Interdependence of producers' adoption decision of agronomic Practices in maize production; evidence from northwest Ethiopia

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Abstract

Background: Ethiopia is one of the third largest maize producing country in Africa. In the country, maize is an essential cereal crop which produced by smallholder farmers both for consumption and commercial purpose. Nevertheless, inability to use most recent agricultural technologies marks low production and productivity of cereal crops in general and maize crop in particular in the study area. Therefore, this research was designed to assess adoption of latest agricultural practices on maize production in northwest Ethiopia.

Methods: Both qualitative and quantitative data were collected using a semi-structured questionnaire administered on 385 maize producers' selected using systematic random sampling technique. Combinations of data analysis methods such as descriptive statistics and multivariate probit model were used for analyzing the data.

Result: The study revealed that four main latest agronomic practices such as inter-cropping, inter-row spacing; intra-row spacing and early planting were dominantly used for maize production in northwest Ethiopia. Likewise, the multivariate probit model result shows some policy relevant variables for instance age of household's , sex, education status, land size allotted to maize, and Frequency of extension contact were significantly influenced their willingness to adopt and use modern agricultural practice in maize production.

Conclusion: Generally, most maize producers were used various agronomic practice simultaneously as a best strategies for yield maximization, nutritional security, risk minimization and income diversification. Therefore, based on the findings, the interdependency of producers' decision to adopt and use latest agronomic practices in maize production should be develop through strengthening extension services, and providing intensive training both for producers and development agents. **Keywords:** Maize; adoption; agronomic practice; Producer; Ethiopia

Background

In developing countries, larger sections of the populations are involved in agriculture sector. Consequently, the sector's production, productivity and efficiency level is improved by using and adopting modern agricultural practice and technologies (Parvan, 2011). Likewise, Ethiopia is one of the developing countries which mainly depend on rain fed agriculture. In the country, agriculture is an engine for the growth of its economy by contributing 70% of raw material for manufacturing sector, 45% of Gross Domestic Product(GDP), 90% of export earning, and hires 83% of labour force(Deressa, 2009). Nevertheless, the performance of agriculture sector are still low particularly in cereal production and productivity (Alemayehu, 2009; Debebe, Haji, Goshu, & Edriss, 2015).

In Ethiopia, various staple crops such as teff, maize, sorghum, wheat and barley are produced by smallholder farmers for commercial and consumption purpose. Amid cereal crops, maize is largely

produced by smallholder farmers and plays significantly role for economic and social development of the country (CSA, 2011).

Likewise, Fig. 1 shows the top five largest maize producer countries in the world are USA which produces more 370 million tonnes followed by China (259 million tonnes), Brazil (97 million tonnes), Argentina (49 million tonnes), and Uganda which produce 28 million tonnes in 2017 crop production year (FAOSTAT, 2019). Figure 2 also revealed that Ethiopia is the 3rd largest maize producer country in Africa. The figure confirmed that the top five largest maize producer countries in Africa were South Africa which produces more 16 million tonnes followed by Nigeria (more than 10 million tonnes), Ethiopia (more than 8 million tonnes), Egypt (more than 7 million tonnes), and Tanzania which produce more than 5 million tonnes in 2017 crop production season (FAOSTAT, 2019). This implies that there is high potential of maize production in Ethiopia though its productivity is low (32.54 quintal per ha) (Alemayehu, 2009) as compared to the international standards of the world average maize productivity (50 quintal per ha) (CSA, 2014). This is because of lack of adopting of appropriate and latest agricultural technologies (Alene, 2007; Jon, 2007). Thus, the production, productivity and efficiency of maize crop can be upgraded by using modern agricultural practices and technologies (Melesse, 2018).

Agricultural technologies are any kinds of techniques which maximize agricultural production, productivity. Therefore, adoption of agricultural technologies through agricultural innovation system plays a vital role in improving agricultural production, productivities and efficiency (Tefera, Tesfay, Elias, Diro, & Koomen, 2016). Modern agricultural technologies also helps for proper and efficient use of new varieties, chemical fertilizers, insecticides, machineries and scientific knowledge and skills in agricultural production (Matunhu, 2011). Therefore, adopting of agricultural technologies are a main tool for reducing poverty and production cost (Kassie, Shiferaw, & Muricho, 2011), and source of diversified income (Maertens & Barrett, 2012).

However, adoption and practices of new and improved technologies can only be productive when effectively implemented in right place at right time because farmers face various problems in adoption, practice and scaling out of agricultural technologies(Pycroft, 2008; Shiferaw, Okello, & Reddy, 2009; Simtowe et al., 2011; Yu, Nin-Pratt, Funes, & Gemessa, 2011). In most developing countries including Ethiopia, adoption of new and improved technologies were influenced by various socio-economic, demographic, institutional factors(Asfaw, Shiferaw, Simtowe, & Lipper, 2012; Di Falco & Bulte, 2011; Pycroft, 2008; Shiferaw et al., 2009; Simtowe et al., 2011; Teklewold, Kassie, & Shiferaw, 2013; Yu et al., 2011).

Generally, various studies have been done on agricultural technology adoption level, extent, speed, practice and decision as discrete choice but not much has been done on possible inter-relationships among the various technologies adoption decision of farmers. Therefore, based on the above statements this study was intended to assess the interdependency of smallholder farmer's adoption decision of new agronomic practices in maize production.

Research Methods

Description of study area

The study was done in central Gondar zone, Amhara region of Ethiopia. The zone is located in the northwest of part of the country and 738 Km far from Addis Abeba. The capital city of central Gondar zone known as Gondar and located at 12° 35' 60.00" N latitude and 37° 28' 0.01" E longitudes with mean altitude of 2133 meters above sea level. In the study area, smallholder farmers are used mixed farming mainly crop and livestock production. The low land of the zone also covered by semi-arid natural forest (Abate, Dessie, & Mekie, 2019b; Dessie, Koye, Koye, & Abitew, 2019). Therefore, the study was conducted on three maize producers' districts specifically, Takusa, East Dembia and West Dembia (Fig. 3).

Methods of data collection and sampling techniques

In this study, various data types were collected from primary and secondary sources. Primary data was collected from maize producers through semi-structured interview and key informant's interviews. The semi-structured interviews were administered on 385 sampled maize producers. Moreover, a three-stage sampling technique was used to select sampled maize producers. In the first-stage, Takusa and Dembia district was selected purposively due to high potentials of maize production both for consumption and commercial purpose. In the second stage, nine maize producer kebeles/villages/ were selected purposively due to best producers' experience in adoption of latest agricultural practice. In the third stage, 385 sampled maize producers were selected through systematic random sampling technique following (Cochran, 1977).

$$n = \frac{Z^2 pq}{e^2} = \frac{1.96^2 (0.5 \cdot 0.5)}{0.05^2} = 385 \quad (1)$$

Where; n = Sample size; Z = confidence level ($\alpha = 0.05$, hence, $Z = 1.96$); p = proportion of the population containing the major interest, $q = 1-p$ and e = allowable error.

Methods of Data analysis and model specification

In order to analysis the data collected from the field and smallholder farmers, various descriptive analysis methods (frequencies, percentages, and means) and econometrics models like multivariate probit model were used. A multivariate probit model is important for studying various technologies effect on a farm simultaneously. Therefore, a multivariate probit model for adoption of multiple-agronomic practice simultaneously in maize production takes the general form as follows;

The adoption of agronomic practice (i) by farmer (j) is Y_{ij}^A defined as the choice of farmer j to use various agronomic practice in maize production i ($Y_{ij}^A = 1$) or not ($Y_{ij}^A = 0$) is expressed as follows:

$$Y_{ij}^A = \begin{cases} 1 & \text{if } 1 \text{ if } Y_{ij}^A = X_{ij}^A \alpha_{ij} + \varepsilon^A \geq 0 \Leftrightarrow X_{ij}^A \geq -\varepsilon^A \\ 0 & \text{if } 0 \text{ if } Y_{ij}^A = X_{ij}^A \alpha_{ij} + \varepsilon^A < 0 \Leftrightarrow X_{ij}^A < -\varepsilon^A \end{cases} \quad (2)$$

where α_{ij}^A is a vector of estimators and ε^A is a vector of error terms under the assumption of normal distribution, Y_{ij}^A is dependent variable for adoption of agronomic practice simultaneously and X_{ij}^A is combined effect of the explanatory variables.

Therefore, to analyse factors that affect adoption agronomic practice on maize production multivariate probit mode (MVP) was used. In multivariate model, the adoptions of several technologies simultaneously are possible. Therefore, to account the expected simultaneity problem, multivariate probit simulation model was used (Abate, Dessie, & Mekie, 2019a; Dessie, Abate, & Mekie, 2018; Long, 1997; Melese, Goshul, & Tilahun, 2018).

$$\begin{cases} \text{Intercrop}_j &= X_1' \beta_1 + \varepsilon_{1j} \\ \text{Interrowspace}_j &= X_2' \beta_2 + \varepsilon_{2j} \\ \text{Intrarowspace}_j &= X_3' \beta_3 + \varepsilon_{3j} \\ \text{Earlyplant}_j &= X_4' \beta_4 + \varepsilon_{4j} \end{cases} \quad (3)$$

Where: Intercrop_j , Interrowspace_j , Intrarowspace_j and Earlyplant_j are binary variables taking values 1 when farmer j selects inter-cropping, inter row spacing, intra row spacing and early planting agronomic practices, respectively, and 0 otherwise; X_1 to X_4 are vector of variables; β_1 to β_4 a vector of parameters to be estimated and ε disturbance term.

In multivariate model, the error terms jointly follow a multivariate normal distribution (MVN) with zero conditional mean and variance normalized to unity and ρ_{ij} represent the correlation between endogenous variables are given by;

$$\begin{bmatrix} \varepsilon_{1j} \\ \varepsilon_{2j} \\ \varepsilon_{3j} \\ \varepsilon_{4j} \end{bmatrix} \sim N \left(\begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}, \begin{bmatrix} 1 & \rho_{12} & \rho_{13} & \rho_{14} \\ \rho_{21} & 1 & \rho_{23} & \rho_{24} \\ \rho_{31} & \rho_{32} & 1 & \rho_{34} \\ \rho_{41} & \rho_{42} & \rho_{43} & 1 \end{bmatrix} \right) \quad (4)$$

$$\begin{aligned} E(\varepsilon/X) &= 0 \\ \text{Var}(\varepsilon/X) &= 1 \\ \text{Cov}(\varepsilon/X) &= \rho \end{aligned} \quad (5)$$

Result And Discussion

Demographic and socio-economic characteristics of households

From a total of 385 sampled maize producers, 94.81% and 5.19% were male and female headed households, respectively. The average age, livestock number, farming experience, land size allotted for maize, output and frequency of extension contact were also 46.23, 5.99, 14, 0.46, 15.27 and 20.61, respectively (Table 1). The majorities (51.17%) of sampled producers were not also attended formal

education and can't read and write. Similarly, large portion of sampled maize producers (54.29% and 67.01%) were not got credit service and market information, respectively. Moreover, most sampled maize producers (87.01%) were a member of farmers' cooperative in the study area (Table 1).

Table 1
Mean and proportion households' characteristics (N = 385)

Continuous variables		Mean	Standard Deviation
Age in years		46.23	0.48
Tropical livestock unit(TLU)		5.99	0.19
Farming experience in years		14	0.25
Land size allotted to maize in ha		0.46	0.06
Output in Quintals		15.27	0.37
Frequency of extension contact per year		20.61	0.92
Dummy variable	Response	Frequency	Percentage
Credit access	Yes	176	45.71
	No	209	54.29
Sex	Male	365	94.81
	Female	20	5.19
Education status	Illiterate	188	48.83
	Literate	197	51.17
Market information	Yes	258	67.01
	No	127	32.99
Cooperative membership	Yes	335	87.01
	No	50	12.99

Table 2 illustrated that various new agronomic practice were adopted and used by maize producers so as to produce the optimum output. The multiple response of sampled household revealed that most producers (98.44%) and 98.18% were used inter-row-spacing (75 cm btween row) and intra-row spacing (30 cm between plant), respectively. This implies that inter-row-spacing and intra-row spacing were a new agronomic practice and best strategy to produce maximum production. Likewise, 95.58% of producers were used early planting (producers planted maize at the onset of rain season) as a best a strategy to produce mazie for direct consumption and marketing purpose (what we call in amharic “eshet”). Moreover, 65.45% of producers were adopted and used inter-cropping to minimize risk by growing

diversified crop on small plot of land. This result is in line with the finding (Dessie, Abate, Mekie, & Liyew, 2019) revealed that smallholder farmers grows multiple crop on small plot of land to minimize risk, nutritional security and livelihood improvement.

Table 2
Proportion of agronomic practices adopted by households

Decision	Recommended Agronomic Practice							
	Inter-cropping		Inter-row spacing		Intra-row spacing		Early planting	
	N	%	N	%	N	%	N	%
Yes	252	65.45	379	98.44	378	98.18	368	95.58
No	133	34.55	6	1.56	7	1.82	17	4.42
Total	385	100	385	100	385	100	385	100

Adoption of multiple agronomic practices in maize production

The result in Table 3 endorsed that, the Wald test ($\chi^2(6) = 54.060$, Prob > $\chi^2 = 0.000$) is statistically significant at 1% level. This implies that the subsets of coefficients of the model were jointly significant and the explanatory power of the variables involved in the model was also adequate. The results of the likelihood ratio test (LR ($\chi^2(6) = 46.455$, Prob > $\chi^2 = 0.000$)) also corroborated that, the independence of adoption decision of producers on four agronomic practice ($p_{21} = p_{31} = p_{41} = p_{32} = p_{42} = p_{43} = 0$) was rejected at 1% significance level. This implies the households' decisions to adopt and use four agronomic practices in maize production were interdependent. Therefore, a multivariate probit (MVP) model was fits the data marvelously (Table 3).

Table 3

Overall model fitness, probabilities, and correlation matrix of the agronomic practice from the MVP model

Variables	Inter-cropping	Inter-row spacing	Intra-row spacing	Early planting
Predicted probability	0.655	0.987	0.978	0.954
Joint probability(success)	0.609			
Joint probability(failure)	0.001			
Estimated correlation matrix				
	ρ_1 (intercropping)	ρ_2 (inter-row spacing)	ρ_3 (intra-row spacing)	ρ_4 (ealy planting)
ρ_1 (inter-croping)	1			
ρ_2 (inter-row spacing)	0.305	1		
ρ_3 (intra-row spacing)	-0.037	0.891***	1	
ρ_4 (ealy planting)	-0.209	0.530***	0.656***	1
Likelihood ratio test of $\rho_{21} = \rho_{31} = \rho_{41} = \rho_{32} = \rho_{42} = \rho_{43} = 0$				
$\chi^2(6) = 46.455$ and $\text{prob} > \chi^2 = 0.0000$ ***				
Numbers of draw (#)5				
Numbers of observation	385			
Log likelihood	-324.118			
Wald χ^2 (48)	54.060			

The simulated maximum likelihood (SML) estimation result confirms that the probability of producers to adopt inter-row spacing, intra-row spacing, early planting and inter-cropping agronomic practice in maize production were 98.7%, 97.8%, 95.4% and 65.5%, respectively. Additionally, the probability of producers to jointly adopt and use the four agronomic practices simultaneously was 60.9%, while their failure to jointly adopt was 0.1% (Table 3).

The econometric model result endorsed that variables such as producer's age, sex, education status, land size allotted to maize, and frequency of extension contact were significantly influenced maize producer's decision to adopt agronomic practice (Table 4).

Table 4
Multivariate probit estimations for determinants of adoption of agronomic practices

Variables	Coefficients (choice of agronomic practices by producers)			
	Inter-cropping(1)	Inter-row spacing(2)	Intra-row spacing(3)	Early planting(4)
Age of household	0.011	-0.045**	-0.021	-0.031*
Sex of household	-0.338	1.073*	1.072**	-2.944
Education status	0.051	-0.205	-0.257*	-0.036
Land size	-0.181**	0.560	0.335	0.377*
Credit access	0.166	0.185	0.318	0.508
Frequency of extension contact	0.011***	0.002	-0.014	-0.034***
constant	0.197	2.714**	1.963**	6.291
Note: Dependent variable; adoption of agronomic practice; ***, ** and * are statistically significant at 1%, 5% and 10% significance level, respectively. Source: own survey result, 2019				

Age of producer was negatively influenced the probability of adopting inter-row spacing and early planting at 5% and 10% level of significance, respectively. This implies that as the age of household increased by a year, the likelihood of adopting inter-row spacing and early planting agronomic practice in maize production decrease by 4.5% and 3.1%, respectively. This is due to the fact that aged maize producers are reluctant to adopt new agronomic practice in maize production. This result is indorsed with the finding of (Abate et al., 2019a; Dessie et al., 2018) they revealed that older producers are reluctant to adopt new output market technologies than younger producers.

Sex of households was positively and significantly influenced the likelihood to adopt inter-row spacing and intra-row spacing agronomic practice in maize production at 10% and 5% level of significance, respectively. It implies that male headed households are more likely to adopt and use good agronomic practice in maize production than female headed households. The possible elucidation is that male producer can contribute more labour to adopt and use labour intensive agronomic practices such as inter-row spacing and intra-row spacing in maize production than female headed households. This result consistent with the finding of (Melesse, 2018) endorsed that the adoption of agricultural technologies depends on the amount of labor available at farm.

Land holding size was negatively and a positively influenced the adoption of inter-cropping and early planting agronomic practice in maize production at 5% and 10% level of significance, respectively. This implies that as the land size allotted for maize production increased by a hectare, the probability of adopting of inter-cropping and early planting agronomic practice were decreased and increased by 18.1% and 37.7%, respectively. This can be explained as intercropping agronomic practice needs small plot of

land than early planting. Likewise, farmers adopt and use early planting agronomic practice to produce green maize for food and commercial purpose in short period.

The education status of household was negatively and significantly affect the probability of adopting intra-row spacing agronomic practices in maize production at 10% level of significance. This implies that as household head's become literate, the likelihood of adopting intra-row spacing agronomic practices in maize production decrease by 25.7%. This can be explained by the fact that as a producer becomes literate, he/she has good skill and knowledge of agricultural technologies, which enables them to adopt less costly and labour saving agricultural technologies to produce maximum yield.

Frequency of extension contact has a negative and significant effect on the adoption of inter-cropping and early planting agronomic practice in maize production at 1% significant level. This implying that as the frequency of extension contact increase, the likelihood of producer to adopt inter-cropping and early planting agronomic practice increase and decrease by 1.1% and 3.4%, respectively. This can be explained by the fact that as producers acquired extension service, they can adopt and use inter-cropping agronomic practice than early planting in order to minimize risk, improve the soil fertility and to increase diversified income source.

Conclusion And Recommendation

Enhancing crop production and productivity using improved agricultural technologies are vital tools to boost income, to reduce food shortage, hunger, famine, food insecurity and poverty in Ethiopia. However, various socio-economic, demographic and institutional factors influenced producer's decision to use latest agricultural technologies and practices in maize production. Therefore, this study was aimed to identify farm household's adoption decision interdependency of agricultural practice on maize production in northwest Ethiopia. The finding revealed that majority of maize producers' use intercropping, inter-row spacing, intra-row spacing and early planting agronomic practice for maize production simultaneously. The result of multivariate probit model revealed that, aged maize producers are reluctant to adopt new agronomic practice in maize production. It also indicated that as compared to female headed households, male headed households' plays significant role to adopt and use labour intensive agronomic practices such as inter-row spacing and intra-row spacing in maize production. The result also shows producers were used early planting agronomic practice to produce green maize for food and commercial purpose during early onset of rain. Moreover, literate producer has good skill and knowledge of agricultural technologies, as a result adopt less costly and labour saving agricultural technologies to produce the optimum amount of maize output. Furthermore, the multivariate model result revealed that, as farmers got extension service, they can adopt and use inter-cropping agronomic practice than early planting in order to minimize production risk, improve the soil fertility and diversified income source. Based on the findings, the agronomic practices adoption decision of smallholder farmer should be develop through strengthening extension services, and providing intensive training both for producers and development agents. Generally, for holistic maize production and marketing there should be strong

integration and cooperation among smallholder farmers, traders, agricultural research institutes, consumers, village and district development agents and policy makers.

Declarations

Authors' contributions

All authors read and approved the final manuscript.

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Competing interests

The authors declare that they have no competing interests.

Availability of data and materials

The author wants to declare that they can submit the data at any time based on publisher's request. The datasets used and/or analyzed during the current study will be available from the author on reasonable request.

Consent for publication

Not applicable

Ethical approval and consent to participate

Ethical clearance letters were collected from University of Gondar research and community service directorate and Central Gondar zone administrative office to care for both the study participants and the researchers. During survey, official letters were written for each district and kebele/villages/ informed verbal consent was obtained from each client, and confidentiality was maintained by giving codes for each respondent rather than recording their name. Study participants were informed that clients have a full right to discontinue or refuse to participate in the study. Hence, all participants throughout the research, including survey households, 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.

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Abbreviations

CSA: GDP: Gross Domestic Product; Central Statistical Agency; e: Error; ETB: Ethiopian Birr; FAO: Food and Agriculture Organization; LR: Likelihood Ratio; ML: Maximum Likelihood; n: Sample Size; Z: confidence level; MVP: Multivariate probit model; SML: simulated maximum likelihood;

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Figures

Fig.1 Top five maize producers countries in the world

Figure 1

Top five maize producers countries in the world

Fig.2 Top five maize producer countries in Africa

Figure 2

Top five maize producer countries in Africa

Fig.3 Map of study area

Figure 3

Map of study area

Supplementary Files

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