

Journal Brief

FACTORS AFFECTING ADOPTION OF INTEGRATED SOIL FERTILITY MANAGEMENT TECHNOLOGIES BY BEAN FARMERS IN MACHAKOS AND BUNGOMA COUNTIES, KENYA

R. A. Emongor^{1,5#}, ²E. Katungi² and R. Uside³

¹Kenya Agricultural and Livestock Research Organization (KALRO), Food Crops Research Institute, National Agricultural Laboratories Kabete, P.O. Box 14733-00800 Nairobi, ²International center for Tropical Agriculture (CIAT), Kawanda National Agricultural Research Institute, P. O. Box 6247, Kampala, Uganda. ³KALRO, Non-Ruminant Research Institute-Kakamega, P.O. Box 169-50100, Kakamega

ABSTRACT

Common bean is an important pulse crop in East Africa. Bean yields have been low and on the decline in Kenya. The decline in bean yields has been due to biotic and abiotic stresses, such as low rainfall, pests and diseases, low soil fertility, among others. Research was carried out to determine factors that influenced adoption of Integrated Soil Fertility Management (ISFM) technologies in Bungoma and Machakos counties, Kenya. Multi-stage sampling procedure was used to randomly sample 502 smallholder farmers in Bungoma and Machakos counties. Primary data was collected from sampled farmers by carrying out face-to-face interviews using a structured questionnaire. Collected data was analysed using descriptive statistics and Logistic regression. Descriptive statistics results showed that the adoption and use of ISFM varied in the two counties. For example, approximately 32% of farmers in Machakos County did not use ISFM technologies compared to 14% in Bungoma. Approximately 33% of the sampled farmers in Machakos County used manure compared to 8% in Bungoma County. The Logistic regression results showed that region, level of education of the household head, access to extension services, whether the household was food secure and availability of markets for beans significantly influenced the choice of ISFM by farmers. Therefore, to improve adoption of ISFM, there is need to strengthen the extension services and improve bean markets in the study sites.

Keywords: Technology adoption, integrated soil fertility management, common bean, Logit model

INTRODUCTION

Common beans (*Phaseolus vulgaris* L) are important in the diet of rural and urban low-income households and has been identified as one of the crops that can contribute to their food and nutrition security. Regular consumption of common bean and other pulses is now promoted by health organizations because it reduces the risk of diseases, such as cancer, diabetes or coronary heart diseases (Katungi *et al.*, 2009). This is because common bean is low in fat and is cholesterol free. It is also an appetite suppressant because it digests slowly and causes a low sustained increase in blood sugar. Researchers have found that common bean can delay the reappearance of hunger for several hours, enhancing weight-loss programs (Katungi *et al.*, 2009). As a protein source, common beans are relatively cheap compared to animal-based proteins, such as beef and chicken. Therefore, promotion of improved bean varieties and other technologies, such as Integrated Soil Fertility Management (ISFM) is imperative if production and consumption of dry beans is to be increased. However, the slow or non-adoption of bean and related technologies is a major concern.

In Kenya, common bean is the most important pulse crop grown by smallholder farmers even though its output has been declining over the years, despite efforts to increase the physical land area under common beans (GoK, 2006). In 2007, common bean production in Kenya was approximately 428,000 metric tons, while demand was estimated at 500,000 metric tons (FAO, 2010). Common bean yields in Kenya have been low and, in some cases, have either remained constant or declined over the years. Smallholder farmers in the country have attributed the decline in bean yields to a number of abiotic stresses, such as low rainfall, poor soils and biotic factors such as

[#]Corresponding author: rosemary.emongor@kalro.org

pests and diseases, low adoption and non-use of improved technologies (Kombe, 2005).

Scientists have developed a number of technologies, which have been disseminated to smallholder farmers to be used to control pests and diseases and to maintain soil fertility in order to improve bean productivity. These comprise simple technologies, such as new varieties and more complex, knowledge-intensive ones, such as integrated pest and disease management and ISFM. Integrated soil fertility management is a set of agricultural practices adapted to local conditions to maximize efficiency of nutrients and water use to improve agricultural productivity. These technologies can contribute to increased bean production if adopted and applied by farmers. However, there has been low adoption of these technologies by the target end users to make significant impact on their livelihoods (Becker *et al.*, 1995; Rogers, 2003).

Considering the importance of ISFM technologies in improving bean yield, it is important to understand the factors that enhance or constraint its adoption. In this respect, research was conducted to determine factors that influenced the adoption of ISFM technologies among smallholder bean farmers in Machakos and Bungoma counties of Kenya. The specific objectives of the research were to: (i) assess the factors that were likely to influence the adoption of ISFM technologies and, (ii) draw implications on the effective ways to increase the uptake of these technologies by smallholder bean farmers in order to improve bean productivity.

MATERIALS AND METHODS

Study sites

Two study sites were selected, Machakos County in eastern Kenya and Bungoma County in western Kenya to represent the Arid and Semi-Arid Lands (ASALs) and high potential areas, respectively

Machakos County is sub-divided into 11 Sub-counties. Mwala and Kathiani Sub-counties were selected for the study (Figure 1). Extension staff from the county assisted researchers to select the two sub-counties because many smallholder farmers compared to the other sub-counties grew common beans.

Mwala Sub-County covers 483 km² with 171.8 km² suitable for agriculture, whereas Kathiani Sub-County covers a total area of 205.8 km² with about 171.8 km²

being suitable for agriculture. The two sub-counties fall within agro-ecological zones UM2-UM3 and LM2-LM5 (Jaetzold *et al.*, 2006). Rainfall is bimodal with short rains from October to December and long rains from March to May. Rainfall varies between 500-750mm per annum. The soils are mainly sandy loam with Murrum. The slope of the land ranges from gentle to steep. The major economic activities in the Sub-counties include livestock production (dairy, local zebu animals, sheep, goats and indigenous poultry) and crop farming. The major crop enterprises include maize, beans, cowpeas, pigeon peas and horticultural crops, such as mangoes, pawpaw, onions and tomatoes. The major limiting factor to agricultural production is inadequate water and lack of adequate inputs such as fertilizer and seed.

Bungoma County is sub-divided into 10 Sub-counties. In this study, Bungoma East and Bungoma Central sub-counties were selected. These sub-counties were selected for the study (Figure 2) because beans were grown there in large quantities by small holder farmers.

Bungoma Central covers 235.4 km² of which 195.4 km² is suitable for agriculture, whereas Bungoma East covers 401 km² with 325 km² suitable for agriculture. The two Sub-counties fall within agro-ecological zones UM1-UM4 and LM1-LM2 (Jaetzold *et al.*, 2006). The total population of the two sub-counties was 353,790 persons and 70,000 households with an average farm size of 2.0 ha per household. Rainfall received was bimodal with first (long) rainy season from March to July and second (short) rainy season from September to October. Rainfall varies between 1000-1700 mm per annum. The soils are well drained, deep to extremely deep dark reddish brown friable clay, friable sandy clay loams and brown sandy loams. The slope of the land ranges from gentle to fairly steep. The major economic activities in the sub-counties include livestock and crop production.

Data sources

Both secondary and primary data were used in the study. Primary data was collected using a structured questionnaire in the months of June, July and August 2012.

Sampling strategy and data collection

Multi-stage random sampling procedures was used to obtain the sample of farmers for primary data collection as follows:



Figure 1: Map showing Machakos County study sites

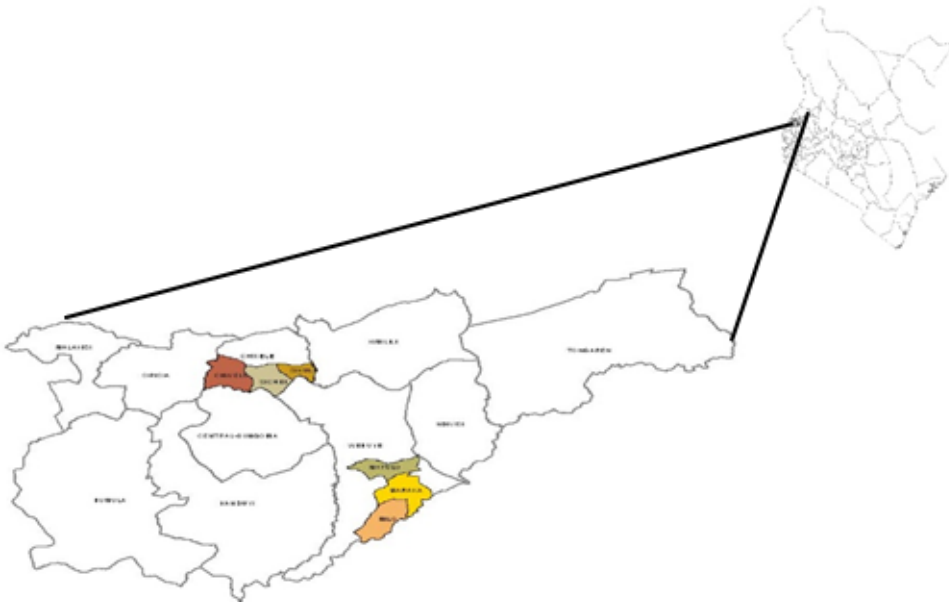


Figure 2: Map showing the Bungoma County study sites

Machakos County: Mwala and Kathiani sub-counties were selected. From each Sub-county, three sub-locations were randomly selected. In Kathiani, Ngiini, Kaiani and Mitaboni while in Mwala; Mbiuni, Kyanganga and Makiliva were selected, respectively. Simple random sampling was used to select farmers from the lists of households provided by the Assistant chiefs of the selected Sub-locations. Forty-two farmers were randomly selected from each sub-location. The total sample was 252 households from the six sub-locations.

Bungoma County: Bungoma East and Bungoma Central were selected. The three sub-locations selected from Bungoma East were Milo, Maraka and Matulo, whereas Sichei, Sikulu and Chwele Rural sub-locations were selected from Bungoma Central. Simple random sampling was used to select 252 households from the lists compiled by the Assistant Chiefs from the six sub-locations.

Individual interviews were conducted with household heads or designated member of the household, such as wife, son or daughter of the sampled household head. A total of 504 households were interviewed in Bungoma and Machakos counties.

Analytical methods

Descriptive statistics and a logistic regression (logit) model were used to analyse the household characteristics and factors that influenced the choices to adopt ISFM technologies by bean farmers.

Logistic regression model

A number of studies have investigated various socio-economic, cultural and political factors that influence the farmers' decision to adopt new technologies (Adesina and Zinnah, 1993). In this study, the logit model was used to analyze factors that influence farmer's choice to adopt ISFM technologies in bean production in Machakos and Bungoma Counties in Kenya. The logistic equation is given as follows (Greene, 2000):

$$\text{Pr}(Y=1) = \frac{e^{\beta'X}}{1+e^{\beta'X}} \tag{1}$$

With the cumulative distribution function given by:

$$F(\beta'X) = \frac{1}{1+e^{-\beta'X}} \tag{2}$$

where, β' represents the vector of parameters associated with X, Pr represents probability that the farmer chooses to use ISFM, F is function

Definition of variables in the empirical model

The variables in the logit model were as follows:

Dependent variable

The dependent variable was a dummy variable, which took a value of one if a household adopted ISFM and zero otherwise.

Independent variables

The independent variables consisted of nine variables: household size (HHSIZE), gender of household head (GHHD), age of the household head (HHAGE), farm size (FARMSIZE), education level (NYEARS), which was indicated by the number of years the household head had spent in school, access to extension services (ACCEXT). Other variables were: Household food security (HHFSECURE), available markets for bean products (MKTAVB) and the region (REGN).

The total number of people living in the household (HHSIZE) was obtained by calculating the adult equivalent of the number of household members at the time of the survey. It was envisioned that household size may influence the adoption of ISFM technologies. Households with a large number of people may be forced to use technologies that increase food production, as there are more mouths to feed compared to smaller families. This variable is expected to have a positive impact on adoption and use of ISFM by the household.

Another variable was gender of household head (GHHD). Generally male-headed households tend to have more resources and access to information on various types of technologies compared to female-headed households. This variable was presented as a dummy variable assuming the value of 1 if household was male-headed, zero otherwise. This variable's impact on adoption of ISFM technologies is unknown. It can either be positive or negative.

Another variable, which was thought to have influence on the adoption of these technologies by household was the age of household head (HHAGE). This variable is taken as a proxy for experience of the farmer in the growing of beans and use of ISFM. It was measured in number of

years. Older household heads may have more experience in using the technologies available and also they may have resources such as land compared to their younger counterparts. On the other hand, older household heads may be more averse to taking risks so that they do not easily adopt new types of technologies. It follows that younger household heads may be able to adopt new technologies such as ISFM in a bid to increase output of crops on their farms. Therefore, this variable is expected to have either a positive or a negative impact on choice of the specified technology.

The fourth explanatory variable that may influence the choice ISFM technologies by the household was related to the size of the farm (FARMSIZE). Households with large parcels of land may be able to try out new technologies as they do not face a land constraint encouraging them to adopt new bean and ISFM technologies to increase production at the farm level. This variable is expected to have a positive impact on choice of new technologies by households in the study area.

Another variable that was considered to influence adoption of ISFM by the household was level of education (NYEARS) which is a continuous variable indicating the number of years the household head had attended formal school. This variable may influence the choice of new technologies by households as more educated household heads may be in formal employment giving them access to finance which might give them opportunity to try out new technologies. Also educated household heads may have access to better information on new technologies and also they may have the necessary income to adopt newer or alternatives technologies such as ISFM.

The Region (REGN) where the household was located was also incorporated as a dummy variable. Bungoma County in western was selected to represent the high potential areas whereas Machakos in Eastern represented the low or ASAL areas.

Assuming the probability that farmer n will choose to use ISFM technologies is equal to the proportion of bean farmers using ISFM technology, the empirical model estimated was given by:

$$\text{CHOICE of ISFM} = \beta_1\text{REGN} + \beta_2\text{FARMSIZE} + \beta_3\text{GHHD} + \beta_4\text{HHEADAGE} + \beta_5\text{NYEARS} + \beta_6\text{HHSIZE}$$

$$+ \beta_7\text{ACCEXT} + \beta_8\text{HHFSECURE} + \beta_9\text{MKTAVB}$$

Estimation was done using the maximum likelihood method after conducting pairwise Pearson's product-moment correlation analysis to detect potential multicollinearity among the independent variables. The significance of the model parameters was determined by Wald statistic, while the adequacy of the model was checked using chi-squared likelihood ratio statistic and pseudo- R^2 .

RESULTS AND DISCUSSION

Household characteristics for Bungoma and Machakos study sites

Characteristics of the sampled households are presented in Table I. On average, land holdings were smaller for female-headed households in Bungoma County which indicated that in most of East and Central African countries, land was mainly owned by males. Approximately 17.5 and 22 % of the households in Bungoma and Machakos, respectively, were headed by females even though some respondents in the male-headed households were females. The analysis using disaggregated data by gender of the household head showed that mean land under beans was about 0.52 ha in Bungoma and 0.85 ha in Machakos (Table I). This result concurs with the results of the USAID/ KALRO impact study carried out in October 2017 in Machakos County (KALRO, 2017). As indicated above, more land was planted with beans in Machakos County compared to Bungoma County. This could be attributed to the maize and bean diet prevalent in eastern Kenya.

Most households owned at least one mobile phone in the two study sites. This may mean that mobile phones could be an important garget in passing information to the farming households in these two study sites. Short message service (SMS) could be an important dissemination pathway especially for farmers with a high level of literacy. Most households in the two study sites did not own any rain water harvesting gargets, such as water storage tanks which implies minimal rain water harvesting even in areas of high annual rainfall, such as western Kenya. Rain water harvesting can contribute immensely to improvement in agricultural production as farmers will be able to irrigate and produce high value crops, such as vegetables during the dry seasons.

TABLE I-CHARACTERISTICS OF HOUSEHOLDS IN BUNGOMA AND MACHAKOS COUNTIES

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Household characteristics	Western Kenya (Bungoma East and Bungoma Central)			Eastern (Mwala and Kathiani- Machakos)		
	Female	Male	All	Female	Male	All
Land						
Mean land Size (ha)	1.76	2.37	2.24	3.2	3.2	3.44
Mean land size under beans (ha)	0.43	0.54	0.520	0.798	0.815	0.853
Demographics						
Sample by HH gender (%)	22	78	-	17.5	82.5	-
Sample by respondent gender (%)	30	70	-	51.6	48.4	-
Mean Household head age (years)	50.0	46.6	47.4	54.1	47.7	53.6
Formal education (years-mean)	6.9	9.5	9	7.1	10.2	10
Farming the Primary occupation of Household Head (%)	78	64	67.2	95	76	79.4
Number of mobile phones	1.04	1.52	1.42	1.04	1.51	1.67

Use of ISFM technologies by farmers in Bungoma and Machakos Counties

In both regions, farmers used both organic and inorganic fertilizers in producing crops. There were more farmers using ISFM technologies (which included mineral fertilizers, organic matter (manure, compost, crop residues, green manure) and improved germ plasma) in Bungoma County compared to Machakos County. There were approximately 14% non-users of ISFM in Bungoma County compared to 32% in Machakos County. There was more use of manure in Machakos (32.54%) compared to 6.75% in Bungoma County. Due to climatic conditions in Machakos County, livestock keeping is more pronounced, therefore easy availability of manures compared to Bungoma. Farmers used a combination of ISFM technologies as follows: DAP and Manure 24% in Bungoma and 12% in Machakos. Other practices included use of manure and fertilizer without naming type of fertilizer, terracing and mulching.

Factors that influence adoption of ISFM technologies in Bungoma and Machakos counties

The results from the logit Model indicate that all identified variables together contribute to determine the adoption of

ISFM technologies. Farm size, gender of the household head, age of the household head and household size were not statistically significant (Table II). The region variable was statistically significant at 1%, which implies that the region where the farmer is located will influence their choice to adopt or not to adopt ISFM technologies. For instance, Bungoma County has high rainfall with conditions that favour mineral depletion from the soil compared to Machakos County, therefore these results confirm the descriptive results that there were more non-users of ISFM in Machakos County compared to Bungoma County.

Education level of the household head had a positive influence on the adoption of ISFM technologies and was significant at 10% significance level. This result is similar with the results of a number of studies that have indicated that the level of education influences adoption of agricultural technologies. Research carried out by Mlenga (2015) working in Swaziland found that education level of the household head influenced adoption of conservation agriculture. The results showed that a household head with some form of education was three times more likely to adopt conservation agriculture compared to a household head without any education.

TABLE II- PARAMETER ESTIMATES OF THE LOGIT MODEL

Variable	Coefficient	Std error	Z	P> z
Region	1.32	0.220	6.00	0.000**
Farm size (Ha)	0.06	0.317		0.860
Gender of household head (male=1, 0 otherwise)	0.124	0.195	0.63	0.526
Household head age (number of years)	0.143	0.007	1.86	0.62
Education level (number of years spent in school)	0.055	0.031	1.79	0.073*
Household size (number of people in the household in man equivalents)	-0.044	0.032	-1.37	0.171
Access to extension services	0.828	0.232	3.56	0.000***
Whether household food was secure	-0.387	0.223	-1.74	0.082*
Available market for bean product	0.494	0.209	2.37	0.018**
Constant	--3.31	0.724	-4.57	0.000***
Number of observation = 484				
LR chi ² (9) = 65.5				
Prob > chi ² = 0.000				
Pseudo R ² = 0.0977				

* P>0.05, **P>0.01 and *** P<0.001

Access to extension services was a highly significant factor in influencing the adoption of ISFM technologies in Bungoma and Machakos counties. A number of studies have shown that access to extension significantly influences adoption of agricultural technologies (Donkor *et al.*, 2016; Wossen *et al.*, 2017). For example, the study by Donkor *et al.* (2016) found that access to extension significantly promoted adoption of chemical fertilizers by smallholder farmers in Ghana. The study further established that access to extension services and adoption of fertilizer exerted a positive influence on rice productivity.

Available markets for common beans was statistically significant at 5% significance level. Market failures often limit smallholders' ability to be linked to markets (Gyau *et al.*, 2013). Improving markets for smallholder farmers will go a long way in enabling farmers to adopt new agricultural technologies which in turn will impact positively on productivity.

The study revealed the factors which influenced the adoption of ISFM in the study sites. The application of these results in the study sites could assist policy makers to enact policies that may improve adoption of ISFM. The

variables that significantly influenced adoption of ISFM by bean farmers could be strengthened to enable more farmers to assess and adopt the technologies.

Caution should be taken in using the results of this study in other regions, which have different climatic conditions, and agro-ecological zones as the study used cross-sectional data that may be applicable to the study sites only.

CONCLUSION AND RECOMMENDATIONS

This study concludes that farmers in the two study sites used ISFM in their crop production activities. More farmers in Bungoma County used these technologies compared to those in Machakos County. Availability of functional and reliable markets for the farmer's produce is important in increasing uptake of ISFM technologies. Therefore, effort should be made to create and link farmers to markets to increase adoption of new and improved technologies.

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