Determinants of Adoption of Improved Open Pollinated Varieties of Maize in Drought Prone Areas of Central Ethiopia

Bedru Beshir (Graduate School of International Development, Nagoya University)
Koichi Usami (Graduate School of International Development, Nagoya University)
Yoshiaki Nishikawa (Graduate School of International Development, Nagoya University)

エチオピア中部の干ばつ常襲地域における農民のトウモロコシ放任受粉改良品種採用を規定する要因

ベドル　ベシール（名古屋大学大学院国際開発研究科）
宇佐見晃一（名古屋大学大学院国際開発研究科）
西川　芳昭（名古屋大学大学院国際開発研究科）

エチオピア中部の干ばつ常襲地域では，高収量かつ干害耐性の放任受粉品種が導入されたにもかかわらず，トウモロコシの単収が低い．収量が安定して種子の再生産が可能であるトウモロコシ放任受粉品種が勧奨され，品種の選抜と伝播に農民を取り込んだ農民参加研究グループが研究・普及手法として実施されている．本研究の目的は，農家聞取調査によって収集したデータをロジットモデルで分析し，トウモロコシ放任受粉改良品種の採用を規定する要因を明らかにすることである．分析の結果，トウモロコシ放任受粉改良品種採用において，農地面積及び農民参加研究グループは採用を促し，最寄り穀物市場までの距離及び干ばつ頻度は採用を抑えていた．エチオピアの他の干ばつ常襲地域では，干害による低い単収という問題をトウモロコシ放任受粉改良品種採用の向上によって解決する場合，農民参加研究グループという研究・普及手法は有効である．

1. Introduction

Maize is a major cereal crop in Ethiopia contributing 21% of the daily calorie requirements of the population (Rashid, 2010). Increasing the yield of maize is vital to maintain farm household food security, particularly in drought prone areas such as Central Rift Valley areas of Ethiopia where 46% of the cultivated area is allocated to maize and maize constitutes nearly two-thirds of the crop production. To increase the maize productivity, Ethiopia has pursued the application of improved variety seeds and accompanying inputs, focusing on high rainfall areas. Meanwhile, areas of low rainfall had virtually been forgotten by maize research and extension. In the past two decades, however, substantial amounts of resources have been devoted to the development of improved maize varieties, including those for drought prone areas, and about half a dozen improved open pollinated varieties (OPVs) of maize were released. The research and extension of maize has employed a new approach namely Farmer Research Group (FRG). An FRG approach refers to a farmer participatory research method through which a research team, extension workers and groups of farmers jointly conduct trials on farmers' fields on selected topics, which are based on the needs of farmers. Accordingly, FRG based improved OPVs of maize selection, seed production and dissemination was implemented on farmers' fields at their residence *Kebeles*[1].

As far as OPVs and hybrid maize are concerned, each has its own advantages and disadvantages. OPVs are composed of plants of different genetic makeup that respond differently to environmental stresses, such as drought, and they are more stable in yield. OPVs have different flowering dates, which is a useful mechanism to withstand intermittent short drought stress crop failure. The seed of

OPVs can be recycled for an average of three years without considerable yield reduction thus, suitable for small-scale farmers. On the other hand, hybrids are high yielders, needing more stable moisture conditions and intensive management. Hybrids have uniform flowering dates and are highly affected by any window of drought particularly during flowering, therefore less stable in yield than OPVs. Furthermore, hybrid seed has to be renewed every year.

Thus, open pollinated varieties are considered more suitable in drought prone areas where drought is a major yield-limiting factor. Seed production of OPVs is cheaper because farmers can maintain part of their grain produce or obtain from local sources. Seed, especially from OPVs, is affordable and a scale-neutral agricultural input that is expected to be readily adopted by small-scale farmers of Ethiopia. In this aspect, OPVs of maize seed is a high priority over hybrids.

Nevertheless, the average productivity of maize is still low in drought prone areas. In Ethiopia, drought prone growing areas consist of approximately 40% of the maize growing area yet contribute only 20% of the total production. That is mainly because the adoption rate of improved maize seed is low and farmers continue using varieties, which are old and do not have drought tolerance traits. Thus, the understanding and analysis of the factors influencing the adoption of improved OPVs of maize in this area is a question of empirical research.

Therefore, this paper aims to analyse factors influencing the adoption of improved OPVs of maize in drought prone areas of Central Ethiopia.

2. Methodology

(1) Study area and data collection

A cross-sectional sample survey was conducted in the East Shewa Zone, Ethiopia. The area is characterized by drought prone agro-ecology where moisture is scarce and the rainfall pattern is variable. The evapotranspiration rate is in excess of the rainfall in most months except for two to four rainy months of the year. The mean annual rainfall is 768 mm, with annual minimum and maximum mean temperatures being 12.6 and 28.5°C. The soil of the area is light, loose, and porous with low water holding capacity. The soil is of volcanic origin and fragile, thus easily eroded by rain.

Data for this study were collected through a farm household survey conducted in 2011, employing a multi-stage sampling procedure. The East Shewa Zone was purposively selected considering its drought prone agro-ecology, area allocated to maize production and experience in employing the Farmer Research Group approach. Indeed, 4 out 10 districts of the zone: Adama, Boset, Dugda and Adami-Tulu-Jido-Kombolcha (ATJK) were selected based on area allocated to maize production. Subsequently, thirteen maize producing *Kebeles* were randomly selected. Finally, 277 farm household heads were randomly chosen from agricultural land use taxpayer lists of their respective District Revenue Offices. Structured questionnaires were employed to solicit information through face-to-face interviews.

(2) Analytical framework: model and variables

The adoption decision of an improved variety is assumed to be the product of a complex preference comparison made by a farm household. Factors influencing the adoption of improved varieties can be estimated using Logit, Probit or Tobit models. A farm household decision to adopt improved varieties is assumed to be a dichotomous outcome of adoption or non-adoption. Hence, when the outcome is a dichotomous dependent variable measured by a nominal dummy, either Logit or Probit Models can be employed. A choice between the two models is sticky since both models provide equally efficient parameter estimates (Demaris, 1992). Nonetheless, when continuous independent variables are included in the model, the Logit Model well fits for testing the hypotheses about relationships between categorical outcome variables and one or more categorical or continuous independent variable. Shakya and Flinn (1985) suggested the application of the Probit Model for the functional form with limited dependent variables that are continuous between 0 and 1 and the Logit Model for dichotomous dependent variables. On the other hand, the Tobit Model assumes the outcome variables to be in continuous scale, which is cut-off or censored at some particular value. Hence, the Tobit Model is not suitable for the estimation of dichotomous dependent variables. Therefore, the Logit Model was selected since the dependent variable is dichotomous and the independent variables are constituted from both categorical and continuous variables.

Logit Model (Menard, 2002) for the log odds of adoption of improved OPVs of maize can be specified as:

$$\text{Logit (Y)}=\beta_0+\beta_1X_1+\beta_1X_2+\ldots+\beta_kX_k$$

The logit (Y) can be converted to the odds by exponentiation, [odds that Y=1]=$e^{\text{logit(y)}}$

$$\text{Odds (Y=1)}=e^{\ln[\text{odds(Y=1)}]}=e^{\beta_0+\beta_1X_1+\beta_2X_2+\ldots+\beta_kX_k}$$

A change of one unit in an independent variable (X) multiplies the odds by e^{β}. The odds can be converted back to the probability that (Y=1) by the formula P (Y=1)=[odds that Y=1]/[1+odds that Y=1]. The equation is given by the formula:

$$P(Y=1)=\frac{e^{(\beta_0+\beta_1X_1+\beta_2X_2+\ldots+\beta_kX_k)}}{1+e^{(\beta_0+\beta_1X_1+\beta_2X_2+\ldots+\beta_kX_k)}}$$

The model assumes dichotomous results of binary response of adoption (as 1) and absence of adoption (as 0). Y stands for the conditional probability that a farmer adopts improved OPVs of maize, while (1-Y) represents the conditional probability that a farmer does not adopt improved OPVs of maize; βs are coefficients of independent variables; and Xs are independent variables.

The choice of independent variables in this study is based on the review of literature of adoption studies, preliminary observation and discussions with groups of farmers to refine the independent variables, as there is no firm economic theory that dictates the choices of independent variables in adoption studies.

Adoption literature suggests that a farmer's decision to adopt an agricultural technology depends on farm household socio-economic, institutional and environment factors (Mariano *et al*., 2012; Feder *et al*., 1985). It is expected that a farm household head's decision to adopt, or not to adopt an improved variety is influenced by a combined effect of a number of factors related to the farmer's objectives and constraints. The analysis on adoption assumes that there exists an innovation and the study of adoption decisions evaluates determinants for adoption (Alene *et al*., 2000). Empirical studies conducted in high rainfall areas in Ethiopia and elsewhere (Feleke and Zegeye, 2005; Gemeda *et al*., 2001) present a range of factors such as gender, age, education, landholding, livestock holding, extension visits, etc. to explain the adoption of improved maize varieties. The results of those factors are not consistent and vary from study to study.

Therefore, the Logit Model for adoption of improved OPVs of maize is specified as follows.

$$OPVA=\beta_0+\beta_1(Gnd)+\beta_2(Age)+\beta_3(Hhsiz)+\beta_4(Edc)+\beta_5(Frmsz)+\beta_6(Ox)+\beta_7(Extn)+\beta_8(Fld)+\beta_9(Tmkt)+\beta_{10}(FRG\_K)+\beta_{11}(RC\_dist)+\beta_{12}(Drght)+\beta_{13}(Alti)$$

OPVA represents open pollinated varieties of maize adoption; Gnd, gender; Age, age; Hhsiz, household size; Edc. education of household head; Frmsz, farmland size; Ox, oxen owned; Extn, extension visit; Fld, field day participation; Tmkt, time taken to the nearest grain market; FRG_K, being in a Farmer Research Group *Kebele* or otherwise; RC_dist, distance to Agricultural Research Centre; Drght, frequency of drought encountered; and Alti, altitude.

Factors influencing the adoption of OPVs of maize in the drought prone areas can be categorized into three areas. First, human and physical resource endowments, including gender, age, education, household size, farmland size and number of oxen owned. Female headed households are often poor and their access to information and innovations is limited, thus negatively influencing their adoption. Age is a proxy for farmer experience in farming that can generate or erode a confidence to adopt improved varieties. Household size accounts for household farm labour since an intensive management is required for the optimum yield from improved variety. Education of the household head is expected to influence a farmer's adoption decision since it boosts the capacity of the farmer in acquiring, processing and utilizing information. Farmland and livestock are key assets of a farm household. Within livestock, oxen provide extensive draught power. Hence, a farm household's ownership of farmland and oxen is anticipated to positively influence the likelihood of adoption of improved OPVs of maize.

Second, extension visits, field day participation, the time taken to the nearest grain market, membership in FRG *Kebele* and proximity to an Agricultural Research Centre constitute the institutional factors influencing adoption of improved OPVs of maize. Extension visits are presumed to be a major means for farmers to access new and reliable agricultural information and thus is expected to positively influence the adoption decision. A farmer's participation on field days demonstration of improved OPVs of maize is a means to develop a confidence and reduce subjective uncertainty about the variety and thus it is expected to positively influence the likelihood of adoption. Distance to the nearest grain market is a proxy to market accessibility. Farmers residing close to the nearest grain markets are assumed to have access to up-to-date information on the availability of agricultural inputs and outputs, including improved varieties, and hence expected to adopt improved OPVs of maize. Farmer Research Groups (FRG), a family of farmer participatory research, it has been implemented in Ethiopia to identify, release and multiply farmer preferred varieties. In the

FRG approach, farmers are involved in a series of research and extension activities, such as maize variety evaluation and selection, seed production and dissemination activities. Thus, FRG *Kebele*, where farmer participatory research has been conducted, is expected to have a positive influence on the likelihood of adoption of improved varieties.

The third category includes environmental characteristics, namely altitude and drought. In Ethiopia, altitude is the salient feature that alters both temperature and rainfall. The altitude is expected to positively influence the likelihood of adoption of improved OPVs of maize. Drought is a major challenge of crop production particularly in the study area. Drought risk was proxied by the number of substantial yield stress encountered in the past ten years. In drought prone areas, improved variety adoption studies are scarce. The focus of previous adoption studies were on high rainfall areas for its anticipated promising results.

3. Results

(1) OPV maize growing farm households

The basic characteristics of the sample farm households are shown in Table 1. Female-headed households constitute about 16% of the total 277 sample farm households. On average, a household constitutes about 7 persons, headed by 41 years-old adult with a low level of education (2 years). The adoption rate of improved OPVs of maize is still low, 29%. Male household heads tend to more readily adopt than the female household heads.

There was no significant difference between adopters and non-adopters in both their average age and household size. Adopters tend to own larger farmland and more oxen than non-adopters do. Both adopters and non-adopters have the same level of access to extension services as measured by visits. Distance to the nearest grain market is shorter for adopters compared to non-adopters. Drought that substantially stressed maize yields was encountered, on average, three times in the last ten years and the frequency of substantial yield stress encountered tends to be higher among non-adopters. Adopters more frequently participated in field days than non-adopters. Indeed, farmers in FRG *Kebeles* tend to be more readily better adopters than those in non-FRG *Kebeles* do (significant at 1%).

(2) Determinants of adoption of improved OPVs of maize

The independent variables that have shown significant differences between adopters and non-adopters were entered into the Logit Model (Table 2). Prior to running the Logit Model, the presence of multicollinearity among the independent variables was checked using the Variance Inflation Factor (VIF)[2]. Since the highest VIF obtained was 2.7, far less than the threshold 10, there was no problem of multicollinearity.

Results of the Logit Model estimation are presented in

Table 1. Descriptive summary of maize grower sample farm households

Independent variable	All respondents (N=277)	Adopter (N=80)	Non-Adopter (N=197)	F
Gender of the HHH (% male)	84	91	85	3.96*
Age of the HHH (years)	41	40	42	0.95
Household size (persons)	6.7	7.1	6.5	2.06
Schooling of the HHH (year)	2	3	2	6.35*
Farmland size (ha)	2.36	2.68	2.23	5.57*
Oxen owned (head)	2.4	2	1.7	4.52*
Extension visit (times per month)	2.4	2.5	2.4	0.39
Field day participation (%)	20	30	17	3.72
Time to the nearest grain market (minute)	94	83	98	5.14*
FRG *Kebeles* (%)	20	46	10	56.58**
Distance from Agricultural Research Centre (km)	89	92	80	0.26
Drought encounter frequency (in recent ten years)	2.7	2.3	2.9	13.0**
Altitude (m)	1560	1543	1568	2.48

Notes: 1) HHH=Household head
2) * and ** denote statistical significance at 1% and 5%, respectively.
Source: Field survey data

Table 2. Result of Logit Model for adoption of improved OPVs of maize

Independent variables	β	Wald	Sig.	Exp (β)
Gender of the HHH	.611	1.479	.224	1.841
Schooling of the HHH	.018	.114	.736	1.018
Farmland size	.047	2.394	.122	1.048
Oxen owned	–.035	.062	.803	.965
Time to the nearest grain market	–.005	1.970	.160	.996
Field day participation	.287	.607	.436	1.333
FRG *Kebele*	1.848	28.126	.000	6.344
Drought encounter frequency	–.330	6.806	.009	.719
Test		χ^2	P	
Likelihood Ratio (LR) χ^2 (8)		59.88	0.000	
Wald χ^2 (8) statistic		45.81	0.000	
Percent of correct prediction		77.6		
Cox and Snell R^2		.20		
Nagelkerke R^2		.28		

Note: HHH=Household head
Source: Field survey data

Table 2. The model is well fitted to the data as shown by the likelihood ratio χ^2 59.88 ($p<0.001$). The null hypothesis, that all the variables could be dropped, was also rejected at 1% level of significance since the Wald χ^2 45.81 ($P<0.001$).

The factors influencing the adoption of improved OPVs of maize included farmland size, distance to grain markets, drought encountered and FRG *Kebele*. Distance to the nearest grain market was negatively associated with the log odds of adoption of improved OPVs of maize. The frequency of substantial yield stress encountered was found to be negatively and significantly associated with the log odds of the adoption of improved OPVs of maize ($P<0.01$). The log odds of adoption of improved OPVs of maize was found to be strongly and positively associated with FRG *Kebele*.

4. Discussion

Adoption of an improved seed is a dynamic decision making process of introducing agricultural technology into the existing farming system. The decision involves a number of factors that are related to human and physical resource endowments, as well as institutional and agro-ecology conditions. In this study, adoption of medium maturing improved OPVs of maize released and introduced within the past ten years was considered.

Farmland size was shown to positively influence the adoption decision of improved OPVs of maize in the drought prone area of Central Ethiopia. This is in line with the finding of Alene and Hassan (2000) but in contrast to that of Gemeda *et al*. (2001). Distance to the nearest grain market was found to be negatively associated with the likelihood of adoption. Similarly, Feleke and Zegeye (2005) noted the negative and significant association of market distance with adoption of improved maize. This indicates that a farmer living at a distance from market centres is less likely to adopt improved maize varieties than those who are located closer.

Strong association of adoption decision of improved OPVs of maize comes from FRG *Kebele*. Farmers in FRG *Kebeles* were found to be more readily adopted compared to those who were in the non-FRG *Kebeles*. The FRG *Kebeles*, where farmers conducted variety testing and seed multiplication, had an overriding positive influence on the adoption of improved OPVs of maize. Farmers in FRG *Kebeles* were over six times more likely to adopt improved OPVs of maize than the farmers in non-FRG *Kebeles*.

A possible explanation can be because FRG members are in collaboration with researchers and agricultural experts involved in variety evaluation, selection, seed production and dissemination of improved OPVs of maize. Thus, the FRG activities had enhanced other farmers' access to improved OPVs of maize seed. This approach can be employed in similar drought prone areas of Ethiopia to disseminate improved OPVs of maize and help in mitigating food insecurity problems at large.

The frequency of substantial yield stress encountered due to drought was negatively associated with and depressed the adoption of improved OPVs of maize. The negative effect of drought on the adoption of improved variety was observed in previous works (Feder *et al*., 1985). This effect can be tackled by adopting drought tolerant and early maturing varieties tested under farmer participation, like FRG approach for example. The FRG *Kebele* as a proxy for FRG approach found to be the most influential factor in improved OPVs maize adoption. The issue concerning the characteristics of the FRG members which are essentials in enhancing adoption is a point for consideration for further study in explaining OPVs maize adoption in drought prone areas.

5. Conclusion

This study analyzed factors influencing the adoption of improved OPVs of maize, taking farmers resource endowment, institution and agro-climatic conditions into account. Among the resource endowment factors, farmland size positively influences the adoption of improved OPVs of maize. On the other hand, the adoption decision of improved OPVs is negatively influenced by distance from the nearest grain market. The frequency of substantial yield stress encountered due to drought is an impediment to adoption of improved OPVs of maize and is of concern for mitigation through adoption of improved drought tolerant varieties. The finding of the importance of FRG *Kebeles* in the adoption of improved OPVs of maize is interesting, where its influence was found to be significantly high for improved OPVs adoption. It suggests that this approach can be employed as an effective tool in the introduction of improved OPVs of maize to enhance adoption in similar drought prone areas of Ethiopia in contributing to food security.

Notes

1) *Kebele* is the lowest administrative unit in Ethiopia.
2) Variance inflation factor (VIF) is used for testing the multicollinearity. VIF is greater than 10 is considered problematic.

References

［1］Alene, A., D. Poonyth, and R. Hassan. Determinants of Adoption and Intensity of Use of Improved Maize Varieties in the Central Highlands of Ethiopia: A Tobit Analysis. *Agrekon* (12, 2000), pp. 633–643.

［2］Demaris, A. *Logit Modeling: Practical Applications*. London, International Educational and Professional Publisher, (1992), p. 87.

［3］Feder, G., R. Just, and D. Zilberman. Adoption of Agricultural Innovations in Developing Countries: A Survey. *Economic Development and Cultural Change*, (1,1985), pp. 255–298.

［4］Feleke, S. and T. Zegeye. Adoption of improved maize varieties in Southern Ethiopia: Factors and strategy options. *Food Policy*, (12, 2005), pp. 442–457.

［5］Gemeda, A., G. Aboma, H. Verkuijl, and W. Mwangi. *Farmers' Maize Seed Systems in Western Oromia, Ethiopia*. Mexico, D.F., International Maize and Wheat Improvement Center (CIMMYT) and Ethiopian Agricultural Research Organization (EARO), (2001), p. 32.

［6］Mariano, M. J., Villano, R. and Fleming, E. Factors influencing farmers' adoption of modern rice technologies and good management practices in the Philippines. *Agricultural Systems* (4, 2012), pp. 41–53

［7］Menard, S. (2002). *Applied Logistic Regression Analyis. California*,. Sage Publications, Inc., p. 111.

［8］Rashid, S. Variation in staple food prices: Causes, consequence, and policy options. African Agricultural Marketing Project (AAMP, Maputo, (2010), p. 14.

［9］Shakya, P. B. and J. C. Flinn, Adoption of modern varieties and fertilizer use on rice in the Eastern Tarai of Nepal. *Journal of Agricultural Economics*, (1985), pp. 409–419.

（受理日：2013 年 3 月 4 日）