
Access to irrigation farm	1.35	0.738
Distance to farm	1.27	0.790
Labor Availability	1.26	0.791
Extension visit	1.17	0.857
Access to credit	1.15	0.871
Sex of household head	1.12	0.895
Mean VIF	1.59	

Availability of data and materials
The authors want to declare that they can submit the data at whatever time based on your request. The datasets used and/or analyzed during the current study will be available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
The researchers have obtained a support letter from Addis Ababa University. The letter was submitted to Bale Zone Agriculture and Natural Resource Office and obtained consent. Then, the zonal offices have written an official letter to Sinana District Agriculture and Natural Resource Office where the study was conducted. Informed consents were also obtained from the households, discussants, and informants before data collection in conformity with anonymity of the study participant.

Consent for publication
Not applicable.

Competing interests
The authors declare they have no competing interests.

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