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Farmers Choices of Precursor Crop for Wheat Production in Arsi Zone of Ethiopia

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Abstract

Adoption of crop rotation is seen as best agronomic practice for increasing wheat yield in Ethiopia. Most farmers lack improved farming experiences and skills. They focus on production of food crops (mainly cereals) year after year for family needs. Hence practice of crop rotation is one of the options for improving wheat yield. However, there is lack of empirical study on the factors influencing farmers' choices of precursor crop for rotation for wheat cultivation. To fill this gap, this study identified factors influencing farmers' choices of precursor crop to wheat planting. Cross-sectional survey data collected from randomly selected 381 farm households and multinomial logit model were used to achieve the objective. The study identified that farming experience and skill of household head, livestock holding sizes, and access to pesticides had positive and significant effects on farmers' choices of pulse and vegetable crops being precursors to wheat planting. The study also obtained that the mean predicted probabilities were 0.58 and 0.34 for the choices being cereal and pulse crops as precursor crops to wheat planting, respectively. It is suggested that agricultural extension personnel need to focus on the factors that influenced farmers' choices of precursor crops to break cereal monoculture system and improve wheat yield.

Keywords: Wheat in Ethiopia, Precursor crop, Crop rotation, Multinomial logit model

1. Introduction

Food crops productivity change has recently become an issue of developing countries because of its greater impact on economic growth and poverty reduction both in rural and urban areas (Headey *et al*., 2010). Wheat is one of the major food and cash crop for smallholders in Ethiopia. The demand for wheat has been increased due to growing population, urbanization and the expansion of food processing industries in the country. If the country is to feed the rapidly growing population and meet the high demand, it needs to increase the production and productivity of wheat. However, the average national yield of wheat is 21 quintals per hectare (CSA, 2013). This is the lowest yield compared to global average. The low yield is due to limited use of modern inputs and it seems to be a major explanation for its low productivity (Alemayehu *et al*., 2011). The low productivity has made the country unable to meet the high demand and it is net importer of wheat (Rashid, 2010).

Increasing yield requires successful adoption of improved farm inputs and farming practices (Dorosh and Rashid, 2013). One of yield limiting factors in Ethiopia is low adoption and limited use of chemical fertilizers. Increased use of fertilizers has been a major factor explaining perhaps one third to one half of yield growth in developing countries (Fischer *et al*., 2009). Fertilizer use per hectare is low due to high prices and poor markets; and the low fertilizer use explains a large part of the lagging productivity growth for food crops. Therefore, in areas where cereal monoculture is prevalent and famers are unable to afford high prices of chemical fertilizers and pesticides, rotating crops on a given farm using pulses before cereals on specific farm has a substantial effect on reducing crop pests and improving soil fertility and hence productivity.

Crop rotation is one of the oldest and most fundamental agronomical practices, and is thought to have great impact on increasing crop yield. Crop rotation means changing the type of crop grown on a particular piece of land from year to year. It is primarily a management decision based on a desire to optimize financial, agricultural or environmental objectives through profit and yield maximizations as well as through minimized pesticide use (Castellazzi et al., 2008). Rotations primarily help in weed control, improve soil fertility, and increase wheat grain yield when compared to mono-cropping (Harris et al., 2007; Moghaddam et al., 2011). A well planned rotation reduces weed pressure by eliminating the constant niche that mono-cropping provides. A leguminous crop usually precedes cereals for the aim of improving soil fertility. Therefore, the benefits of rotations could arise from increased nitrogen supply, soil organic matter, and improvement in soil structure, and decreased pests, disease or weed competition. Hence, choice of appropriate precursor crop to wheat planting for rotation can affect wheat yield. However, there is lack of documented empirical knowledge in the study area on the factors influencing the choice of precursor crop to wheat planting for rotation. To fill this gap, this study identified factors influencing the choice of precursor crop. Cross-sectional survey data collected from randomly selected 381 farm households and multinomial logit choice model were used to determine factors influencing farmers' choice of precursor crop to wheat planting.

2. Research Methodology

2.1. The study Area

The study area, Arsi Zone, is found in the central part of the Oromia National Regional State of Ethiopia. The zone astronomically lies between 60 45' N to 8^0 58'N and 38^0 32 E to 40^0 50' E. The area is divided into five agro-climatic zones mainly due to variation in altitude. It is dominantly characterized by moderately cool (about 40 percent) followed by cool (about 34 percent) annual temperature. The mean annual temperature of the Zone is found between 20-25^0c in the low land and 10-15^0c in the central high land.
The mean annual rainfall varies from 633.7 mm at *Dhera* station which is in *Dodota* district, and located at altitude of 1680 meters above sea level to 1059.3 mm at *Bekoji* station in *Lemu-bilbilo* district located at an altitude of 2760 meters above sea level. On average, the zone gets a monthly mean rainfall of 85 mm and an annual mean rainfall of 1020 mm. The area receives well distributed rainfall both in amount and season. This characteristics makes the zone good potential for production of various agricultural crops. Wheat is a major crop and it accounts for 42% of the total cereal area cultivated in the study area, with total output of 5.12 million quintals from 0.21 million hectares of cultivated land (CSA, 2013).

2.2. Sampling Technique

A combination of purposive and two stages probability sampling procedures were used for sample selection. In the first case, three major wheat producing districts were purposively selected. The three districts namely, Lemu-Bilbilo, Hetosa, and Dodota were selected. The main reason for purposive selection was due to their representativeness in wheat production both in regional and national perspectives. There are also strong research and extension intervention programs embracing wheat producers in the area. Moreover, newly released improved wheat varieties and improved farming practices were relatively more disseminated and practiced in these areas. Therefore, it was feasible to assess factors that influence farmers' choice of precursor crops to wheat planting in these areas. In the first stage of the probability sampling, a list of major wheat growing lower administrative divisions (*kebeles*) within the selected districts was prepared. Taking in to account the cost of data collection, two *kebeles* were selected from each district with simple random sampling. In the second and final stage, a list of wheat farmers was prepared for each district. Sample farmers were selected by simple random sampling technique. The sample size was determined based on the formula given by Krejice and Morgan (1970), and allocation of sample size to each district was made proportionate to the size of farm household heads population of each district.

2.3. Data Collection

The data for the study was collected from both primary and secondary sources. Cross-sectional data was collected from the survey of randomly selected 381 sample farm household heads. For the primary data collection, specifically designed and pre-tested questionnaire based on the objective of the study, and trained data enumerators was used. Both quantitative and qualitative information were collected. The data collection included households' socioeconomic characteristics (family sizes, age and sex structures, education, etc), land holding (agricultural, grazing, wheat land, and others), access to and utilization of farm inputs (seeds, fertilizers, herbicides and fungicides, extension services), agronomic practices including crop rotation. The survey was carried out in the months of May and June 2013.

2.4. Analytical Methods

In regression models, when the dependent variable is continuous, the linear regression model is probably the most commonly used statistical method. However, when the dependent variable is discrete or categorical outcome, linear regression models are not appropriate. There are a wide variety of non linear models for categorical dependent variables. The model specification which is most commonly used for nominal outcomes with more than two categories that are not ordered is the multinomial logit model (Hausman and McFadden, 1984; Greene, 2012). It is used in a variety of situations in applied econometrics and social sciences. Multinomial logistic regression jointly maximizes the likelihood that the estimates of the parameters predicting each category of the dependent variable could generate the observed sample data. When the dependent variable has only two categories, the multinomial logistic regression estimates reduce to binary logistic regression estimates (Greene, 2012). The method of estimation is maximum likelihood, since qualitative response models cannot consistently be estimated with linear regression methods (Wooldridge, 2010; Greene, 2012). In the present study, Multinomial logit model was used for modeling smallholders' choices of precursor crop for rotation in wheat production. Because a farmer chooses among more than two choices or crop types, making the choice that provides the greatest utility in production processes. Based on (Wooldridge, 2010; Greene, 2012), the multinomial logit model for smallholder choice of precursor crop to wheat planting can be specified as follows.

Let Y_i denotes a random variable representing precursor crop chosen to wheat planting by a farm household, which are discrete and mutually exclusive choices. X_i represents a set of socioeconomic variables that are assumed to influence smallholders' choice of precursor crop to wheat planting, then

$$\text{Prob}\,(Y_i = j) = \frac{e^{X'_i B_j}}{\sum_{j=0}^{J} e^{X'_i B_j}}\ , \qquad (1)$$

is named as the multinomial logit model (Greene, 2012).

The model for precursor crop choice with 3 choice categories is

$$\text{Prob}\,(Y_i = j / X_i) = \frac{e^{X'_i B_j}}{\sum_{j=0}^{2} e^{X'_i B_j}}\ , \ j = 0,1,2. \qquad (2)$$

Where B_j is a vector of coefficients on each independent variables X_i, and j = 0, 1, and 2 are choices of precursor crops when the choices are pulse crops, vegetable crops and cereal crops, respectively. The estimated equation provides a set of probabilities for the choices for a decision maker with characteristics X_i (Greene, 2012). Equation (2) can be normalized to remove indeterminacy in the model by setting $B_0 = 0$. This happens because the probabilities sum to one. Therefore, the probabilities are:

$$\text{Prob}\,(Y_i = j / X_i) = P_{ij} = \frac{e^{X'_i B_j}}{1+\sum_{k=1}^{2} e^{X'_i B_k}}\ , \ j = 0, 1, 2. \qquad (3)$$

Equation (3) gives the J log-odds ratios:

$$\left[\frac{P_{ij}}{P_{ik}}\right] = X'_i(\beta_j - \beta_k) = X'_i\beta_j \ \text{ if K = 0.} \qquad (4)$$

The coefficients of multinomial logit model are difficult to interpret. It also misleads to associate B_j with j^{th} outcome. To interpret the effects of independent variables on the probabilities, equation (3) was differentiated to find the partial effects of the variables on the probabilities.

$$\frac{\partial P_{ij}}{\partial X_i} = P_{ij}\left[\beta_j - \sum_{k=0}^{J} P_{ik}\beta_k\right] = P_{ij}\left[\beta_j - \bar{\beta}\right] \qquad (5)$$

The marginal effects measure the expected change in probability of a choice being made with respect to a unit change in independent variable (Wooldridge, 2010; Greene, 2012). The signs of the marginal effects and the respective coefficients may be different, because the marginal effects depend on the sign and magnitude of all other coefficients. Finally, model validity was tested for the independence of irrelevant alternatives (IIA) assumption using Hausman test.

Various socio-economic factors affect farmers' adoption of new technology and improved farming practices in Ethiopia. In this study, households related socio-economic factors which were assumed to influence farmers choices of precursor crop include age and educational level of household head, farming experience of household head, land and livestock holding sizes, family size, access to pesticides, and annual income from off-farm and livestock production activities. Age was measured in years, education was in number of educational grades completed, farming experience was measured in numbers of years household head fully involved in farming and received extension services, and total land holding size was measured in hectares. Likewise, family and livestock holding sizes were measured in adult equivalent and tropical livestock unit (TLU) respectively. Access to pesticides was dummy variables measured in 'yes' or 'no'. If a household had access to pesticides, they assumed 1, or otherwise 0 if there was no access to pesticides. Annual income was measured in thousand ETB, birr.

3. Results and Discussion

3.1. Descriptive Results

The major crop categories that are cultivated in the study areas include pulses, vegetables, and cereal crops. Proper sequence of crops for rotation can improve soil fertility. A leguminous crop usually precedes cereals to increase cereal crop yield. Table 1 shows percentage of sample farmers who planted pulse, vegetable or cereal crop in 2011/12 cropping season on the farm planted with wheat in 2012/13 cropping season.

Table 1. Percentage of famers with different choices of precursor crop to wheat planting

	District			
Precursor crop	Dodota n =83	Hetosa n = 133	Lemu Bilbilo n = 165	Total N = 381
Pulses	14.5	35.3	43.0	34.1
Vegetable	2.4	12.8	6.7	7.9
Cereal	83.1	51.9	50.3	58.0

Source: Computation from own data.

Table 1 depicts that 58% of sample farmers planted cereals before wheat. About 34 and 8 percents of the farmers planted pulses and vegetables preceding wheat planting, respectively. This indicates that the choice of precursor crop to wheat for many farmers (58%) was cereal crop (i.e. wheat, barley, tef or other cereal) in the study areas. Planting cereal before wheat does not give the benefit of crop rotation that could arise from increased nitrogen supply, soil organic matter, improvement in soil structure, and decreased pests or weed competition. Use of leguminous crop (pulses) as precursor crop to wheat was low, and majority of farmers chose cereals as a precursor crop for rotation for wheat production in all study areas. Relatively, choice of pulses was better (43% of sample farmers) as precursor crop to wheat planting in the highland area (Lemu-Bilbilo district).

Table 2. Percentage of sample farmers planted different crops on wheat farm before 2012/13 cropping season

Crop type	2010/11 season	2011/12 season (precursor)
Pulses	29.9	34.1
Vegetables	1.3	7.9
Cereals	68.8	58.0

Source: Computation from own data

The farm land on which wheat was planted in 2012/13 cropping season was used for planting pulse and cereal crops by 29.9% and 68.8% of sample farmers in 2010/11 cropping season, respectively (Table 2). Similarly, 34.1 and 58 percents of sample farmers planted pulse and cereal crops on the same wheat farm in 2011/12 cropping season, respectively. This shows that majority of farmers planted cereal after cereal at least for three consecutive cropping seasons on the same farm (including wheat planted in 2012/13 cropping season). Breaking cereal monoculture helps resource poor farmers to improve soil fertility, reduce plant diseases and pests and thereby increase yield of crops.

3.2. Econometric Estimation Results

Table 3 provides the maximum likelihood estimates of multinomial logit model for the choice of precursor crop to wheat planting as dependent variable, and set of explanatory variables assumed to affect the probability of the choice being one of the outcome categories, with cereal being the base outcome category.

Table 3. Maximum likelihood estimates for multinomial logistic regression

Independent variables	Choice categories: Pulses coef.(z-value)	Vegetables coef.(z-value)
Age	0.003	-0.118
	(0.13)	(2.65)**
Education	0.041	0.129
	(1.09)	(1.92)
Experience	0.010	0.138
	(0.41)	(2.71)**
Land holding size	-0.032	-0.133
	(0.3)	(0.57)
Livestock holding size	0.056	-0.066
	(1.99)*	(1.02)
Income	0.008	0.041
	(0.47)	(1.5)
Family size	0.027	-0.049
	(0.36)	(0.35)
Access to pesticides	0.632	1.356
	(2.56)*	(3.17)**
Constant	-1.895	-0.881
	(2.65)**	(0.72)

* $p < 0.05$; ** $p < 0.01$. Figures in parentheses are z-values. Base outcome = Cereal

The Wald test (Wald chi2(16) equals to 47.73, with p-value of Prob > chi2 = 0.0001 i.e. $p < 0.0005$) gives significant chi-squared statistic, implying rejection of null hypothesis that all the 16 coefficients associated with independent variables (except the constant) are simultaneously equal to zero. It means that the effect of independent variables on the outcome variable was not zero. The effect of livestock holding size in TLU and access to pesticides on the probability of choosing pulses as precursor crop to wheat cultivation was significant ($p < 0.05$). Age, farming experience of household head and access to pesticides were significant factors ($p < 0.05$) in their effect on the probability of vegetables being precursor crop. Education was also significant variable ($p<0.10$) on households' probability of choosing vegetable crops as precursor to wheat cultivation. A likelihood ratio test also showed that the effect of age and farming experience of household head as well as livestock holding size on choice of precursor crop were significant at 0.05 level. But the effect of access to pesticides was significant at $p < 0.01$. Table 4 gives the predicted probability after multinomial logistic regression.

Table 4. Predicted probability after multinomial logistic regression

Variables	Mean	Std. Deviation	Minimum	Maximum
Pr(precursor=pulses)	0.341	0.113	0.159	0.906
Pr(precursor=vegetable)	0.079	0.074	0.001	0.520
Pr(precursor=cereal)	0.580	0.135	0.087	0.824

The predicted probabilities for outcome categories were calculated after multinomial logistic regression. The mean predicted probability was 0.58 for the choice being cereal as precursor crop to wheat cultivation, and choice being pulse was 0.341, ranging from minimum probability 0.159 to maximum of 0.906. The mean predicted probability for the choice being vegetable was 0.079. This shows that the probability of choice being cereal crop as precursor to wheat cultivation was very high compared to the other two choice categories. This indicates that planting of wheat after cereal was a common farming practice in the study areas. However, it has to be noted that a positive or negative coefficient of multinomial logit need not mean that an increase or decrease in the independent variable leads to an increase or decrease in the probability of an outcome being selected. But the coefficients can be interpreted with comparison to the base category (cereal choice category).

Since the coefficients of multinomial logit can be difficult to directly interpret, the marginal effects could be used to measure the impact on the probability of observing each of the choice outcomes. The marginal effects on choice probabilities evaluated at mean values of the independent variables were computed and given in Table 5. As depicted in the table, for each independent variable there are three marginal effects corresponding to the three probabilities, and these three marginal effects sum to zero because probabilities of each outcome sum to one. The marginal effect on pr(y = pulse) of a change in livestock holding size evaluated at the mean of variables indicates that a unit change in livestock size by one TLU increases by 0.014 the probability of pulses being precursor crop to wheat planting rather than being vegetables or cereals. Similarly, a year increase in age of household head decreases by 0.006 the probability of vegetables being precursor to wheat planting. Cereal crops are the major food and cash crops in the study areas. Households with more livestock holding sizes could have income sources from sale of livestock and livestock products. As a result these households may prefer planting of other crops to cereals. More age of household head associated with more family sizes. Older people usually have more family size than younger ones. To feed the larger family size, households prefer production of food crops (cereals) to other crops.

The marginal effects of farming experience of household head and access to pesticides on the probability of precursor to wheat planting being vegetable crops were significant at 0.01 levels. Similarly the marginal effect of access to pesticides on the probability of the choice being pulse crop was significant at 0.05 levels. The marginal effect of access to pesticides on the probability of choice being cereal crops was also a significant variable at $p < 0.01$. However, the marginal effect of access to pesticides on probability of the choice being cereal crop was negative. This implies that experienced farmers can apply their farming skills and adopt planting of pulses and vegetable crops.

Table 5. Marginal effect after multinomial logistic regression

	Choice category		
Independent variables	Pulses (dy/dx)	Vegetables (dy/dx)	Cereal (dy/dx)
Age	0.003	-0.006	0.003
	(0.58)	(2.97)**	(0.61)
Education	0.007	0.006	-0.013
	(0.82)	(1.61)	(1.48)
Experience	0.000	0.007	-0.007
	(0.06)	(2.88)**	(1.18)
Land holding size	-0.005	-0.006	0.011
	(0.02)	(0.53)	(0.45)
Livestock holding size	0.014	-0.004	-0.010
	(2.24)*	(1.39)	(1.43)
Income	0.001	0.002	-0.003
	(0.28)	(1.5)	(0.76)
Family size	0.007	-0.003	-0.004
	(0.42)	(0.43)	(0.24)
Access to pesticides	0.113	0.065	-0.178
	(2.06)*	(2.47)**	(3.22)**

*$p < 0.05$; **$p < 0.01$. Figures in parentheses are z-values

Access to pesticides has positive effect on the production of pulses and vegetable crops. Farming experience, livestock holding sizes, and access to pesticides have positive and significant effect on farmers' preferences of pulses and vegetable crops. Therefore, improvement in farming experience and skills, more livestock holding sizes, and access to pesticides could help the adoption of pulses and vegetable crops, and breaking of cereal monoculture in crop production in the study area.

4. Conclusion

Low use of chemical fertilizers and improved agronomic practices are some of the reasons for low wheat yield in Ethiopia. The low yield made the country unable to meet the high demand, and the country is net importer of wheat despite its high potential for wheat production. To feed the rapidly growing population and meet the high demand, smallholders need to increase wheat yield through adoption of improved agronomic practices.

Crop rotation is one of agronomic practices believed to increase wheat yield in Ethiopia. However, most farmers practice cereal monoculture system in the study area. Though, great efforts of agricultural extension service to promote crop rotations, most farmers are practicing planting of cereal after cereal. This has negative impact on crops productivity since most farmers are unable to afford the high prices of farm inputs specially prices of chemical fertilizers and pesticides. Crop rotation improves soil fertility, reduces plant diseases and weeds problems, and thereby increases crops yield. Therefore crop rotation, especially precursor crop planted preceding wheat cultivation, has the capacity to improve wheat productivity. However, there is limited empirical knowledge on the factors affecting farmers' choices of precursor crop for rotation for wheat production in the study area. To fill this gap, this study was carried out in major wheat producing zone of the country to identify the factors influencing farmers' choice of precursor crop to wheat planting. Cross-sectional survey data collected from randomly selected 381 farm households and multinomial logit model were used to achieve the objective of the study.

The study identified that farming experience and skill of household head, livestock holding sizes, and access to pesticides had positive and significant effects on farmers' choices of pulse and vegetable crops as precursors to wheat planting. The study also obtained that the mean predicted probabilities were 0.58 and 0.34 for the choices being cereal and pulse crops as precursor crops to wheat planting, respectively. The agricultural policy makers and extension personnel need to give due attention for the factors influencing farmers choice of crop for the promotion of crop rotation for improving wheat yield.

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