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Crop diversification analysis on red pepper dominated smallholder farming system: evidence from northwest Ethiopia

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Abstract

Background: Ethiopia is the homeland of various crops due to its diverse and suitable agro-ecological zones. As a result, smallholder farmers grow multiple crops on a small piece of land both for consumption and commercial purposes in different portions of Ethiopia, including the northwestern part of the country. However, crop diversification status and extent of farmers were not well understood. Therefore, this study examined determinants of crop diversification in a pepper-dominated smallholder farming system in northwest Ethiopia.

Methods: Primary data was collected through a semi-structured interview schedule administered on 385 crop producers selected using a systematic random sampling technique. Moreover, the survey was supplemented by using secondary data, focus group discussions, and key informant interviews. Methods such as the descriptive, inferential statistics, and econometrics model were used for analyzing the data.

Results: The average crop diversification index was 0.77, and most smallholder farmers (92.46%) used crop diversification as a strategy for risk reduction, nutritional improvement, consumption, and commercial needs. Moreover, the Tobit model result revealed that the status and intensity of crop diversification were significantly influenced by farmland, sex, age, land fragmentation, distance to development center, market distance, and non-/ off-farm income participation.

Conclusion: Generally, most farm households used crop diversification as a norm and best strategy for minimizing risk, income source, nutritional and livelihood improvement. Therefore, crop producers, agricultural experts, the Ethiopian government, and partner organizations should give special attention to extension service, market, and infrastructure development to enhance the role of agricultural diversification for households.

Keywords: Crop diversification, Herfindahl index, Household, Tobit model, Ethiopia

Background

In most African countries, agricultural sectors are highly dependent on rain and influenced by climate change and variability such as seasonal dynamics, drought, high temperatures, very low humidity and precipitation. Consequently, low crop yields, lessening soil fertility, high environmental degradation, and augmented agricultural risks are some of the key challenges, which continue to threaten household's food security status (Makate et al. 2016).

In many developing countries including Ethiopia, most smallholder farmers struggle to attain nutritional and food security and poverty alleviation through agricultural diversification (FAO 2012; Michler and Josephson 2017). Hence, Johnston et al. (1995) and Mussema et al. (2015) defined agricultural diversification as the way of farmers growing more than one crop on a given piece of land in any year to reduce vulnerability, marketing risks, and income and biological instability. Diversification is common in every society (Barrett et al. 2001); however, its extent and effect vary from region to region and household to household within the same area (Escobal, 2001). The increasing risks of crop failure due to erratic rainfall and crop disease continue to force farmers to diversify

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their enterprise as a hedge against these risks (Acharya et al. 2012). An increment of agricultural diversification also decreased the likelihood of poor households to become below the poverty line and increased the likelihood of non-poor households to fall into poverty (Michler and Josephson 2017). Therefore, crop diversification plays a vital role in a farmer's decision-making process so as to minimize the risk of agricultural production (Davis and Schirmer 1987).

Many studies also indicated that agricultural diversification has a multiple advantages for most smallholder farmers and the functioning of ecosystems by mitigation of agricultural losses to pests and wildlife (Bommarco et al. 2013; Chaplin et al. 2011) and improving soil fertility (Lin 2011; McDaniel et al. 2014; Tiemann et al. 2015) and biodiversity (Schulte et al. 2017; Tscharntke et al. 2005), and brings about yield stability and nutrition diversity (Lin 2011). Acharya (2011) also asserted that agricultural diversification has a great role in striving for food security. Likewise, agricultural diversification plays a vital role in economic growth by enhancing productivity, household incomes, improving soil health (through crop rotation and nitrogen fixation), and sustainable intensification of agriculture (Mussema et al. 2015).

Michler and Josephson (2017) revealed that crop diversification is the best strategy for households as a source of income, risk reduction, and poverty alleviation. Crop diversification can also increase absolute yields and yield stability for a number of crops and thus increase household income (Abson et al. 2013; Demissie and Legesse 2013; Makate et al. 2016; Njeru 2016). However, Burchfield and de la Poterie (2018) found that many farmers are not willing and able to diversify an enterprise because of the nature of their fields, elevation, soil quality, irrigation infrastructure, and relative position within an irrigation system. Likewise, the unsuitability of the local environmental condition is the main factor which prevented farmers from crop diversification (McDaniel et al. 2014).

Moreover, Ashfaq et al. (2008) revealed that crop diversification levels were influenced by various socioeconomic and institutional factors such as land size, age, education, farming experience, and off-farm income of the farmer, the distance of the farm from the main road and from the main market, and farm machinery ownership. Nuru and Seebens (2008) also found that proximity to a town, access to road, education, liquid wealth, and irrigation access as the significant factors affected crop choices in northern Ethiopia. Furthermore, Mussema et al. (2015) confirmed that crop diversification decisions of the households were significantly influenced by land size, income from sale of grain, walking time to the farm, distance from the district, access to be all-weather, market information, extension service, proportion fertile plots, and number of plots.

In Ethiopia, almost all smallholder farmers depend on the rising and growing of different types of enterprises on a given farming land for their nutritional and livelihood improvement. Farmers in general involved in a variety of enterprises, particularly diversifying crops and livestock. Unlike in commercial farming systems, farmers in subsistence farming used crop diversification as methods for reducing vulnerability, marketing risks, income instability, and food insecurity by cultivating varieties of crops on a given piece of land. Despite agriculture is the main source of livelihood for most Ethiopian smallholder farmers, not much work has been done in northwestern Ethiopia on what factors determine smallholder farmer's decision and extent to diversify their enterprise to maximize their profit and minimize the risk of crop failures. Hence, based on the above statement, the study was intended to empirically answer the following key question: what factors affect the decision and extent of crop diversification by smallholder farmers? The findings of this study can reduce the information gap on agricultural diversification and contributing to work better on production to improve nutrition, income stability, food security, and poverty reduction for most smallholder farmers.
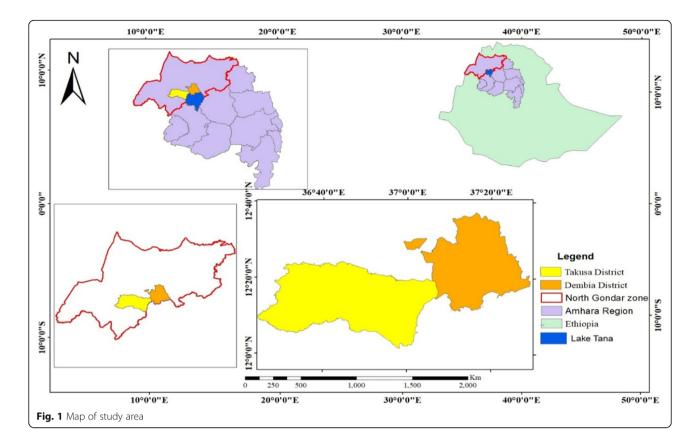
Methods

Description of study area

The study was conducted in North Gondar Zone, Amhara region of Ethiopia. The zone is located in the northwest of Ethiopia and 738 km far from the capital city of the country. The capital city of the zone is Gondar City which located at 12° 35′ 60.00′′ N latitude and 37° 28′ 0.01′′ E longitudes with a mean altitude of 2133 masl. In the zone, the main sources of livelihood for households are crop production, vegetable production, animal production, beekeeping, and spice production particularly pepper, ginger, white, and black cumin. The low land of the zone is dominated by semi-arid natural forests. In the zone, 51% and 49% of the population are men and women, respectively (Dessie et al. 2019; Abate et al. 2019). The survey was done in the 2018 crop season on two large pepper dominated districts specifically, Takusa and Dembia (Fig. 1).

Data collection

A combination of quantitative and qualitative data was collected from both primary and secondary sources. Primary data was collected from crop producers through a semi-structured interview and key informant's interviews. Moreover, to enrich the investigation, secondary data was collected from records of administrative offices, published and unpublished reports, journals, books, websites, and other sources relevant in this study. The interview schedule which consists of semi-structured questions was prepared in English and translated into local language to collect

Fig. 1 Map of study area

information on socio-economic, demographic and institutional characteristics of households. Furthermore, it was pre-tested, and the necessary amendments were made before the actual survey. The semistructured interviews were administered on 385 sample producers, which was the main source of a data-collection tool in the research work.

Sampling design
In order to select the sampled respondents, a multi-stage sampling technique was employed. In the first-stage, Takusa and Dembia Districts were selected purposively due to high potentials of diversified crop production both for consumption and commercial purpose. In the second stage, eight kebeles/villages with largest crop diversification, namely, Mekonta, Chemera, Banbaro, Deber-zuria, Guramba Michael, Arebia, Achera, and Gebaba-salge were purposively selected in consultation with District Agriculture office experts due to the high potentials of crop production and best smallholder farming experience in crop diversification. In the third stage, 385 sampled crop producers were selected by using simple random sampling technique following a scientific sample size determination formula developed by (Cochran 1977).

$$\left[\frac{Z^2 pq}{e^2}\right] = \frac{1.96^2(0.5*0.5)}{0.05^2} = 385 \tag{1}$$

Where n = sample size; Z = confidence level (Z = 1.96); p = 0.5, q = 1-p and e = 0.05 (error term).

Data analysis
In order to effectively handle and analyze the diverse data collected from the field and producers, a combination of descriptive statistics, inferential statistics, and econometric models was used. Chi-square test was used to assess the association of household and farm-related attributes between groups (diversifier vs. non-diversifier). The t test was also used to assess mean differences between crop diversifier and non-diversifier and continues explanatory variables. Furthermore, to investigate the determinants of producer's decision and extent of crop diversification, Tobit model was used.

Empirical model specification
The extent of crop diversification can be determined by using several indices such as Herfindahl index (HI), Simpson's index (SI), Margalef index (MI), Entropy index (EI), Modified entropy index (MEI), Ogive index (OI), Composite entropy index (CEI), and Berger-Parker index (BPI). These indices have been used by many researchers to estimate the extent of crop diversification

practices of farmers (Sisay 2016; Mussema et al. 2015; Nuru and Seebens 2008; Mesfin, Fufa, and Haji 2011; Benin et al. 2004; Abay, Bjørnstad, and Smale 2009; Ashfaq et al. 2008; Bazaz and Haq 2013; Bittinger 2010; Greene 2012; Acharya et al. 2012; Goshu, Kassa, and Ketema 2012).

However, this study used HI because it is the most commonly used index in many literature of crop diversification (Asante et al. 2018; Kanyua et al. 2013; Sichoongwe et al. 2014; De and Chattopadhyay 2010; Bittinger 2010; Malik and Singh 2002; Sisay 2016). Moreover, Theil (1967) used HI to determine the extent of crop diversification for the first time. Likewise, crop diversification index (CDI) was computed from Herfindahl index to measure the extent of crop diversification for all diversified farmers using a method developed by (Hirschman 1964). Hence, the extent of crop diversification was measured by CDI. The CDI values were obtained by subtracting the HI from 1 and 0 (Eq. 3). Moreover, 0 value of crop diversification index which indicates perfect specialization, and a movement towards 1 shows an increase in the extent of crop diversification (Malik and Singh 2002). Generally, the value of CDI increases with the increase in diversification and assumes 0 value when farmers grow and cultivate only one crop.

In this study, the producers basically produce diversified crops such as red pepper, teff, cumin, barley, wheat, sorghum, chickpea, garlic, finger milt, and maize at a time. To compute the Herfindahl index, the authors used the total cropped land (ha) of diversifiers and the proportion of land allocated for growing each crop (ha) in year 2018 harvested season. HI (the sum of squares of all n proportions) and CDI (1-HI) were computed using the formula developed by (Hirschman 1964) in Eqs. 3 and 4.

$$P_i = \frac{A_i}{\sum_{i=1}^{n} A_i} \tag{2}$$

where, P_i=proportion of ith crop, A_i=Area under i^{th} crop (ha),

$$\sum_{i=1}^{n} A_i = \text{Total cropped land (ha)}, \text{and} \, i = 1, 2, 3 \dots \dots \dots \dots n \, (\text{number of crop}).$$

$$\text{Herfinhal Index} = \text{HI} = \sum_{i=1}^{n} P_i^2 \tag{3}$$

$$\text{Crop diversification index} = \text{CDI} = 1 - \text{HI} \tag{4}$$

Crop diversification studies help to determine both factors influencing the household's decision to diversify and the extent of diversification.

Rajasekharan and Veeraputhran (2002) revealed that unlike the Probit and Logit model, a Tobit regression model is very appropriate to estimate decision and extent/density of tree growing simultaneously. Ideally, the OLS model is applicable if all households participate in all types of crop diversification, but in reality, even in this study, all households did not participate in all types of crop diversification. Hence, using OLS regression was assumed to create a sample selectivity bias because the model excludes the non-participants from the analysis. Therefore, the use of the Tobit model is appropriate because the parameter estimates will be biased and inconsistent if OLS is used. However, to mitigate this bias, the study initially used Heckman two-stage model which is developed by Heckman (1979). Selection bias was tested by including the IMR which was not significant.

Moreover, Tobit model is the most common censored regression model which helps to express the observed level in terms of an underlying latent variable. The use of the Tobit model is intuitive because the parameter estimates will be biased and inconsistent if OLS is used. The degree of bias will also increase as the number of observations that take on the value of 0 increases. The values of the parameter's coefficient from a Tobit model cannot directly give the marginal effects of the explanatory variables on the dependent variable; however, their signs only show the direction of the associations (Gujarati 2012).

However, prior to running the Tobit model, the data were estimated for multi-collinearity using the variance inflation factors and contingency coefficient to diagnose this problem and identified no problem. The parameters of the Tobit model were also estimated by using the maximum likelihood method in Stata version 14 software. The Tobit model can be specified following (Tobin 1958; Long 1997; Cameron and Trivedi 2010; Greene 2012).

$$y_{i=\beta X_i + \varepsilon_i} \tag{5}$$

$$y_i = \begin{cases} y_i^* = \beta X_i + \varepsilon_i & , if \; y_i^* > 0 \; (Diversifiers) \\ 0 & , if \; y_i^* \leq 0 \; (Non\text{-}diversifiers) \end{cases}, i = 1, 2, 3, \dots \dots, n \tag{6}$$

Results and discussion
Socio-economic characteristics of households
The total sample size of respondents handled during the survey was 385. Crop diversification levels of farmers depend on various demographic, institutional, and socio-economic factors. This study depicted that more than three-fourth (80.52%) of producers were crop diversifiers, and the other households (19.48%) were non-diversifier.

The mean age of diversified producers (48.98 years) was higher than the non-diversifier (45.56 years) (Table 1).

Table 1 Mean and proportion of producers' characteristics by crop diversification

Variables	Category	Mean/proportion			t/χ^2 statistics
		Diversifier ($n = 310$)	Non-diversifier ($n = 75$)	Overall	
Age	Years	48.98(10.42)	45.56(10.71)	48.31(10.56)	− 2.536**
Family size	AE	3.67(1.42)	3.63(1.12)	3.66(1.36)	− 0.203
Experience	Years	19.29(11.65)	17.13(12.06)	18.87(11.75)	− 1.429
Livestock owned	TLU	6.78(5.01)	6.67(10.49)	8.87(46.09)	− 0.132
Total land size	ha	1.86(0.80)	1.33(0.897)	1.764(0.849)	− 5.093***
Distance to nearest market	Km	5.69(5.19)	3.01(3.54)	5.17(5.02)	− 0.583
Distance to development center	km	2.49(2.89)	2.69(2.36)	2.54(2.79)	0.550
Sex	Male	300(77.92)	67 (17.40)	367(95.32)	7.502***
	Female	10(2.60)	8(2.08)	18(4.68)	
Off/on–farm income	Yes	127(32.99)	34(8.83)	161(41.82)	0.473
	No	183(47.53)	41(10.65)	224(58.18)	
Market information	Yes	206(53.51)	39(10.13)	245(63.64)	5.450**
	No	104(27.01)	36(9.35)	140(36.36)	
Extension access	Yes	246(63.90)	56(14.55)	302(78.44)	0.785
	No	64(16.62)	19(4.94)	83(21.26)	
Credit access	Yes	188(48.83)	48(12.47)	236(61.30)	0.286
	No	122(31.69)	27(7.01)	149(38.70)	
Literacy status	Literate	163(42.34)	36(9.35)	199(51.69)	
	Cannot read and write	147(38.18)	39(10.13)	186(48.31)	1.484

***, **, and *significant at 1, 5, and 10% level respectively. Results in parenthesis are percentage or standard deviation

The result of *t* test indicates that age was statistically significant at 5% significance level. This implies that as compared to younger households, older households grow a variety of crops on a given piece of land due to their best farming experience. This finding is in line with previous studies (Asante et al. 2018; Lemi 2009; Enete and Igbokwe 2009).
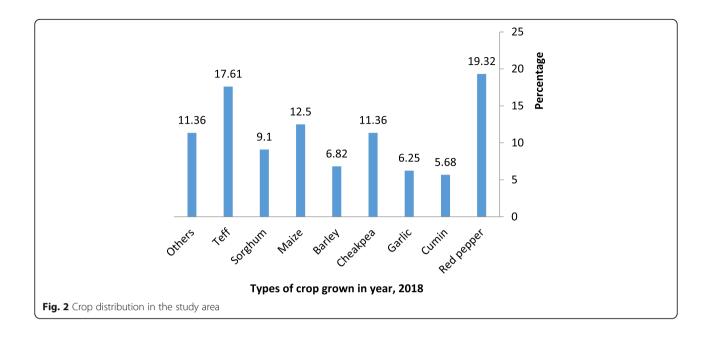
In Ethiopia, the mean landholding size of farmer at the country level is 1.02 ha per household (Teshome, 2014). However, mean landholding size of farmer varies across different portions of Ethiopia. For instance, the mean landholding size of household in the study area is 1.76 ha per household. In the study area, the mean farming land of diversifier household (1.86 ha per household) was higher than non-diversifier (1.33 ha per household) (Table 1). The result of *t* test indicates that total farming land size of farmers was statistically significant at 1% significance level. This means total farming land of households had a direct contribution to growing a variety of crops for livelihood's improvement through income and crop diversification. This result is consistent with Asante et al. 2018; Mussema et al. 2015; Huang et al. 2014; Kanyua et al. 2013; Sichoongwe et al. 2014; Mekuria and Mekonnen 2018, who reported that the practice of crop diversification increased with total farmland. Moreover, 77.92% and 17.40% of male-headed producers were diversifiers and non-diversifiers,

respectively. The result of chi-square test shows that sex was statistically significant at 1% significance level. This implies that as compared to female-headed, male-headed households can grow multiple crops on a given piece of land due to inequality of having and accessing of factors of production. This finding confirmed with the results of previous studies (Demissie and Legesse, 2013 and Lemi, 2009).

Furthermore, 53.51% and 10.13% of diversifier and non-diversifier were accessed market information, respectively. On the other hand, 27.01% and 9.35% of diversifier and non-diversifiers were not accessed market information, respectively. The result of chi-square test indicates market information was statistically significant at 5% significance level. This implies that market information can decrease the uncertainty of the producers associated with crop diversification. These findings are consistent with previous studies (Mesfin, Fufa, and Haji 2011; Mussema et al. 2015).

Household's land allocation for growing diversified crops
The survey result presented in Fig. 2 revealed that producers allocated their total land for growing various crops such as red pepper production (19.32%), teff (17.61%), maize (12.5%), chickpea (11.36%), sorghum (9.10%), barley (6.82%), garlic (6.25%), cumin (5.68%), and other crops (11.36%). This implies most producers

Fig. 2 Crop distribution in the study area

practiced and used crop diversification as a strategy for risk minimization and income diversification, which in turn reduced food insecurity and poverty status of most rural households. This finding is in line with the previous studies (Lemi 2009; Sisay 2016; Mekuria and Mekonnen 2018). Furthermore, households with large landholding willing and able to grow a diverse set of crops reduce the probability to fall into poverty (Michler and Josephson 2017).
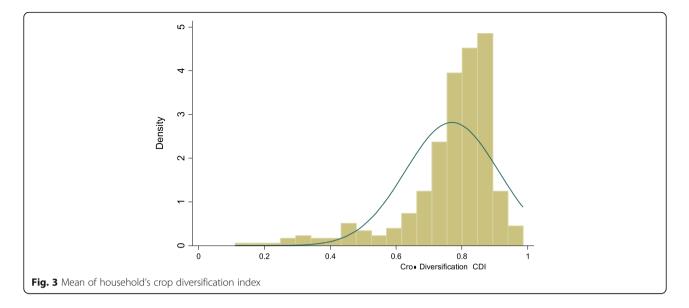
The distribution of crop diversification index

The result presented in Fig. 3 indicated that the mean crop diversification index was 0.769 with a standard deviation of 0.142. This implied there are high levels of crop diversification among farmers. Hence, the mean index in this study was almost comparable with the findings of Mekuria and Mekonnen 2018 and Asante et al. 2018 who found 0.57 and 0.59 in highland of Ethiopia and Ghana, respectively. Figure 3 also depicted that the crop diversification index was normally distributed and moderately skewed to the right suggesting that most households were crop diversifier. It also revealed that 92.46% of the households having indices 0.5 and above suggest a high level of crop diversification among farmers. This study, in line with Mekuria and Mekonnen 2018, confirmed that more than three-fourth (79%) of households had an index of 0.5 and above. Moreover, the estimated crop diversification index was statistically significant among diversifiers at 1% significant level. Michler and Josephson (2017) also confirmed that a 10% increment of crop diversification index decreases the probability of being poor by 17.5%.

Determinants of crop diversification: estimated through Tobit model

The results of the Tobit model are presented in Table 2. The test for multicolinearity revealed that there was no multicollinearity among the explanatory variables. The chi-square of the Tobit regression model indicates that the overall goodness of fit of the model and it was statistically significant at 1% probability level. The model results also indicated that all the significant explanatory variables, which affected the probability of households' decision and extent of crop diversification. The model output suggested that variables such as the size of farmland, sex, age, land fragmentation, distance to development center, market distance, and non-/off-farm income participation were the major factors that significantly affected decision and extent of crop diversification simultaneously.

The findings of this study revealed that size of farm landholding affected crop diversification decision and extent of the households positively and significantly at 1% level of significance. As the size of farm landholding increases by one hectare, the probability of a farmer to participate in crop diversification and the numbers of crops a farmer will grow increase by 11% and 3%, respectively. This implies that large farm landholding may allow households to allot their land to grow a variety of cereal crops than smaller farm landholders. This finding, in line with the previous studies, revealed that land size positively and significantly affected crop diversification (Benin et al. 2004; Ashfaq et al. 2008; Abay, Bjørnstad, and Smale 2009; Bonham et al. 2012). This result is also consistent with recent findings (Makate et al. 2016; Mussema et al. 2015; Kanyua et al. 2013; Sichoongwe 2014; Huang et al. 2014) reporting that an increase in the

Fig. 3 Mean of household's crop diversification index

availability of farmland leads farmers to practice crop diversification.

Sex of household positively and significantly affected crop diversification decisions and extent at 10% and 1% level of significance, respectively. As compared to female-headed households, in the male-headed households the probability to participate in crop diversification activities and the number of crops a farmer grow increase by 15% and 3%, respectively. This implies male-headed households are risk-takers, hold more resource, and more likely to grow multiple crops for improving their family livelihoods than female-headed. This finding is consistent with the finding of Abay, Bjørnstad, and Smale ([2009]) who reported that unlike female-headed,

Table 2 Tobit regression result on status and intensity of crop diversification

Variables	Coefficient	Std. Err.	t value	Probability coefficient	Intensity coefficient
Age of household (year)	0.001[***]	0.0004	2.59	0.002[***]	0.0008[***]
Sex (1 = male, 0 otherwise)	0.05[**]	0.02	2.46	0.15[*]	0.03[***]
Literacy status (1 = literate, 0 otherwise)	0.01	0.007	1.39	0.03	0.007
Farm experience (year)	− 0.0005	0.0004	− 1.29	− 0.001	− 0.0003
Family size (AE)	− 0.004	0.003	− 1.29	− 0.01	− 0.003
Land size	0.05[***]	0.005	9.39	0.11[***]	0.03[***]
Livestock holding (TLU)	− 0.00001	0.00001	− 0.77	− 0.00003	− 9.65e-06
Fragmentation (number)	− 0.02[***]	0.005	− 4.45	− 0.06[***]	− 0.02[***]
Fertility of soil ((1 = fertile, 0 otherwise)	− 0.003	0.011	− 0.29	− 0.01	− 0.002
Distance to development center (km)	− 0.002[*]	0.001	− 1.76	− 0.005[*]	− 0.002[*]
Access to extension(1 = yes, 0 otherwise)	− 0.02	0.010	− 1.42	− 0.03	− 0.01
Access to credit ((1 = yes, 0 otherwise)	− 0.007	0.008	− 0.94	− 0.02	− 0.005
Market information (1 = yes, 0 otherwise)	0.005	0.009	0.60	0.01	0.004
Market distance (km)	0.003	0.0008	3.46	0.01[***]	0.002[***]
Cooperative membership (1 = yes, 0 otherwise)	0.007	0.008	0.92	0.02	0.005
Participation of off income (1 = yes, 0 otherwise)	− 0.03	0.008	− 3.86	− 0.07[***]	− 0.02[***]
Constant	0.68	0.028	24.26		
	Number of obs = 385 LR chi^2(16) = 149.52[***] Pseudo R^2 = − 0.3166 Log likelihood = 310.92				

Dependent variable = decision and extent of crop diversification
***, **, and * show the value statistically significant at 1%, 5%, and 10% level, respectively

male-headed households positively and significantly affected the barley variety diversification in Ethiopia. Asante et al. 2018 also confirmed that male-headed households were more inclined to increase the extent of diversifying than female farmers. Likewise, Demissie and Legesse (2013) stated that due to cultural, religious, and financial constraints, female-headed households had fewer roles in income diversification. Moreover, Lemi (2009) revealed that large dependents and female-headed characterized poor farm households in rural Ethiopia. Furthermore, Shezongo-Macmillan (2005) revealed that as compared to male-headed household, female-headed households were less responded to crop diversification in Zambia due to inequality of having and accessing of resources. However, studies (Rehima and Dawit 2012; Rehima et al. 2013; Sisay 2016) indicated that female-headed households positively affected the probability of crop diversification.

Walking distance from residence to the development center is a proxy variable of extension service and significantly and negatively affected crop diversification decision and intensity of farmers at 10% levels of significance. The results showed that as the walking distance to the development centers increases by 1 km, the likelihood of a farmer to participate in crop diversification and the number of crops a farmer will grow decrease by 0.5% and 0.2 %, respectively. This implies farmers who are far away from development centers incurred high transportation costs, poor access of extension advice and input supplies such as improved seeds, fertilizers, and farming tools. As a result, the extent of crop diversification and production for commercial purposes declines. This result is consistent with the previous finding of Sisay (2016) who reported that the walking distance from residence to the development center negatively and significantly affected the decision and extent of crop diversification.

Distance from the market has a positive and significant effect on crop diversification at 1% significance level. The results of this study showed that an increase of a 1 km walking distance to the market leads to increase the likelihood of households participating in crop diversification by 1% and the number of crops a farmer will grow also increase by 0.2%. This implies farmers who were far from the market incurred higher transaction costs for getting information, technology, and industrial consumable goods and services. As a result, the household's decision and intensity of crop diversification increase to meet and improve their family consumption and nutritional needs. The result also implies those farmers who are close to urban market tend to allocate more farmland for the production of cash and commercial crops while those who are far away from a market tend to allot much of their farmland for the production of staple (non-cash) crops for consumption and subsistence purpose. This finding, in

line with the findings of recent studies (Mussema et al. 2015; Sichoongwe et al. 2014; Ibrahim et al. 2009; Nuru and Seebens 2008), revealed that market distance had a positive and significance effect on household's crop diversification decision and extents because they entirely produced staple crops for the purpose of family consumption. Likewise, Kankwamba, Mapila, and Pauw (2012) stated that farmers located far away from markets are found to diversify crops to meet their wide subsistence and nutritional needs. However, some studies indicated that market distance negatively and significantly influenced crop diversification (Sisay 2016).

The age of households was positively and significantly associated with the decision and intensity of crop diversification at 1% significance level. As an additional year added to the age of the household head, the likelihood to participate in crop diversification activities and the number of crops a farmer will grow increased by 0.2% and 0.08%, respectively. This implies older farmers can reduce production adversity by growing multiple crops on a given piece of land, and their decision and intensity of crop diversification were also determined by their past production experience. This result confirmed with the findings of Asante et al. (2018) and Lemi (2009) who revealed that age of households positively and significantly affected crop diversification. Likewise, Enete and Igbokwe (2009) also confirmed that older households were more likely to produce and sell various crops.

Land fragmentation affected negatively and significantly households' decision and intensity of crop diversification at 1% significance level. An addition of one plot led to decrease the likelihood of households participating in crop diversification by 6%, and the number of crops a farmer will grow also decreased by 2%. This implies that farmers who operate on a different number of farm plots maintained lower crop diversity, perhaps due to similar soil and agro-ecological zone among plots, which lead to growing similar and high-value crops either for consumption or commercial purposes across different plots. The findings of this study are in line with a recent study of Sisay (2016) who stated that the numbers of fragmented land had a negative and significant effect on crop diversification. However, inconsistent to this finding, some previous studies showed that the number of fragmented land and fragmentation index positively affected agricultural diversification (Abay, Bjørnstad, and Smale 2009; Mussema et al. 2015; Mesfin, Fufa, and Haji 2011; Rehima et al. 2013; Nagarajan, Smale, and Glewwe 2007).

The coefficient for household participation in off-/non-farm income activities negatively and significantly affected the probability and intensity of crop diversification at 1% level of significance. In those households that participated in off-/non-farm activities, the likelihood of farmer's participating in crop diversification and the numbers of crops grow by farmers decrease by 7% and

2%, respectively. The result suggests that participation on off-/non-farm income activities provide as a source of income to households and their livelihoods as a result negatively contributed to the practice of crop diversification. However, Asante et al. (2018) revealed that off-farm income had a positive and significant effect on the crop–livestock diversification.

Conclusion and recommendations
The diversified farming system remains a source of income, risk reduction strategy, and means to improve the livelihoods of households in northwestern Ethiopia. Crop diversification strategy also plays a significant role in households particularly on the source of income and a means for nutritional improvement. It is also used as a mechanism of risk reduction strategy to obtain food and income from multiple crop sources. However, various socio-economic, demographic, and institutional factors influenced the household's decision and intensity of crop diversification. Our results revealed that the majority of smallholder farmers (92%) has a crop diversification index of above 0.5, and the average crop diversification index was 0.769 implying high levels of crop diversification. The results of inferential statistics such as chi-square and *t* test revealed that various socio-economic parameters such as age, sex, market information, and farmland size were had a significant association and mean difference between groups. Moreover, the result of Tobit regression model indicated that various policy-relevant variables such as age, sex, land size, distance to development center, market distance, and land fragmentation had a significant influence on the status and extent of crop diversification simultaneously. For instance, an older male headed household has more resource and farming experience in crop diversification. Likewise, the smallholder farmer's status and intensity of crop diversification was found to increase with more farm land owned and near market distance. However, it was declined with more land fragmentation and participation in off-/non-farm activities due to similar agro-ecological zone and high contribution of off-/non-farm activities on enhancing household's income source. Given the potential and significant role of crop diversification to improve the livelihood of most smallholder farmers, the following implication has given to the development of the practice of crop diversification strategy. In most developing countries, smallholder farmers provide and supply food for most country citizens. Therefore, the government should consider and undertake policies that will improve smallholder farmers' access to and control over land because it allows farmers to grow multiple crops for the purpose of enhancing food and nutrition security status and poverty reduction. As the farmers who are far away from markets, they are willing and able to diversify crops for nutritional and consumption purposes. If markets are brought closer to farmer, they will diversify crops for commercial purposes. It implies that the ability of households to adopt new agricultural technology such as crop varieties and inorganic fertilizers are related to the market. Hence, the government should facilitate and improve the markets and road infrastructure by bringing closer to the farmers. Moreover, in most developing countries including Ethiopian, the resources are mainly undertaken by male-headed farm households. Therefore, there should be policies that enhance the equitable distribution of resources and involvement of female-headed farm households in crop diversification strategy. Generally, this study provides information on why, how, and what smallholder farmers diversify on agricultural fields. Likewise, the information generated could help a number of organizations including research and development organizations, academicians, traders, producers, policy-makers, extension service providers, government, and non-governmental organizations to assess their activities and redesign their mode of operations and ultimately influence the design and implementation of policies and strategies on agricultural sectors. Further research should be conduct on the impacts of livelihood diversification strategies on household's food security status.

enumerators, the supervisors, and key informants were fully informed of the objectives of the study. They were approached friendly in free moods until the end of this research

Consent for publication

Not applicable

Competing interests

The authors declare that they have no competing interests.

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