International Scholars Journals

African Journal of Agriculture and Food Security ISSN 2375-1177 Vol. 8 (12), pp. 001-010, December, 2020. Available online at www.internationalscholarsjournals.org © International Scholars Journals

Full Length Research Paper

Adoption of irrigated wheat varieties among agro-pastoralists; The case of Fentale District, Upper Awash Valley of Northeastern Ethiopia

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Accepted 21 September, 2020

This study was intended to examine the rate at which the hitherto pastoralist communities are adopting the newly popularized irrigated wheat varieties, and the factors influencing adoption decisions. The study employed multi-stage sampling procedures to select 120 sample respondents from four pastoral kebeles in Fentale district of northeastern Ethiopia. Logit model was used to analyze the determinants of adoption while simple descriptive analysis of percentage, mean, frequency as well as chi-square and t-tests were used to describe the characteristics of sample households. The study reveals that the rate of adoption of irrigated wheat varieties among farmers is 18%. The logit estimate showed that level of education of household head, family size in adult equivalent, extension access to wheat, access to training and presence of off-farm activities have positively and significantly influenced the probability of being adopter. However, age of household head and distance to the main irrigation water source (main canal) had negative effect on the decisions of farmers to adopt irrigation wheat varieties. Strengthening extension services, providing comprehensive and continuous practical and theoretical trainings and improving irrigation water distribution through maintaining secondary and tertiary canals are areas of intervention for rapid and continuous adoption of irrigated wheat varieties.

Keywords: Adoption, Irrigated wheat, Upper Awash, Fentale, Northeastern Ethiopia, Logit.

INTRODUCTION

Agriculture plays an important role in economic growth, enhancing food security, poverty reduction and rural development. Most Sub-Saharan African countries are characterized by low agricultural productivity. One of the reasons for poor production is that African agriculture is predominantly rainfed, which is in most cases unreliable resulting in poor yields and the changing weather conditions would further exacerbate the situation, exposing smallholders to negative impact of climate change (Todaro, M *et al*., 2012). This is also concerning the context of Ethiopia.

Agricultural activities are engaged by 80 percent of Ethiopia's population and 70% of export earnings (African Economic Outlook, 2015). In Ethiopia, the economy depends on agriculture, in that the sector contributes about 36 percent of the national income which is derived from agricultural commodities (i.e. coffee, oil seeds, and sesame). Despite its importance, the agricultural sector of the country is characterized by subsistence-oriented production system dominated by smallholder farming entirely reliant on rain. To reach the objectives of food security and nutrition for all as well as to reduce poverty, there is a need to progressively transform the agricultural sector by increasing productivity through diffusion and adoption of modern agricultural technologies.

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Within agriculture, crop productions contribute the lion share, which on average makes up 60% of the sector's outputs, of which cereals production play substantial role, contributing 30% to the overall GDP, 62% of the agricultural GDP, 40% of the food expenditure, 60% of the calorie intake, 60% of the rural employment, and 80% of the total cultivated area (Mekonen B., 2017). Small-scale farmers, who practice rain-fed mixed farming by employing traditional technology, adopting a low input and low output production system, dominate the cereal crop production. Small-scale farmers produce 94% of the food crops and 98% of the coffee, the latter being the leading export goods of the country. Private and state commercial farms produce just 6% of food crops and 2% of the coffee grown (Gebre-Selassie A, and Bekele T., 2010).

Among cereal crops, wheat (*Triticum aestivum*) has assumed a strategic food security crop in Ethiopia in terms of areas of land allocated, volume produced, number of farmers engaged and cash generation. Most of the crop production including wheat takes place in highlands where 44% of total area is cultivated, where 95% of land under crop is located, where 90% of the total population lives, and where declining vegetative cover is very common (Ayenew, 2015). The primarily rainfed wheat yields for smallholder farmers in Ethiopia are still low and lagging behind by about 33% and 60% of Kenyan and South African averages between 2009 and 2013 (Lulit *et al*., 2016).

Wheat production has also lagged behind national consumption and resulting in increased annual average import of more than one million tons between 2007 and 2017 (Figure 1).

Moreover, both the supply and demand for wheat tend to grow between 2010 and 2030 period, with the rate of growth of demand exceeding that of supply (Kathren B. *et al*., 2010). It is becoming increasingly evident that required food supplies cannot be met by rain fed conditions alone. Thus, for Ethiopia to exit from wheat import, domestic production needs to increase quite significantly through harnessing its fertile and irrigable lowland areas. As a result, cognizant of the fact that the dependence on unreliable rainfall is a limiting factor for agricultural productivity, the government of Ethiopia has given special attention to irrigated agriculture. Kay, M (2001) asserts that irrigation is not only an important tool in helping farmers insure against droughts and playing an integral role in transitions from subsistence to commercial farming but can substantially boost the production of staple foods and high-value crops, amidst low land holding. This underlines the need for a "research based" agriculture that uses biological and technical intervention to increase land and labor productivity. In general, raising agricultural output and productivity on a sustainable basis necessitates large scale adoption and diffusion of new technologies (Mehumud *et a*l., 2009). Irrigated wheat technologies are among the newly introduced crop technologies under irrigated farming system. And on the basis of this attention, a number of irrigated agricultural technologies have been generated and efforts have been made to accelerate the diffusion and adoption of these innovations. Consequently, the production of irrigated wheat issue is becoming more and more imperative for expanding domestic wheat production in the lowland areas of the country including Afar, Somali, SNNP and some parts of Oromia.

In the study area, Fentale district, irrigated wheat varieties have been demonstrated, popularized and disseminated among the farmers through different extension methods and organizations such as Research center (WARC), Office of Agriculture and NGOs. Nowadays, farmers produce wheat primarily as an alternative food source and for market sale. However, it was found out that farmers did not adopt the irrigated wheat varieties, as they would have been expected to be. This could be ascribed to various factors, which appeared to have some bearing on the farmers' decision to adopt irrigated wheat varieties. Thus, it is of utmost importance to reveal those underlying factors, which may account for the observed variations in the adoption level of irrigated wheat varieties among the farmers in Fentale district. To this end, the findings of this study are expected to render very valuable information for further promotion of this important crop in the study area. The key findings from this study could also help to fine tune extension system in such a way that the technical and socioeconomic constraints to irrigated wheat production can be addressed.

Without due consideration of socioeconomic and biophysical factors that may affect the adoption of irrigated agricultural technologies, it is impossible to design proper development program and enhance their contribution to the rural households' economy in particular and the improvement of the food situation of the country in general. Evaluation of factors influencing the adoption of possible technology could play a decisive role in developing feasible and suitable development programs. Technologies that are forwarded to resource poor farmers should meet a variety of needs of these people and be acceptable from a socio-cultural perspective besides technical and economic considerations. Observing the pattern of the farmers' attitude towards adopting certain agricultural technologies would give a basis for the selection of viable interventions. It is also noted that understanding the factors that have determined adoption in the past offers relevant information about the characteristics, which will facilitate the quicker and wider adoption of forthcoming technologies. Hence, this study is intended to identify the determinants of irrigated wheat varieties adoption process and suggest possible interventions to speed up the technology transfer process in the study area and elsewhere in the country with similar agro-ecology.

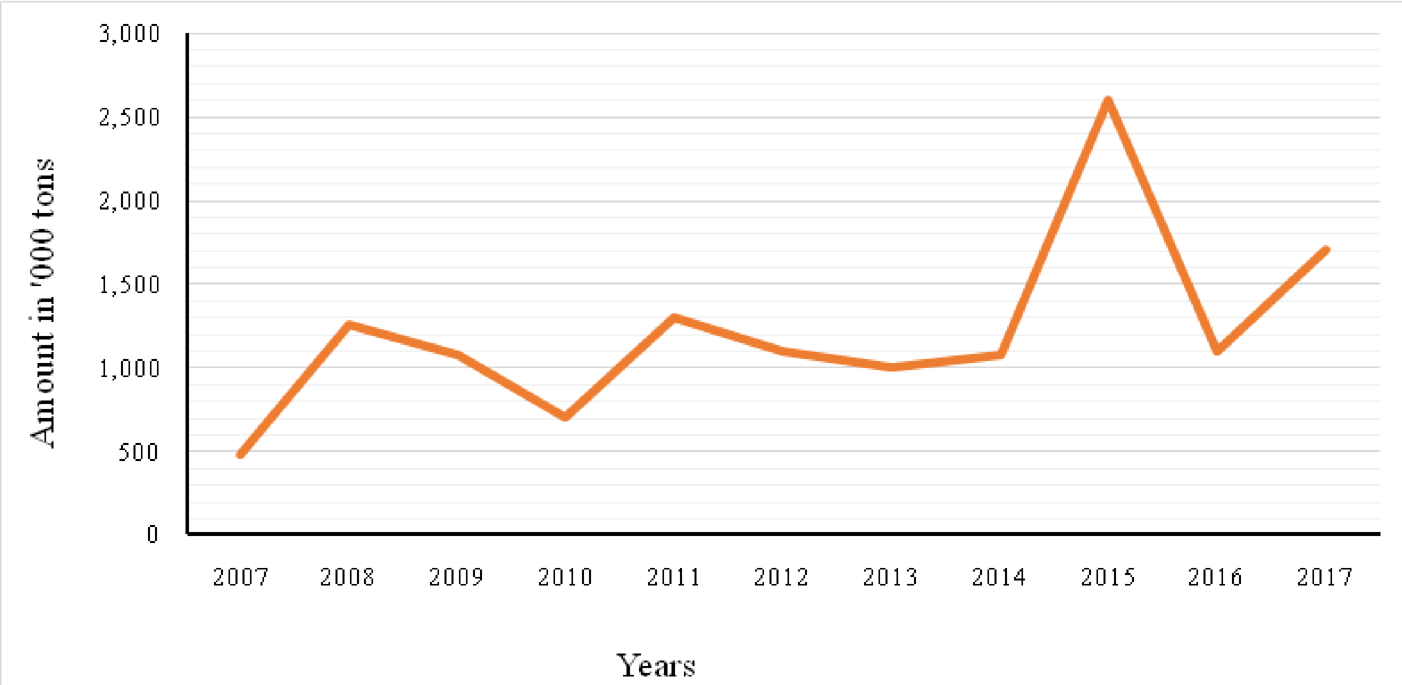

Fig. 1. Amount of imported wheat.
Source: USAID, 2016.

RESEARCH METHODOLOGY

Description of the study area

Data for this study were collected from Agro-pastoralists in Fentale district of Oromia regional states in the Upper Awash Valley of Central Rift Valley where irrigated agriculture was practiced among the hitherto completely pastoralist communities.

Fentale is one of the districts of East Showa zone of Oromia National Regional State, Ethiopia, located at about 198 km East of Addis Ababa in the Great Rift Valley lies between 8^0 54' north latitude and 36^0 23' to $39^0$54' east longitude. It is bordered on the southeast by the Arsi Zone, on the southwest by Boset district, on the northwest by the Amhara Region and on the northeast by the Afar Region. The average annual rainfall is 486 mm. It has a yearly maximum temperature ranges from 32 to 42 degree centigrade while the minimum temperature ranges from 10 to 22 degree centigrade. Most parts of this District range from 900 to 1000 meters above sea level; Mount Fentale (2007 meters) is the highest point. Rivers, which flow in the area, include the Awash and the Germama; Lake Basaka is an important body of water in this District. In eleven of the eighteen peasant associations of Fentale District, the predominant agricultural practice is pastoralism. Based on data from CSA (2012) Fentale District has an estimated human population of 95646, of which 50593 and 45053 were male and female, respectively. It has 18 peasant associations and 9,696 households out of which 26.5% are urban dwellers, which is less than the Zone average of 32.1%. With an estimated area of 1,521.78 square kilometers, Fentale has an estimated population density of 62.9 people per square kilometer, which is less than the Zone average of 181.7 (CSA, 2012). The *Karrayu* are still practicing pastoralism raring their livestock which mainly include cattle, goat, sheep, and camel, even though there are some indications of shift towards agro-pastoralism due to different external factors. Gebre (2009) writes that farming system to some extent appears to be clan specific, in which the majority of the *Karrayu* clan has been engaged in pastoral way of life, while the *Ittu* are mostly agro-pastoralists. The agricultural production system is mixed crop-livestock agricultural system whereby livestock production is a dominant system. Maize, onion, tomato and other vegetable and fruit crops are important and major crops in terms of quantity and area grown in study area.

Sampling technique and sample size

The target population of the study was the smallholder growers of irrigated crops in Fentale district. Multi-stage sampling procedure was used in the selection of representative sample. In the first stage, the district (Fentale) was selected purposively based on previous intervention efforts of introduction and popularization of irrigated wheat varieties. In the second stage, through a systematic random sampling procedure, four agro-pastoral administrative units (Kebeles) namely *Busie*, *Deresedin*, *Gidara* and *Seriweba* were selected. In the third stage, sample respondents were selected randomly. The sample size was computed based on Cochran (1977) and Kothari (2004) as:

$$n = \frac{Z^2 * N * P * q}{e^2(N-1) + Z^2 * p * q} \quad (1)$$

Where,

n = is the sample size, N = is the total target population size '*Z*' is the standardized normal deviation set at 1.96–95% confidence level, '*p*' is the estimated proportion of an attribute that is present in the population (.5), '*q'* is the estimated proportion of an attribute that is not present in the population (1 −*p*) (.5), and '*e*' is degree of accuracy required normally set at 10% alpha level. Accordingly, a total of 120 sample households were selected for this study.

Data collection and analysis

Semi-structured questionnaires were used to collect data through face-to-face interviews with representative sample of irrigated crop growers in Fentale district. The data collected included, among them, some household characteristics, socioeconomic aspects and institutional characteristics. The data were analyzed using STATA version 14. By classifying respondents into adopters and non-adopters, chi-square and t-test were applied to see associations and differences between adopters and non-adopters over different attributes. Binary logistic regression model was used to analyze the determinants influencing adoption decisions.

Model specification

In this study, regardless of the intensity, a household head was considered as an adopter if he or she sows any irrigated wheat variety for the last consecutive years including 2016/217 cropping year. The decision to either adopt or not adopt was treated as dependent variable and has a binary nature taking the value of 1 for adopters and 0 for non-adopters. In this regard, an econometric model employed while examining probability of farm households' agricultural technology adoption decision was the binary regression model. The binary model is motivated by the fact that, when faced with a decision regarding an innovation, a farmer either adopts or rejects the technology. The study applied a binary logistic regression model to analyze the factors influencing the adoption of irrigated wheat varieties. The logistic regression model was chosen because there is widespread literature showing that farmer adoption decisions can be analyzed using logistic regression and because of its mathematical convenience and simplicity (Greene, 2008). The logistic model predicts the logit of the response variable (adoption of irrigated wheat varieties) from the independent variable(s). The likelihood of the farmer being an adopter of irrigated wheat varieties is predicted by odds (Y = 1); that is, the ratio of the probability that Y = 1 to the probability that Y # 1:

$$Odd\ Y = \frac{P(Y=1)}{(1-P(Y=1))} \quad (2)$$

The binary logistic regression model is specified as follows (Equation (3)):

The logit (Y) is given by the natural log of Odds;

$$\ln\left(\frac{p(Y_i=1)}{(1-p(Y_i=1))}\right) = \log Odds = Logit(Y) \quad (3)$$

This can be expanded as

$$Logit(Y) = \alpha + \sum \beta_1 X_1 + \sum \beta_2 X_2 + \cdots + \sum \beta_n X_n + \varepsilon_i \quad (4)$$

Where, Y = dependent variable (adoption) with 1 = adopters and 0 = otherwise; *a* = intercept; β_1... β_n = coefficients of the independent variables; χ_1, ..., χ_n = the independent variables; P (p) = probability of adopting irrigated wheat varieties; 1 - P = probability that a farmer does not adopt irrigated wheat varieties; and ln = natural log.

With the independent variables of this model (χ_1 = age, χ_2 = gender, and so on), logistic regression for 'ADOPTION' in the study is expressed in the following form:

$$Logit(Adoption) = \ln\left(\frac{P}{1-P}\right) = \alpha + \beta_1 age + \beta_2 gender + \beta_3 edu + \beta_4 famly + \beta_5 lvstck + \beta_6 frmexpr + \beta_7 farmsize + \beta_8\ distwtrsrc + \beta_9 offfrmactv + \beta_{10} extncntct + \beta_{11} traning + \varepsilon_i \quad (5)$$

Given the dependent variable (adoption), to estimate the magnitude of parameters or variables the percentage probability of adoption, marginal effect of variables was calculated. Marginal effect of a variable is the effect of unit change of that variable on the probability of P *(Y = 1|X = x)*, given that all other variables are constant. The marginal effect is expressed as:

$$\frac{\partial p\,(Y_i=1/X_i)}{\partial X_i} = \frac{\partial E\,(Y_i/X_i)}{\partial X_i} = \varphi(X_i'\beta)\beta \quad (6)$$

Hypothesized Variables Influencing Adoption of Irrigated Wheat Varieties

The explanatory variables used in this paper were selected based on the adoption literatures that reflect farm and farmers' characteristics, institutional and access related attributes which are described as follows in Table 1:

RESULTS AND DISCUSSION

Descriptive Results

In this study, adopters are classified as farmers who planted any of the irrigated wheat varieties irrespective of the area planted, and non-adopters are those who did not cultivate any of wheat varieties.

Table 1. Explanatory variables, description and their priori expectation.

Variable	Description	Measurement	Hypothesis
SEXHHH	Sex of household head	Dummy (1=male, 0 otherwise)	+
AGEHHH	Age of household head	Continuous	+/-
EDULVLHHH	Educational level of household head	Dummy (1=literate, 0 otherwise)	+
FMLYSZAE	Family size in adult equivalent	Continuous	+
LVSTCKTLU	Livestock holding in TLU	Continuous	+/-
FRMEXPRNC	Farming experience (crop farming)	Continuous	+
FRMSIZE	Farmland size in ha	Continuous	+/-
DSTWTRSRC	Distance of farmland to irrigation water source	Continuous	-
NFACTVT	Non-farm activities	Dummy (1= yes, 0, otherwise)	+/-
EXTNCNTCT	Extension contact	Dummy (1= yes, 0, otherwise)	+
TRNEVNT	Participation in training and events	Dummy (1= yes, 0, otherwise)	+

Source: By authors; (+/-) indicates a positive or negative relationship with the dependent variable

The adoption status, demo-graphic, socio-economic and institutional characteristics of respondent households are described in Table 2.

Accordingly, only 18.33% of the sampled households were found to be adopters while the majority, 81.67% of the respondent households, were non-adopters of irrigated wheat varieties. As observed in the table, out of the total sampled respondents, 85.83% of them were male-headed households and the rest 14.17% were female-headed. This is an indication that male-headed households dominate farming in the study area, which is expected in pastoral and agro-pastoral context.The mean age of sampled household head was 36.79 years ranged between 25 to 63 years with 52.5% of them can at least able to read and write. Regarding the household size, expressed as Adult Equivalent (AE), the overall average family size of the sampled respondents was 4.88 members.

The farmland holding of respondents ranged from 0.25 to 2 hectares with mean holding size of 0.79 ha. On average farmers in the study area stayed 9.38 years in farming activities with a minimum and a maximum of 3 and 21 years. With respect to distance of the farmland from the main irrigation canal, the sampled farmers reported an average of 0.5 km. Furthermore, 48% and 30% of the respondents had accesses to extension services and trainings on irrigated wheat production practices respectively.

Table 3 presents the results of statistical significance tests on equality of proportion for discrete variables for adopters and non-adopters. There appeared to be a significant difference in level of education of the household head, access to extension services and training, and off-farm work participation among adopters and non-adopters, with the former being able to read and write and had more accesses to extension services and training as well as participated in off-farm activities. On the other hand, gender of the household head did not show significant difference between the adopters and non-adopters. This result agrees with the findings of Shiferaw and Tesfaye (2006) and Teshale *et al*. (2006).

Similarly, Table 4 describes the results of statistical significance tests on equality of mean for continuous variables of adopters and non-adopters. As shown in Table 4, age of household head and distance of the farmland from the main water source showed significant differences between adopters and non-adopters with the former being younger and nearer to the water sources. This result is in line with Shiferaw and Tesfaye (2006) and Mahdi E. *et al*. (2012) who reported negative and significant relationship between age and adoption of improved technologies.

Regarding the household size, expressed as Adult Equivalent (AE), the overall average family size of the sampled respondents was 4.88 members. The study further revealed that the mean family size of adopters was 4.87 while that of non-adopters was 4.88. Thus, the results showed that there was no significant different between adoption groups in terms of family size. Mahdi E. *et al*. (2012) also did not find significant different between household size and adoption of improved sorghum varieties. Further, livestock holding (TLU), farm size and farming experience did not show significant differences between adopters and non-adopters.

Factors Affecting Adoption Decisions of Irrigated Wheat Varieties

In order to achieve the objectives of the study, some demographic, socioeconomic and institutional factors that were hypothesized to affect the decision to adopt irrigated wheat varieties were included in the logistic regression model and the results are represented in Table 5. The marginal effects of the variables on the probability of the farmer's adoption of the irrigated wheat varieties, which were calculated on the mean values of the variables, are also presented in the same table.

From Table 5, it can be noticed that the likelihood ratio statistics as indicated by chi-square are highly significant ($P < 0.01$), suggesting that all the model parameters were jointly significant in explaining the dependent variable. The pseudo R^2 were 0.61 suggesting that the specification

Table 2. General characteristics of respondent households.

Variable	Description	Mean	Std. Dev.
IWV_adoption	1= if respondent plants IWV	0.183	0.389
Gender	1= if the head is male	0.858	0.350
Age	Age of household head in years	36.791	6.801
Level of educ.	1= if the head is literate	0.525	0.501
Family size	Number of household members in AE	4.882	1.402
Farm size	Cultivated area by household in hectare	0.785	0.316
Livestock size (TLU)	Number of livestock in TLU	10.951	5.211
Farm experience	Number of years the household involved in farming activities	9.375	4.339
Distance to water source	Distance of the farmland from water source in km	0.503	0.363
Extension access	1= if extension service is available	0.483	0.502
Training access	1= if the head received training on irrigated wheat	0.300	0.460
Off-farm activity	1= if participated in off-farm work	0.175	0.382

Source: Own survey data, 2016/17

Table 3. Summary statistics of households using discrete variables.

Variables		Adopters (n=22)		Non-adopters (n= 98)		Chi^2
		Frequency	Percent	Frequency	Percent	
Gender	Male	19	86.36	84	85.71	0.0062
Education level	Read and write	20	90.91	43	43.88	20.568***
Extension access	Yes	19	86.36	39	39.80	15.602***
Access to training	Yes	15	68.18	21	21.43	18.701***
Non-farm activities	Yes	8	36.36	13	13.27	6.639**

Source: Own survey data, 2016/17

Table 4. Summary statistics of household characteristics (continuous variables).

Variable	Adopters		Non-adopters		t-test
	Mean	Std. Err.	Mean	Std. Err.	
Age (years)	32.32	.831	37.79	.699	-3.579***
Family size (AE)	4.87	.248	4.88	.147	0.033
Livestock size (TLU)	11.16	.891	10.90	.549	0.206
Farm size (ha)	0.83	.060	0.78	.033	0.724
Farming experience (years)	9.86	1.099	9.27	.419	0.583
Distance from water source (km)	0.35	.027	0.54	.039	-2.227**

Source: Own survey data, 2016/17

*Note: **significant at 5%, ***significant at 1%*

fits the model well and the variables included in the model explain 61% of variation in the decision of adoption. The model has correctly classified more than 91 percent of the farmers adopting irrigated wheat varieties over the last couple of years, indicating the goodness of fit of the model. The results indicated that explanatory variables; level of education of household head, family size in adult equivalent, extension access to wheat, access to training and presence of off-farm activities have positively and significantly influenced the probability of being adopter. However, age of household head and distance to the main irrigation water source (main canal) had negative significant effect on the decisions of farmers to adopt irrigation wheat varieties (Table 5).

The binary logistic regression model results showed that the **age** variable is an important factor influencing the irrigated wheat varieties adoption decisions. The variable age of the farmer negatively influenced irrigated wheat adoption and was statistically significant at the 1% significance level (p = 0.008). The coefficient of the age of the farmer was negatively associated with the adoption of irrigated wheat adoption, which indicates the receptiveness toward technology among the younger farmers in the study area. This is in line with the findings of Berihun *et al.,* 2014; Gebregziabher *et al*., 2014; Hailu *et al*., (2014); and Jeleta *et al*., (2015). The possible justification is that older farmers are accustomed to conventional practices and are unlikely to change. On the other hand, Hagos (2016) and Kaleb and Workneh (2016) found a positive influence of age on agricultural technology adoption. The marginal effects, computed at the mean levels of the variables, result for age showed that the probability of being an adopter declines by 0.45

Table 5. Logit estimates of the probability of adoption decisions.

Variable	Coefficient	Std. Err.	Z	P > |z|	dy/dx
Gender	.7357	1.8740	0.39	0.695	.0056
Age	-.4684***	.1754	-2.67	0.008	-.0045
Level of educ.	2.6035**	1.1164	2.33	0.020	.0301
Family size	.9146*	.5298	1.73	0.084	.0088
Farm size	.1882	1.8300	0.10	0.918	.0018
Livestock size (TLU)	.0609	.0978	0.62	0.533	.0006
Farm experience	.1276	.1222	1.04	0.297	.0012
Distance to water source	-8.2822**	3.8873	-2.13	0.033	-.0793
Extension access	2.1638**	.9575	2.26	0.024	.0256
Training access	2.5292**	1.0233	2.47	0.013	.0497
Off-farm activity	2.4065*	1.2367	1.95	0.052	.0600
Constant	6.0738	4.6259	1.31	0.189	
LR chi^2 (11) = 69.64					
Prob > chi^2= 0.0000					
Log likelihood= -22.3497					
Pseudo R^2= 0.6091					
Correctly predicted= 91.67%					

*Note, *** = significant at 1%, ** = significant at 5% and * = significant at 10%.*

Table 6. Distribution of households by major constraints of irrigated wheat production.

Constraints	Response	Frequency	Percent	Rank
Lack of technical knowledge about the crop	Yes	75	62.50	V
Shortage of input supply	Yes	89	74.17	III
Low price of wheat grain	Yes	74	61.67	VI
Irrigation water shortage	Yes	84	70.00	IV
Lack of harvest and post-harvest machines	Yes	91	75.83	II
Bird attack	Yes	105	87.50	I

Source: Own survey, 2016/17.

percentage points as the age of the household increases by one more year.

The result showed that the coefficient for effect of **education level of household head** on adoption of irrigated wheat varieties was positive and statistically significant at 5% significance level. Households headed by literates are relatively more likely to adopt irrigated wheat varieties in the study area**.** This result confirms findings by Weir and Knight (2000) andZegeye *et al*, (2001). The probability to adopt irrigation wheat varieties increased by 3 percentage points as a household head becomes literate.

The coefficient of **household size** measured in adult equivalent, was found to be statistically significant (P<0.01) and positively associated with adoption of irrigated wheat varieties. This implies that increase in family size positively influences, through increasing the availability of labor, the decision to adopt irrigated wheat varieties. The more the number of household members the more likely the household to adopt the irrigated wheat varieties. This is perhaps because larger households seek to diversify income sources or/and ensure food security by growing crop/wheat. Assefa and Gezahegn (2010) reported a similar result on the adoption of improved technologies in Ethiopia. When family size increases by one more member (in adult equivalent), the probability of farmers becoming an adopter increases by 0.09 percentage points.

Distance to irrigation water source was negatively related with adoption of irrigated wheat varieties and negatively and statistically significant at 5% level of significance. The negative sign indicates the importance of proximity to irrigation water sources leading to minimizing the risk of water shortage. Proximity of farmlands to main irrigation water source is essential for timely delivery of water and less canal maintenance and fuel costs. Producers' reluctance in adopting irrigated wheat technologies mainly steams from lack of irrigation water where the technology is in question for increasing yield rather believed to damage the productive potential of crops sown. Due largely to this reason, if farmland gets far from the water source, the probability of adopting the intended technology was found to be low. Hence, due to distributional and irrigation canal maintenance problems, as distance from the nearest irrigation water source increases by one kilo meter, the probability of being an adopter of irrigated wheat varieties decreases by 7.9 percentage points.

In line with a priori expectation, **extension contact** has been found to have positive and significant ($P<0.1$) effect on adoption of irrigated wheat technologies. The magnitude of positive sign shows that, farmers who had extension contacts are 2.6 percentage points more likely to adopt irrigated wheat varieties unlike non-visited or non-contacted counterparts. Therefore, farmers who have more frequent visits from extension workers are more likely to adopt technologies or farming practices that they are exposed to through extension services. The result shows the important role played by extension agents as sources of information that influence adoption of irrigated wheat varieties. The findings are consistent with the works of Admassie and Ayele (2010) and Beshir *et al*. (2012).

Training is one of the extension events where by farmers get practical skill and technical information for new technology. Results of the study indicated that adoption of irrigated wheat varieties was positively and significantly affected by acquiring training at 5% significant level (Table 5). This may be explained by the fact that farmers who have training gain better knowledge on production practices and technologies than non-trained. The implication is that emphasis has to be given to farmers' improved technology package through training to enhance adoption of irrigated wheat varieties. The result is agreed with findings to Tesfaye *et al*. (2001). Similarly, the probability of being an adopter increases by 4.5 percentage points as farmers have access to trainings.

Participating in different off-farm activities was found to have a positive and significant relationship with irrigated wheat adoption decision, which is statistically significant at 10% level of significance. Off-farm income could best be taken as an important ingredient of adopting new agricultural technologies in such a way that farmers could easily afford purchased inputs; and these farmers are mostly exposed to new and updated information since they move from one town to another and contacted with different people with different background. Due to this reason, off-farm participants, citrus paribus, have 6-percentage point higher probability of adopting irrigated wheat varieties unlike off-farm non-participants.

Constraints of Irrigated Wheat Production

There are many factors that are directly or indirectly deter production ofirrigated wheat varieties in the study area. Table 6 reports distribution of households by major constraints of irrigated wheat production. Accordingly, bird attack was the most serious constraint of irrigated wheat production reported by 88% of the respondents. Lack of harvest and post-harvest machineries, shortage of input supply (seed, chemical fertilizers, herbicides) and irrigation water shortage were the other production challenges reported by 76%, 74% and 70% of respondents respectively.

Respondents also mentioned lack of technical knowhow (63%) and low price of wheat grain (62%) as challenges of irrigated wheat production.

CONCLUSION AND RECOMMENDATION

The study analysed the rate and determinants of adoption of irrigated wheat varieties by taking Fentale district of north-eastern Ethiopia as a case study. The study employed logit econometric model based on data collected from 120 irrigated wheat growing farm households drawn from *Busie*, *Deresedin*, *Gidara* and *Seriweba* pastoral kebele administrations of Fentale district.

Results of descriptive statistics revealed thatthe majority of irrigated wheat farmers were headed by male and possessed less than one hectare of farmland size. Further, the chi-square test showed that there were significant differences in age and education of household head, access to training and extension services, distance to the water source and participation of non-farm activities between the adopters and non-adopters. The rate of adoption of irrigated wheat varieties in the study area was only 18.33%. This can be considered as good sign from the point of view the time when the technologies are generated and diffused.

The econometric model results of the study revealed that the factors influencing the probability of adoption were age, education of household head, family size,distance of farmland to irrigation water source, accesses to extension services and trainings as well as participation in off-farm activities.Youngers were more adopters of irrigated wheat varieties than elder counterparts, which indicates the receptiveness of younger farmers towards technology. Distance to irrigated water source negatively and significantly influenced adoption of irrigated wheat varieties in the study area. Access characteristics like, extension services, trainings and off-farm activities had positively and significantly explained the adoption of irrigated wheat varieties. Similarly, both level of education and family size positively and significantly influenced the adoption of irrigated wheat varieties.

The following are recommendations drawn from this study in relation to adoption of irrigated wheat varieties in the study area.

The study has shown the importance of extension contacts in promoting new technologies. It also managed to show that extension access alone is not enough; continuous and extensive theoretical and practical training is critical in determining the level of adoption. Based on the findings of this study, it is important to make consideration in targeting large households and younger farmers who are more likely to be adopters. However, the attitude of older farmers to wards new technologies need to be changed through extensive practical and theoretical trainings.

To enhance the adoption of irrigated wheat technologies, there is a need to change the mindsets of the farmers in the community. Thus, there is a need to train farmers on irrigated agricultural technologies to improve their appreciation especially in areas where farmers have limited or no opportunities and exposures to such technologies either formally or informally. Moreover, irrigation problems need to be given emphasis by introducing new system or by redesigning the irrigation canals.

Acknowledging the dynamism of technology adoption and diffusion, similar research should be conducted after certain years on the levels and determinants of adoption of irrigated wheat varieties in the study and similar areas.

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