Journal of Applied Agricultural Economics and Policy Analysis, 2019, Vol. 2, No. 1, 16-21
Available online at http://pubs.sciepub.com/jaaepa/2/1/3
Published by Science and Education Publishing
DOI:10.12691/jaaepa-2-1-3

Drivers of Adoption of Conservation Agriculture Practices in Maize-based Production Systems in Eastern Uganda and Western Kenya

Dorothy Birungi Namuyiga*, Bernard Bashaasha

Makerere University, School of Agricultural Sciences, Department of Agribusiness & Natural Resource Economics, P.O Box 7062, Kampala, Uganda
*Corresponding author: dbirungi8@gmail.com

Received December 12, 2018; Revised January 15, 2019; Accepted February 16, 2019

Abstract Increasing crop yields sustainably appears to be the only way out of the chronic decline in food availability and climate change effects in Sub-Saharan Africa, given the growing populations, shrinking farm sizes and degrading soils. The adoption of soil fertility technologies for example, conservation and inorganic fertilizer is still very low especially in Uganda. To date, no study has investigated factors that affect farmers' adoption of these technologies in Eastern Uganda (Tororo and Kapchorwa districts) and western Kenya (Bungoma and Trans-Nzoia districts). The objective of the study was to analyze the factors that influence choice of adoption of Conservation Agriculture (CA) practices in maize-based production systems in the region. Ordered Probit model was employed to analyze determinants of adoption. The study used cross sectional data from 790 randomly sampled respondents. Fifty-seven percent of the respondents had adopted CA and had an average of 45 years, household size of seven members, average land owned was 3 acres and distance travelled to access input and output markets was 1.2 Km. Factors that affected the different levels of adoption included maize variety planted, use of hired labor and access to input credit. Policies that will lead to increased investment in better infrastructures, increased investment in provision of extension services and subsidy programs for agricultural inputs are recommended.

Keywords: *conversation agriculture, maize-base production systems, ordered probit model, Eastern Uganda and Western Kenya*

Cite This Article: Dorothy Birungi Namuyiga and Bernard Bashaasha, "Drivers of Adoption of Conservation Agriculture Practices in Maize-based Production Systems in Eastern Uganda and Western Kenya." *Journal of Applied Agricultural Economics and Policy Analysis*, vol. 2, no. 1 (2019): 16-21. doi: 10.12691/jaaepa-2-1-3.

1. Introduction

With growing population, shrinking farm sizes, and rapidly degrading soil, increasing crop yields sustainably appears to be the only way out of the chronic decline in food availability in Sub Saharan Africa (SSA), [1,2]. This realization has triggered renewed attention to enhancing agricultural productivity growth in Africa since the early 2000s [3]. At the minimum, a doubling of agricultural yields is required over the coming decades [4] in economies where a majority of the populations depend on smallholder rain fed farming for their livelihoods. Inappropriate agronomic practices have led to enhanced soil erosion, estimated in the order of 5-10t/ha/yr [5].

Many of the farming systems especially monocultures in the region are far from their productive potential while accelerated economic growth in Africa now offers demand-side opportunities for agriculture [6]. To sustainably increase crop productivity, increased investments in nutrient additions to the soil are essential and globally agreed upon [7]. Agricultural productivity growth can be achieved through a number of ways including the use of fertilizers (both organic and inorganic) and Conservation Agriculture Practices (CAPs)[1] including mulching, cover cropping and minimum/no tillage, among other options.

Conservation Agriculture (CA) revolves around three main principles: minimum soil disturbance; permanent soil cover, primarily by retaining crop residues as mulch; and crop rotation, especially with legumes [8]. Proponents argue that the potential benefits of CA can be equally extended to Africa and Asia regions [8,9], largely dominated by smallholders.

In practice, farmers have been found not to adopt all the principles of CA due to several reasons such as limited access to inputs (herbicides, cover crop seeds), labor constraints, or insufficient resources to grow cash crops [10,11,12]. What farmers practice may therefore be quite

[1] Conservation Agricultural Practices (CAPs); the simultaneous application of minimum soil disturbance, crop residue retention, and crop diversification is a key approach to address declining soil fertility and the adverse effects of climate change in Southern Africa (Thierfelder, C., et al., 2018).

different from the ''ideal'' CA developed in on-station trials so that it is less certain what benefits are actually realized by farmers [13]. Adoption of CA was, however, has been reported to be low mainly due to lack of training, poverty and land ownership issues [12].

Although there has been certain agricultural productivity growth in SSA during the past several decades, especially for cereals, current growth lags far behind that in other regions of the world and is well below what is required to meet food security and poverty reduction goals. For example, studies in Western Kenya consistently reported that maize yields are lower than the expected yields based on research recommendations [14], the annual maize yield in the region was 27% less than the potential yield (1.80 against 6.67 tons ha^{-1}) [15]. SSA displays the greatest gaps between potential yields and actual yields for a number of crops, particularly maize and rice [16].

Generally, inadequate awareness and skills on soil-fertility improvement technologies still prevails amongst small holder farmers in the region. Several studies in Uganda (for example; [17,18,19,20]), others in Kenya (for example; [14,21,22]), have investigated the factors affecting the use of only inorganic fertilizers. Therefore, this study is addressing the gaps in the use of CA practices as soil fertility improving technologies to achieve sustainable food production in the region.

The main objective of the study was to assess factors affecting the integrated adoption of three CA practices as a means to enhance sustainable soil fertility in maize-based production systems in Eastern Uganda and Western Kenya. Specifically, adopters of CA in the study region were characterized and the drivers for the adoptions identified.

2. Materials and Methods

2.1. Study Area, Survey Design and Data Collection

The study area comprised four districts: Tororo and Kapchorwa districts in Eastern Uganda, Bungoma and Trans-Nzoia districts in Western Kenya. These districts were selected for inclusion in the East Africa CAPS project because of their agro-ecological and geographical locations. Tororo and Bungoma districts are both located in low lying areas that experience bimodal rain patterns and low soil fertility. In contrast, Kapchorwa and Trans-Nzoia districts are located at relatively high altitudes and have higher agricultural potential with a single long rainy season. The four districts have high human population density and rampant poverty. Farming in these areas is characterized by low input and low-output systems. Maize, the staple food crop, dominates the cropping pattern and is often intercropped with beans.

The data used in this study was collected during the East Africa CAPS household baseline survey in Uganda and Kenya. The survey was conducted by three local NGOs (AT-Uganda, Manor House agricultural center, and SACRED-Africa in Kenya). Design of the baseline survey was a collaborative effort between the NGOs, Makerere University in Uganda, Moi University in Kenya, University of Wyoming (USA), and other individual collaborators in the East Africa CAPS project.

The survey employed a two-stage stratified sampling procedure in which each of the four districts formed a sampling stratum in the first stage. Tororo and Bungoma represented low agricultural potential areas, while Kapchorwa and Trans-Nzioa represented high agricultural potential areas. All sub-locations/sub-counties within each stratum were identified using the latest population census in each country; fifteen of these sub-locations were sampled for the study. The second stage of sampling involved constructing a list of all households in each stratum, with help from local administrators. In total, 790 households were sampled, including 202 households from Tororo district, and 200, 188 and 200 households from Kapchoprwa, Bungoma and Trans-Nzoia districts, respectively.

Structured questionnaires were used to collect data. They were administered through face-to-face interviews with household heads, or in their absence, other adult household members who were present. The questionnaire covered broad themes on geographical, household, institutional, socio-economic and biophysical variables. These variables were deemed relevant to understanding baseline conditions in which target households were living and operating at the time of the survey. The data, after being collected, were pooled into a cross-sectional dataset that provides a representative sample of target households in the four districts. In addition to the structured questionnaire, Focus Group Discussions (FGDs) were conducted with farmer groups in each of the study locations. FGDs were designed to capture farmer's perceptions, attitudes and other information that were not captured during the structured interviews.

2.2. Data Analysis

Primary data were entered and analyzed in STATA software 14. Descriptive statistics in form of percentages, means and standard deviations were generated to identify socio-economic characteristics of farmers. Comparison of socio-economic characteristics across the region and districts was made using t-tests for continuous variables and percentages for categorical variables. To determine factors influencing the choice of CA soil fertility improvement technologies, an ordered probit model was used.

2.3. Theoretical Model

The major body of the existing economic research on technology adoption has been concerned with the question of what determines the decision of a farmer to adopt or reject an innovation [23]. However, there is a relative dearth of empirical research in addressing the choice of which soil-fertility improvement technology package to adopt. This is important given the increased need for sustainable land management in the face of shrinking per capita land, and the increasing awareness of the harmful effects of inorganic fertilizers on soil health. Traditionally, use of CA practices namely; mulching, minimum tillage and crop rotation have been treated and analyzed as mutually exclusive soil fertility management options yet in reality a number of farmers do practice them in a complementary manner. This research makes a contribution in terms of understanding this complementarity.

Ordered probit model was used to achieve objectives of this study. Adoption choice in this research entailed ordered responses which were encountered during the cross sectional survey. Farmers have adopted or waned the use of soil improvement technologies, given differing resources, education, aims and utility preferences [24]. Maximum Likelihood Estimation (MLE) models are appropriate for such discrete scenarios. Following [25], the ordered probit model is built around a latent regression in the same manner as the binomial probit model. For this study, respondents have their own choice of which CA practice to adopt which depends on certain measurable factors **x** and certain unobservable factors, ε, then,

$$y^* = x'\beta + \varepsilon \tag{1}$$

As usual, $y*$ is unobserved, what is observed is

$$y = \begin{cases} 0 \text{ if } \ y^* \le 0, \\ 1 \text{ if } \ 0 < y^* \le \mu_1, \\ 2 \text{ if } \ \mu_1 < y^* \le \mu_2, \\ \text{J if } \ \mu_2 < y^*, \end{cases} \tag{2}$$

which is a form of censoring. The μ_s are unknown parameters to be estimated with **β**. The ancillary parameters/threshold values vary with the individual respondents . Respondents with similar socio economic characteristics and communication behavior are expected to have similar ancillary parameters. This is because according to the central limit theorem the ancillary parameters are normally distributed [26,27]. We assume that ε is normally distributed across observations, in addition we normalize the mean and variance of ε to zero and one. The probability of the respondents choosing a specific ranking can be expressed as [26,28];

$$Prob(y = 0|X) = \phi(-x'\beta),$$

$$Prob(y = 1|X) = \phi(-x'\beta) - (-x'\beta),$$

$$Prob(y = 2|X) = \phi(-x'\beta) - \phi(-x'\beta). \tag{3}$$

For all probabilities to be positive, we must have

$$0 < \mu_1 < \mu_2 \ldots\ldots\ldots < \mu_{j-1}$$

Where ϕ is the cumulative probability function of a standard normal distribution function. However, the marginal effects of the regressors **x** are not the coefficients, thus for the three probabilities above, marginal effects are usually calculated to determine how much each explanatory variable increases or decreases the likelihood of respondents in each of the 3 categories of the dependent variable;

$$\frac{\delta \text{ Prob}(y = 0|x)}{\delta \text{ x}} = -\phi(x'\beta)\beta,$$

$$\frac{\delta \text{ Prob}(y = 1|x)}{\delta \text{ x}} = \phi[(-x'\beta) - \phi \ \mu - x'\beta)]\beta,$$

$$\frac{\delta \text{ Prob}(y = 2|x)}{\delta \text{ x}} = \phi(\mu - x'\beta)\beta. \tag{4}$$

The marginal effects should sum to zero by cancelling one another out across the response categories.

2.4. Empirical Model Specification

Regarding soil improvement technology adoption, farmers rarely adopt the total package. In the present study, three CA practices namely; mulching; minimum tillage and crop rotation practices are being investigated. Farmers usually adopt one CA practice for example mulching, two and a few take up the total package (all the three CA practices). For purposes of this analysis, i separate the total package into a number of categories: *benchmark or base category* (farmers who do not use any of the soil improvement management practices), *partial CA1* [farmer adopts any one of the three CA practices], *partial CA2* [farmer adopts any two of the CA practices], *full CA* [farmer adopts all the three CA practices; mulching, minimum tillage and crop rotation].

The empirical model that was estimated is specified as follows;

$$\begin{aligned} y_i^* = {} & \beta_0 + \beta_1 AGE_i + \beta_2 Gender_i + \beta_3 EDU_i \\ & + \beta_4 HHS_i + \beta_5 INLAND_i + \beta_6 EXT_i \\ & + \beta_7 INCRDT_i + \beta_8 DIST_i + \beta_9 OFFINC_i \\ & + \beta_{10} MEG_i + \beta_{11} HRDLBR_i + \beta_{12} MVP_i \\ & + \beta_{13} Ctry\ dummy_i + \beta_{14} DstrctAZ_i + \varepsilon_i \end{aligned}$$

Where

y_i^* = unobserved soil fertility improvement technology

y_i = component of soil fertility improvement technology

y_i = 0 if $y^* \le 0$, indicating did not take up any technology, the benchmark category

y_i = 1 if $0 \le y^* < \mu_1$, indicating farmer used ***partial CA1*** practices (any one of the three CA practices; mulching, minimum tillage or crop rotation)

y_i = 2 if $\mu_1 \le y^* < \mu_2$, indicating the farmer used ***partial CA2*** (any two of the three CA practices)

y_i = 3 if $\mu_2 \le y^*$, indicating the farmer adopted the ***full CA*** package

β_1----β_{14}= Parameters to be estimated and ε_i= Error terms.

2.5. Explanation of Variables and *apriori* Expectations

It is hypothesized that a farmer's decision to adopt a particular soil fertility management practice at any time is influenced by the combined effect of a number of factors related to farmers' objectives and constraints [29]. The variables in the model were hypothesized to influence the choice of soil fertility management technological package positively (+), negatively (-), or both positively and negatively (+/-) [30].

Table 1. Description of explanatory variables

Variable	Variable	Description of the variable	Expected sign
X1	AGE	Age of the household head in complete years	-
X2	GENDER	Sex of household head, 1=male, 2= female	-
X3	FS	Size of the household	+/-
X4	EDU	continuous, completed years in school	+
X5	LAND	Total land owned by the household in acres	+
X6	EXTA	Access to agricultural extension agents, 1=yes, 0= no	+
X7	INCRDT	Access to input credit, 1=yes, 0=no	+
X8	DIST	Distance to input and output markets in km	-
X9	OFFINC	Household earns some income outside farm activities e.g salary from employment	+ +
X10	MEG	Membership to farmer associations/groups, 1=yes, 0=no	
X11	HRDLBR	Household hires labor for farm activities, 1=yes, 0= no	+
X12	MVP-IMP	Planted improved maize variety, 1= yes, 0=no	+/-
X13	CTRY	Country dummy, Uganda=0, Kenyan =1	+
X14	Agro-ecology	Agro-ecology dummy Tororo and Bungoma=0, Kapchorwa and Trans-Nzoia=1	+

3. Result and Discussion

3.1. Descriptive Statistics of Variables Used in the Ordered Probit Model

A number of descriptive statistics were employed to get a feel of the study area and respondents as shown in Table 2. For continuous variables, farmers' age, land owned, use of hired labor and distance to marketing centers are significant. In comparison, farmers in Kenya are older, owned larger acreage, had more years in farming and travelled longer distances to marketing centers compared to Uganda counterparts.

Kenya respondents were more educated at 57% compared to 28% education levels for Uganda. In addition, they have more membership in farmer associations which puts them to a better stand in extending networks for accessing crucial information. Though 87% of farmers in Eastern Uganda reported crop production as their main occupation, they are less involved in farmer associations compared to their counterparts in Western Kenya. However, the use of CA practices (USECA) was about the same in both countries at 58% in Uganda and 57% in Kenya though not significant. The use of CA is very important because modern inputs like fertilizer are still very expensive for the smallholder farmers in SSA.

Model estimates of the factors that influenced adoption choices for CA practices in the study region are shown in Table 3. The marginal effects of changes in the regressors on the response probabilities are interpreted. The χ^2 results show that the likelihood ratio statistics are highly significant (P = 0.000) suggesting that the model has strong explanatory power. A very low log likelihood ratio (-392.56) implies that the penalty is low for any variable specified in the model. At least no variable has a coefficient equal to zero, therefore all covariates in the model affect adoption of CA practices. LR χ^2 (14) = 77.39 imply that the null hypothesis that all coefficient are simultaneously zero is rejected.

Factors that significantly affected partial adoption included total land owned by the farmer (acres), access to input credit (INCRDT), off-farm income (OFFINC), use of hired labor (HRDLBR), maize varieties planted previous season (MVP), country dummy (CTRY) and district agro-ecology dummy. In addition to these, household (HHS), distance to input markets (DIST), access to extension services (EXT) and membership to farmer associations were significant factors in influencing full CA adoption.

Table 2. Descriptive statistics of variable used in the ordered probit model

Variable	Unit	Mean			P-Value
		Uganda (n=388)	Kenya (n=402)	Total (N= 790)	
Farmer's age	Years	44.79 (14.92)	49.16 (12.21)	46.94 (13.82)	0.000***
Household size	number	7.25 (3.14)	7.55 (3.39)	7.39 (3.27)	0.169
Land owned	acres	3.08 (2.09)	3.82 (2.16)	3.39 (2.13)	0.000***
Hired labor	number	3.50 (2.49)	3.23 (2.12)	3.44 (2.65)	0.000***
Farming expc	years	2.3 (0.9)	2.40 (0.9)	2.4 (0.9)	0.598
Distance to market centers	Km	1.17 (1.0)	3.33 (2.18)	2.23 (2.19)	0.000***
Percentages					
Education	1=yes, 0=no	28.1	57.22	42.66	0.000***
Extension access	1=yes, 0=no	20.4	26.29	23.29	0.050**
Input credit access	1=yes, 0=no	11.19	39.95	25.32	0.000***
Membership to farmer associations	1=yes, 0=no	32.84	61.60	46.96	0.000***
Use of CA technologies	1=yes, 0=no	57.71	56.96	57.34	0.008**
Use of improved maize varieties	1=yes, 0=no	58.46	90.21	77.47	0.000***
Involved in crop production	1=yes, 0=no	87.31	67.27	70.05	0.000***

Source: Survey data.

Table 3. Determinants of CA technology adoption

Variables	*Partial CA1*		*Partial CA2*		*Full* CA	
	δy/δx	p-value	δy/δx	p-value	δy/δx	p-value
AGE[a]	0.035	0.628	0.034	0.565	0.069	0.301
GENDER	0.060	0.370	0.059	0.281	-0.003	0.860
EDU	-0.004	0.828	0.002	0.863	0.002	0.738
HHS	0.004	0.580	0.007	0.212	0.046	0.046**
INLAND[a]	0.049	0.059*	0.046	0.031**	-0.001	0.980
EXT	-0.026	0.570	0.001	0.978	0.078	0.064*
INCRDT[a]	-0.063	0.178	0.069	0.088*	-0.021	0.301
DIST[a]	-0.020	0.361	-0.022	0.224	0.095	0.088*
OFFINC	0.749	0.196	0.063	0.076*	-0.007	0.787
MEG	-0.005	0.855	-0.003	0.884	0.106	0.012**
HRDLBR	0.137	0.002**	0.059	0.075*	0.244	0.000***
MVP	0.223	0.000***	-0.012	0.805	1.689	0.000***
CTRY	0.724	0.000***	0.474	0.000***	0.430	0.000***
DISTRICT(agro-ecology)	0.313	0.000***	0.166	0.000***	0.174	0.000***

Number of observations = 775
LR χ^2 (14) = 77.39
Prob> χ^2 = 0.0000
Log likelihood = -392.56
Pseudo R^2 = 0.1597

a = Logarithm, *, ** ,***Represents significance at 10% 5% and 1% levels respectively, in parenthesis are standard errors
Source: survey data
NB: CA1 represents Conservation Agriculture package one, CA2 represents Conservation Agriculture package two and Full CA represents Conservation Agriculture package.

Hired labor use had a positive and significant impact on farmer's adoption choice. There is a high probability that farmers in the study area could increase their crop yield if they take advantage of hired labor especially since CA practices require a lot of labor. The results are consistent with [32,33].

Maize variety planted (MVP) is significant and positive therefore influencing partial adoption of CA practices. Results of the marginal effects show that farmers who used improved maize varieties in the previous seasons were 22% more likely to fall in partial CA1 adoption. This is attributed to the responsiveness of the improved maize seed to improved soil fertility management technologies, thus becomes an important catalyst for the adoption of these technologies (Morris and Byerlee, 1998).

Access to extension services was positive and statistically significant. The obtained result is consistent with results of [34,35]. This implies that extension services receipt help in improving adoption choices of farmers sampled. The advice given by the extension agents during trainings and farm visits helps farmers to improve their management skills and to acquire knowledge on new practices [36].

4. Conclusions

Farmers in the study region practiced CA though at slightly varying levels, Kenya at 57% and Uganda at 58%. The major determinants for adoption choice of these practices included total land owned, access to input credit, use of hired labor, access to extension services, distance to market centers, use of improved maize varieties and location (agro-ecology).

Therefore, the study recommends policies that will lead to increased investment in better infrastructure and access to and control of credit and extension services in the study region. In addition, future policies should consider agro-ecology/farmer location as a main factor, lowlands and highland receive varying levels of rainfall thus they should be considered differently.

Acknowledgements

The study acknowledges Alliance for a Green Revolution in Africa (AGRA) for the sponsorship and SANREM-CRSP (Innovation Laboratory) supported by USAID for provision of the dataset used in this study.

Conflict of Interest

The authors have no conflict of interest to declare

References

[1] Paarlberg, R. 2010. Food Politics: What Everyone Needs to Know, *Oxford University Press*, New York.
[2] Sanchez, P.A., Denning, L., Nziguheba, G. 2009. The African Green Revolution moves forward. *Food Security* 1, 37-44.
[3] Rashid, S., Dorosh, P.A., Malek, M., Lemma, S. 2013. Modern Input Promotion in Sub-Saharan Africa: Insights from Asian Green Revolution. *Agricultural Economics* 44 (2013) 705-721
[4] SEI. 2005. Sustainable pathways to attain the millennium development goals assessing the role of water, energy and sanitation. *Research report prepared for the UN World Summit*, 14 September, 2005, New York. Stockholm Environment Institute, Stockholm http://www.sei.se/mdg.htm.
[5] Shepherd K., M. Walsh, F. Mugo, C. Ong, T.S. Hansen, B. Swallow, A. Awiti, H. Mwangi, D. Nyantika, D. Ombalo, M. Grunder, F. Mbote and D. Mungai. 2000. Linking Land and Lake, Research and Extension, Catchment and Lake Basin: Final Technical Report–Startup Phase, July 1999 to June 2000. *Working Paper* 2000-2, ICRAF.
[6] Montpellier Panel Report. 2013. Sustainable intensification: A new paradigm for African agriculture, London.

[7] Mapila, M.A.T.J., Njuki, J., Delve, R.J., Zingore, S., & Matibini, J. 2012. Determinants of fertilizer use by smallholder maize farmers in the Chinyanja Triangle in Malawi, Mozambique and Zambia, Agrekon: *Agricultural Economics Research, Policy and Practice in Southern Africa,* 51:1, 21-41.

[8] Food and Agricultural Organisation (FAO). 2009. How to Feed the World in 2050 (Food and Agriculture Organization of the United Nations, Rome).

[9] Wall, P. 2007.Tailoring conservation agriculture to the needs of small farmers in developing countries: an analysis of issues. *J. Crop Improv*. 19, 137-155.

[10] Baudron, F., Mwanza, H.M., Triomphe, B., Bwalya, M. 2007. Conservation Agriculture in Zambia: A Case Study of Southern Province. African Conservation Tillage Network, Centre de Cooperation Internationale de Recherche Agronomique pour le Development.

[11] Shetto, R., Owenya, M. 2007. Conservation Agriculture As Practised In Tanzania: Three Case Studies. African Conservation Tillage Network, Centre de Coope´ ration Internationale deRecherche Agronomique pour le Developpement, *Food and Agriculture Organization of the United Nations,* Nairobi, Kenya.

[12] Kaumbutho, P., Kienzle, J. 2007. Conservation Agriculture As Practised in Kenya: Two Case Studies.African Conservation Tillage Network, Centre de Cooperation Internationale de Recherche Agronomique pour le Developpement, *Food and Agriculture Organization of the United Nations, Nairobi, Kenya.*

[13] Bolliger, A., Magid, J., Amado, T.J.C., Neto, F.S., Ribeiro, M.D.D., Calegari, A., Ralisch, R., de Neergaard, A. 2006. Taking stock of the Brazilian ''zero-till revolution'': a review of landmark research and farmers' practice. Adv. Agron. 91, 47-110.

[14] Nambiro, E. and Okoth, P. 2013. What factors influence the adoption of inorganic fertilizer by maize farmers? A case of Kakamega District, Western Kenya. *Tropical Soil Biology and Fertility Institute of CIAT (CIAT-TSBF), c/o World Agroforestry Centre* (ICRAF), P. O. Box 30677-00100, Nairobi, Kenya.

[15] Salasya B, Mwangi W, Mwabu D, Diallo A. 2007. Factors influencing adoption of stress-tolerant maize hybrid (WH 502) in western Kenya.*African Journal of Agricultural Res*ources 2: 544-551.

[16] Licker, R., Johnston, M., Foley, J.A., Barford, C., Kucharik, C.J., Monfreda, C., Ramankutty, N. 2010. Mind the gap: how do climate and agricultural management explain the 'yield gap' of croplands around the world? *Glob. Ecol. Biogeogr*. 19, 769-782.

[17] Okoboi, G. and Barungi, M. 2012. Constraints to Fertilizer Use in Uganda: Insights from Uganda Census of Agriculture 2008/9. *Economic Policy Research Centre, Kampala, Uganda,* Research Series #88

[18] Kasule, B.S. 2009. Inorganic fertilizer in Uganda- Knowledge gaps, profitability, subsidy and implications of a national policy. *International Food Policy Research Institute*. Kampala, Uganda.

[19] Namazzi, J. 2008. Use of Inorganic Fertilizers in Uganda. Uganda Strategy Support Program, Brief No. 4.*International Food Policy Research Institute*. Kampala, Uganda.

[20] Kato, E. 2000. "An analysis of factors affecting adoption of K131 bean variety by women groups in Luuka County, Iganga district." MS thesis, Makerere University.

[21] Ariga, J. and T.S. Jayne. 2010. "Factors Driving the Increase in Fertilizer Use by Smallholder Farmers in Kenya, 1990-2007".

[22] Kipsat, M. J. 2002. Economic analysis of the use of non-conventional fertilizer technologies in Vihiga district of western Kenya. *Phd thesis*, Moi University.

[23] Genius, M., Pantzios, C. and Tzouvelekas, V. 2006. Information Acquisition and Adoption of Organic Farming Practices, *Journal of Agricultural and Resource economics* 31(1): 93-113

[24] Bogdan, R. C and Bilken, S. K. 2009. Qualitative Research for Education; An Introduction to Theories and Models, available from http://www.francescoiannicom/Digital%20Portfolio/pdf%20files/EDU7900%20Qualitative%20Research%20for%20Education.pdf 11 pages

[25] Green, H. W. 2003. Ecomometric Analysis, 5th edition, Prentice-Hall, Upper Saddle River, New Jersey.

[26] Chen, X., F. Zhang, V. Römheld, D. Horlacher, R. Schulz, M. Böning-Zilkens, P. Wang, and W.Claupein. 2006. Synchronizing N supply from soil and fertilizer and N demand of winter wheat by an improved N min method. *Nutrient Cycling in Agroecosystems* 74(2): 91-98.

[27] Maddala, G. 1983. Limited Dependent and Qualitative Variables in Econometrics, *Cambridge University Press, Cambridge.*

[28] Greene, W.H. 2000. Econometric Analysis (4th edition).*Prentice Hall*, New Jersey.

[29] CIMMYT. 1993. The Adoption of Agricultural Technology: A Guide for Survey Design, Mexico, D.F: CIMMYT.

[30] Makokha, S., S. Kimani, W. Mwangi, H. Verkuijl, and F. Musembi. 2001. Determinants of Fertilizer and Manure Use in Maize Production in Kiambu District, Kenya. Mexico, D.F.: International Maize and Wheat Improvement Center (CIMMYT) and Kenya Agricultural Research Institute (KARI).

[31] Giller, E. K., Witter. E., Corbeels. M., Tittonell . P. 2009. Conservation Agriculture and Smallholder farming in Africa: The heretics view, *Field Crops Research* 114, 23-34

[32] Mor, S. and Sharma, S. 2012. Technical Efficiency and Supply Chain Practices in Dairying: The Case of India. *Agricultural Economics—Czech*, 58, 85-91.

[33] Abatania, L.N., Hailu, A. and Mugera, A.W. 2012. Analysis of Farm Household Technical Efficiency in Northern Ghana Using Bootstrap DEA. *Proceedings of the* 56*th Annual Conference of the Australian Agricultural and Research Economics Society*, Perth, 7-10 February 2012.

[34] Alemdar, T., Bahadir, B. and Oren, M.N. 2010. Cost and Return Analysis and Technical Efficiency of Small Scale Milk Production: A Case Study for Cukurova Region, Turkey. *Journal of Animal and Veterinary Advances*, 9, 744-847.

[35] Rahman, S.A. and Umar, H.S. 2009. Measurement of Technical Efficiency and Its Determinants in Crop Production in Lafia Local Government Area of Nasarawa State, Nigeria. *Journal of Tropical Agriculture, Food, Environment and Extension,* 8, 90-96.

[36] Majiwa, E.B., Kavoi, M.M. and Murage, H. 2012. Smallholder Dairying in Kenya: The Assessment of the Technical Efficiency Using the Stochastic Production Frontier Model. *JAGST*, 14.