FACTORS THAT INFLUENCE ADOPTION OF INTEGRATED SOIL FERTILITY AND WATER MANAGEMENT PRACTICES BY SMALLHOLDER FARMERS IN THE SEMI-ARID AREAS OF EASTERN KENYA[1]

[FACTORES QUE INFLUYEN EN LA ADOPCIÓN DE PRÁCTICAS DE MANEJO INTEGRADO PARA LA FERTILIDAD DEL SUELO Y GESTIÓN DEL AGUA POR PEQUEÑOS AGRICULTORES EN LAS ZONAS SEMIÁRIDAS DE KENIA ORIENTAL]

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SUMMARY

In arid and semi-arid lands (ASALs), low adoption of integrated soil fertility and water management (ISFWM) technologies has contributed to food and nutrition insecurity. A study was conducted to assess factors influencing smallholder farmers' adoption decision of ISFWM technologies in Mwala and Yatta Sub-Counties. A questionnaire was administered to 248 respondents in the study region. Selection of household heads was done in 'Farmer-led adoption approach' sites otherwise known as Primary and Secondary Participatory Technology Evaluations (PPATEs and SPPATEs) and Non-PPATEs/SPATEs sites in both Sub-Counties. Relationships between different variables were determined by the Tobit model. The results revealed that group membership (P<0.016), inaccessible credit services (P<0.017), gender (P<0.025), age and access to agricultural extension services (P<0.027) influenced adoption of ISFWM technology significantly. Cost of inputs and access to radio information (P<0.01), access to appropriate farm machines (p<0.001), cost of labor and farmers' perception on seasons' reliability (P<0.004) and out-put markets (P<0.006) were reported to affect adoption of ISFWM practices highly significantly. Descriptive statistic results indicated that majority of the respondents (93.9%) in the project areas were adopting a combination of tied ridges, organic fertilizer and improved seed compared to only 6.1% in the non-project area. There was also significantly (P<0.01) higher adoption (76.5%) of a combination of tied ridges, both fertilizer and improved seed in the project area in contrast to merely 23.5% in non-project area, as well as those adopting (80%) a combination of zai pit, both fertilizer and improved seed compared to only 20% in non-project area. Policy makers should focus on availability of affordable credit facilities and farm machines, ease access to information, labor and input-output markets for enhanced farm productivity and livelihoods of the smallholder farmers in ASALs.
Key words: Low adoption; food and nutrition security; Tobit model.

RESUMEN

En las tierras áridas y semiáridas, la baja adopción de tecnologías integradas de fertilidad del suelo y gestión del agua (ISFWM) ha contribuido a la inseguridad alimentaria y nutricional. Se realizó un estudio para evaluar los factores que influyen en la decisión de adopción de las tecnologías ISFWM de los pequeños agricultores en los subcondados de Mwala y Yatta. Se administró un cuestionario a 248 encuestados en la región del estudio. La selección de los jefes de hogares se realizó tanto en sitios de "Adopción liderada por agricultores" (también conocidos como sitios Primarios y Secundarios de Evaluaciones Tecnológicas Participativas (PPATE y SPPATE)) como sitios No-PPATE/SPATE en ambos sub-condados. Las relaciones entre las diferentes variables fueron determinadas por el modelo Tobit. Los resultados revelaron que la afiliación al grupo (P<0.016), los servicios de crédito inaccesibles (P<0.017), el género (P<0.025), la edad y el acceso a servicios de extensión agrícola (P<0.027) influyeron en la adopción del ISFWM. El costo de los insumos y el acceso a la información de radio (P<0.01), el acceso a las máquinas agrícolas apropiadas (P<0.001), el costo de la mano de obra y la percepción de los agricultores sobre la fiabilidad de las estaciones (P<0.004) afectaban significativamente a la adopción de las prácticas del ISFWM. La mayoría de los encuestados (93.9%) en las áreas del proyecto estaban adoptando una combinación de surcos,

fertilizantes orgánicos y semillas mejoradas en comparación con sólo el 6.1% en el área no relacionada con el proyecto. También hubo una adopción mayor (P<0.01) de una combinación de surcos, tanto de fertilizantes como de semillas mejoradas en el área del proyecto, en contraste con el 23.5% en áreas no relacionadas con el proyecto, así como los que adoptaron (80%) una combinación de "zai pit", fertilizante y semilla mejorada en comparación con sólo el 20% en áreas no relacionadas con el proyecto. Los responsables de la formulación de políticas deberían centrarse en la disponibilidad de facilidades de crédito y máquinas agrícolas asequibles, facilitar el acceso a la información, el trabajo y los mercados de insumo-producto para aumentar la productividad agrícola y los medios de subsistencia de los pequeños agricultores en tierras áridas y semiáridas.

Palabras clave: Baja adopción; Seguridad alimentaria y nutricional; Modelo Tobit.

INTRODUCTION

Agriculture is an important sub-sector in Kenya's economy contributing 26% to the country's gross domestic product (GDP) and employing 75% of the country's workforce (ERA, 2015). A study by Bett, (2006) reported that frequent food and nutrition insecurity is experienced in Kenya due to the problems faced in the agricultural sub-sector which include population pressure, poor soils, inadequate rainfall, and persistent use of inappropriate agricultural practices. Other studies (Mati, 2005; Toborn, 2011; Ajayi *et al.,* 2007; Shiferaw *et al.,* 2009; Gichangi, 2007; Nabhan *et al.,* 1999; Irungu *et al.* 2011; ICARDA, 2012) reported that limited availability of affordable farm inputs like fertilizers, improved seed, poor roads and market infrastructure, locally produced farm machinery coupled with labor shortages influence adoption of ISFWM technologies by the smallholder farmers. Similarly, Waithaka *et al.* (2007) observed that lack of appropriate knowledge base to combine rainwater harvesting structures with suitable agronomic measures contributed to low adoption of the ISFWM technologies.

Mismanagement of the soils in the arid and semi-arid lands (ASALs) of Kenya has led to degradation of millions of acres of land through erosion, compaction, salinization, acidification and continuous cropping without nutrient replenishment (Gruhn *et al.,* 2000; Kathuli *et al.,* 2014; Miriti *et al.,* 2007). Farmers have also indicated that inadequate quantities of organic fertilizers in relation to farm requirements compounded by high labor demands during its application presents itself as the major constraint they experience for its use (Omiti *et al.,* 1999; Gichangi *et al.,* 2007)

The history of Kenya's efforts to improve integrated soil fertility management shows clearly the positive and the negative aspects that have precipitated to the present situation. Thus Kenya's modern agricultural foundation was laid in the early twentieth century with the arrival of the white settlers (Bett, 2006). During the Swynnerton plan of the early 1950's, a plan to address the looming agricultural crisis in

Kenya was drawn up. The plan laid down the foundation for farmer education extension system, the agricultural policy and the Kenya land tenure system including soil and water management practices (Bett, 2006). However, Kimaru and Jama (2006) observed that the colonial authorities in Kenya used coercive approaches to introduce new land use and soil conservation methods such as terracing and forced destocking to manage natural resource use. The latter may have contributed to negative attitudes to soil fertility and water conservation measures among smallholder farmers' in ASALs (Kimaru and Jama, 2006). Though research and extension have attempted to extend ISFWM technologies to the ASALs, adoption has remained low. The reasons behind this low adoption have not been well elucidated.

The objectives of this study were therefore to assess and document factors that influence smallholder farmers' adoption of ISFWM technologies in Mwala and Yatta Sub-Counties and to compare adoption levels of ISFWM technologies in the pilot project and non-pilot project sites in the study regions.

Factors affecting smallholder farmers adoption of ISFWM practices in ASALs

A summary of data from household heads in the study area hypothesized to influence ISFWM practices comprised of: age, gender, education, group membership, land size, land tenure systems, costs of inputs, access to radio, cost of labor, availability of appropriate farm machinery, access to information and services, access to credit and output markets, farmers' perception on seasons' reliability and perception on improved seeds,. These factors were regressed using Tobit model to determine their significance in influencing adoption of ISFWM technologies**.**

Research question

What are the main factors that influence smallholder farmers' adoption of ISFWM technologies in Mwala and Yatta Sub-Counties?

Is there any difference in adoption levels of ISFWM technologies of smallholder farmers' between the project and non-project sites in Mwala and Yatta Sub-Counties.

Specification of analytical model

Tobit analytical model

A farmer's decision to apply a technology such as soil fertility management can be explained by a set of factors that influence the welfare criterion of expected utility. These factors are related to both the characteristics of the technology, its environment and the potential adopter. The set of factors that influence the technology choice can be broadly categorized into four major groups, technology attributes; farmer's resources; policy and institutional environment; and farmer's attributes, including preferences, risk profile, and ability to use information (Staal *et al.*, 2003). The adoption behavioural model is frequently used as conceptual frame work to examine variables associated with technology adoption (Shakya and Flinn, 2008).

Smallholder farmers are therefore assumed to make ISFWM adoption practices on basis of utility maximization (Freeman and Omiti, 2003). Thus farmers' efficacy maximization framework has been used in a number of studies to model farmers' adoption decisions using Tobit model (Jogo *et al.*, 2013). The Tobit model measures not only the probability that the smallholder farmer will adopt ISFWM practice but also the intensity of use of the technology once adopted (Akinwumi and Zinnah, 1993). Moreover, Tobit procedure is a special case used for more general censored regression model (Mudiwa, 2011) and is efficient and consistent (Nobeji *et al.*, 2011).

Following conceptual framework described by Freeman and Omit (2003), we assume that farmer's adoption decision is based on an underlying utility function. Since the farmer has a choice to adopt the recommended ISFWM practices or not to adopt, let the farmer's choice be represented by Y_i^*, where $Y_i^*=1$ if the farmer chooses to adopt the ASALs recommended ISFWM packages (which includes tied ridges/ zai pit + Combined organic and inorganic fertilizers + improved seed) and $Y_i^*=0$ if otherwise. The latter may include use of less combinations of recommended ISFWM practices in ASALs.

The specifications of ISFWM adoption decision is therefore based on a Tobit model defined as

$Y_i^*=\beta x_i + \varepsilon_i$
$Y_i = Y_i^*$ if $Yi^* > c$

$Y_i = 0$ if $Yi^* \leq c$

Where:
Yi^* is a latent variable indexing adoption, Y is an observable but censored variable measuring both the adoption and intensity of use of ISFWM practices, c is an unobservable threshold, β is a vector of unknown parameters, X is a vector of explanatory variables and ε_i are residuals that are independently distributed with i zero mean and constant variance.

MATERIALS AND METHODS

Description of the study area

The assessment of the main factors that influence smallholder farmers' adoption of ISFWM technologies and adoption levels was conducted in pilot research areas found in lower eastern Kenya. The research study which was funded by the Canadian and Kenya governments had been established to assess the effects of different ISFWM technologies on crop yield. It had activities in the ASALs of LM AEZ IV and V of Yatta and Mwala Sub-Counties, Machakos County, Kenya.

The technologies tested in the project areas comprised of improved crop varieties versus the local varieties such as improved green gram versus the locally adopted varieties, improved cowpea in comparison with the local varieties, and improved maize in comparison with the local varieties. This was conducted alongside with the recommended agronomic practices such as appropriate spacing, early planting and weeding, use of soil conservation technologies like tied ridges and open ridges as well as organic and inorganic fertilizers'.

Mwala Sub-County lies in geographical coordinates of 00º 38'N 33º 29' E/ 0.633º N 33.483º E, altitude between 1100-1550m a.s.l (KNBS 2009). The Sub-County covers an area of 481.5 km^2, a population of 89,211; 42,992 males and 46,219 females and 16,685 households (Jaetzold and Schmidt, 2006). The study cross-examined only 331 household heads in this region (Table 1). Yatta Sub-County lies between 700-800 m a.s.l and latitude 0° 03′ and 1°12′ South and longitude of 37°47′ and 38°57′ East (Jaetzold and Schmidt, 2006). The Sub-County covers an area of 1059km^2, with a population of 125,755; 60,794 males and 64,961 females and 24,630 households (Jaetzold and Schmidt 2006). However, the study interviewed 306 household heads located in this area (Table 1).

The two Sub-Counties falls under lower midland agro-climatic zone IV and V, which are classified as ASALs (Jaetzold and Schmidt, 1983). The rainfall distribution ranges from 500 to 800 mm annually

(Nguluu *et al.,* 2014; Ibraimo and Munguambe, 2007) which is erratic, unreliable and occurs as short duration with high intensity storms coupled with partial or total crop failure in over 50% of the times (Walker, 2008). The rainfall reliability is 66% with less than 100-450mm received during the growing period of both short rain and long rain seasons that ranges between 80-530mm (Jaetzold and Schmidt, 2006).

Soils in the region are fragile and prone to decline in fertility, attributable to erosion hazards due to poor natural and human-modified vegetation cove. The soils situation above contributes to a large extent to low land value per unit area. Moreover, the soils are generally sandy-loam, shallow, and deficient in major plant nutrients such as nitrogen and phosphorus, and susceptible to hard pan formation due to their inherent low organic matter (Kathuli *et al*., 2014).

The research design

Household heads were chosen based on the extension model formally referred to as the 'Primary and Secondary Participatory Agricultural Technology Evaluations' (PPATEs/SPATEs) or, in lay terms, the 'farmer-led adoption approach' (Leigh *et al*., 2014). Selection of PPATEs was based on identification of farmer groups who were at least 15 members in number, presently carrying out any agricultural activities together and willing to donate one hectare of land for the period the project trials were to be conducted. The SPATEs were invited by the PPATEs

the following seasons to come and learn from the PPATEs' experimental field trials.

According to Leigh *et al*. (2014), the PPATE/SPATE model builds on strengths of collective action, learning networks, participatory process, social capital and established peer extension practices. Thus the model was designed for technology evaluation and scaling-up of adoption of the improved practices on the basis of farmers' priorities, ranked according to selection criteria including equity, ecological, food security, nutritional and economic values. The model constitutes both technology and technique; that is, it contained what to adopt to build resilient farming systems, and how to scale up that adoption. According to Parvan (2011) a technology is a complex input process supplied to farmers by organizations with deep technical expertise while a technique is a way of doing a thing or an activity. Thus farmer-led adoption approach catalyses both horizontal and vertical scaling-up and adoption of resilience-building technologies and practices (Leigh *et al*., 2014) such as use of soil and moisture conservation structures' (e.g. tied ridges in comparison with open ridges), improved seeds and appropriate plant spacing and use of fertilizers.

Selection of household heads was also done from non-project areas otherwise referred to as non-PPATEs/SPATEs areas where the farmer led adoption approach did not register its present during the entire project period (i.e. from March 2011-August 2014).

Table 1. Target population distribution of household heads in the selected villages in the study area

Mwala Sub- County	LM AEZ	Location/FRDA	Mean no. of Households /Village	No. randomly selected
PPATEs	4	Masii	79	16
	4	Miu	72	15
	5	Kyawango	53	31
		Sub-Total	204	62
Non-PPATES	4	Wetaa	73	31
	5	Kaitha	54	31
		Sub-Total	127	62
		Total	331	124
Yatta Sub-County				
PPATEs	4	Ndalani	74	31
	5	Katangi	54	16
	5	Kinyaata	53	15
		Sub-Total	181	62
Non-PPATES	4	Kwa Ndolo	68	31
	5	Kyua	57	31
		Sub-Total	125	62
		Total	306	124
		Grand total	637	248

Source: Information obtained from chiefs and sub-chiefs based on 2009 census

Household sample size determination for the ISFWM technologies survey.

The sample size for the study was determined using the formula described by Magnani (1997) as shown:

$$n = \frac{t^2 \times p(1-p)}{m^2}$$

Where:
n= required sample size
t = confidence level at 95% (standard value of 1.96)
p = Estimated % of soil fertility and water management practices in the study area= 20.2% (Gathaara et al., 2010; Odhiambo, 2015; Ogada et al., 2014)
m = margin of error at 5% (standard value of 0.05)

Based on the above formula the sample size was expected to have a total of 247.7 respondents. This was slightly adjusted to 248 for ease of sampling and avoid non-integer samples in the different zones and areas.

Sampling of household heads.

A multi-stage sampling process involving a combination of purposeful, random and substitution sampling was applied in order to draw a representative sample of household (OECD Statistics, 2005; Geta et al., 2013). The first step involved purposive selection of the two Sub-Counties (Mwala and Yatta) based on AEZ and areas with highest concentration of ISFWM activities. A purposive identification of non-project areas was also used to identify sites that were far from the project sites with buffer zones in between to ensure no influence of information by the project activities. Random selection of the respondents was done from the list of entire population of household heads provided by the local sub-chiefs and the local Sub-County Agricultural Officers in each study area. A random sample of 124 households was taken in each Sub-County, for a total of 248 households. In case of any missing household heads substitution selection was

involved of the next household in the list. Global Position System (GPS) tool was used to identify precisely the position of homesteads of all households in question.

Data was collected for October-November 2012 short rains (SR) season and March-April 2013 long rains (LR) season using both qualitative and quantitative data collection techniques. Administration of the 248 questionnaires started in Mid-March 2014 and concluded after three weeks. The questionnaire captured data on the socio-demographic characteristics, economic characteristics and machine related characteristics of the household heads in the study area.

Data analysis.

Relationships between different variables were determined by the Tobit model, as described by Maddala (1999). Comparison on ISFWM technology adoption levels between PPATEs and Non-PPATEs was achieved via IBM SPSS version 22 using descriptive statistics.

Different combinations levels of ISFWM technologies practiced in Mwala and Yatta Sub-Counties

ISFWM is defined as a set of soil fertility management practices that includes the use of fertilizer, organic inputs, improved germplasm combined with soil moisture conservation structures and with the knowledge on how to adapt these practices to local conditions with the main aim of maximizing agronomic use efficiency of the applied nutrients and improving crop productivity (Sanginga et al., 2009; ISFM Africa, 2012; Vanlauwe et al., 2010; Odendo et al., 2009, Adolwa et al., 2012). Based on the above definition, for any household in the study area to have adopted ISFWM technologies, the farmer must have acknowledged to have practiced any of the following adoption levels (Table 2).

Table 2: Different combinations levels of ISFWM technologies practiced in Mwala and Yatta Sub-Counties

OR+org+local seed*	TR+org+local seed	ZP+org+local seed
OR+org+improved seed	TR+org+improved seed	ZP+org+improved seed
OR+inorg + local seed	TR+inorg+ local seed	ZP+inrg+local seed
OR+inorg+ improved seed	TR+inorg+ improved seed	ZP+inorg+improved seed
OR+combined fert + local seed	TR+combined fert+local seed	ZP+combined fert + local seed
OR+combined fert+improved seed	TR+combined fert+improved seed**	ZP+combined fert+improved seed**

Key. OR-open ridges, org-organic fertilizer, inorg-inorganic fertilizer, fert-fertilizer, combined fert- combination of both organic and inorganic fertilizers, Tr-tied ridges and ZP-zai pit
*least recommended, **highly recommended for arid and semi-arid lands

RESULTS AND DISCUSSION

Factors affecting adoption.

Social characteristics

Social characteristics such as age, gender, education and group membership significantly influenced adoption of ISFWM technologies. Age significantly ($p \leq 0.05$) and negatively (-0.676) influenced the adoption of ISFWM practices (Table 3). This was in agreement with earlier findings (Bett, 2006; Tizale, 2007), who elucidated that older farmers had shorter planning horizons and were more reluctant to invest in soil conservation technologies which take a long time before benefits are realized. However, Chiputwa et al. (2011) found age to have a positive effect on adoption and indicated that older farmers had experience in beneficial technologies and were shown to adopt them. Clearly the effects of age seemed to be linked to past experience. Therefore, the study findings confirm that farmers' decision making is complex and may be influenced by multiple factors that may affect positively or negatively adoption decision of any technology.

Gender was captured as a social role which significantly ($P \leq 0.05$) and positively (0.685) influenced adoption of ISFWM technologies. Gender issues in agricultural production systems and technology adoption have been investigated for a long time with most of such studies showing mixed evidence regarding the different roles men and women play in technology adoption (Abunga et al., 2012). These results are in agreement with those reported by (Baffoe-Asare et al., 2013, Jera and Ajayi, 2008) who showed that male farmers are resource endowed by virtue of their cultural settings and more apt to adopt new technology. Moreover, due to many social-cultural values and norms, males have freedom of mobility and consequently have greater access to information (Okuthe et al., 2013). Besides, females are normally occupied with domestic activities and are also less resource (financial and human) endowed impacting negatively on both adoption decision and the extent of use of ISFWM practices such as fertilizer (Martey et al., 2014). Thus the positive coefficient implies that the more female members of the households are involved in ISFWM practices, the more they are likely to adopt these practices.

Studies on the effect of education on adoption of agricultural technologies are mixed (Bett, 2006; Manyeki et al., 2013). In this study education had a negative (-0.033) coefficient and significantly ($P \leq 0.01$) related to the probability of adoption of ISFWM technologies in both Sub-Counties. The likely explanation of the negative influence to adoption of ISFWM technologies is that household heads who acquire education tend to look for other off-farm jobs and this reduces the time spent on the farm (Mwangi et al., 2015; Odendo et al., 2011). This agreed with findings by (Mwangi et al., 2015; Odendo et al., 2011) but disagreed with those reported by others who have found education to influence adoption positively (Kassie et al., 2009; Manyeki et al., 2013; Chiputwa et al., 2011; Mugwe et al., 2012) indicating that with more education farmers pick beneficial technologies and rationalize them.

Table 3: Tobit regression analysis results showing factors affecting smallholder farmers' adoption of isfwm technologies in Mwala and Yatta Sub-Counties.

ISFWM adoption variables	β)	Std. Err.	P value
Age	-0.676	0.303	0.027*
Gender	0.685	0.303	0.025*
Education	-0.033	0.013	0.010**
Group membership	0.207	0.085	0.016*
Land size	-0.001	0.002	0.452
Land tenure systems	-0.207	0.112	0.068
Costs of inputs	-1.307	0.18	0.000**
Access to radio	0.066	0.012	0.000**
Cost of labor	0.645	0.221	0.004**
Availability of farm machinery	0.025	0.158	0.001**
Access to extension services	0.675	0.303	0.027*
Inaccessible credit services	-0.028	0.012	0.017*
Access to markets	-2.55	0.091	0.006**
Perception on season reliability	-0.258	0.089	0.004**
Perception on improved seeds	0.16	0.094	0.09
Constant	3.844	0.263	000

The study found that association of the household head to any organization significantly (P≤0.05) and positively (0.207) influenced ISFWM technology adoption. The positive coefficient indicates that as farmers' participate in more organizations, they are more likely to take up new ideas including new ISFWM technologies. These findings are supported by reports by Martey *et al*. (2014) that suggested that participation in agricultural development projects was expected to influence farmers' fertilizer adoption and fertilizer use intensity positively. Furthermore, when agricultural projects provide crucial information to enhance the productive skills of farmers such as marketing of outputs, farmers' adoption decision is also influenced positively (Mwangi *et al.,* 2015) while it is negative if contribution to productive skills is minimal (Martey *et al.,* 2014).

There are two main seasons' in lower eastern Kenya, the October-November short rain (SR) season and March-April long rain (LR) season. The adopter perceptions paradigm suggests that the adoption process starts with the adopters' perception of the problem and technology proposed (Nyanga *et al*., 2011). According to Nyanga *et al*. (2011), this paradigm argues that perceptions of adopters' are important in influencing adoption decisions. Thus the study established that farmers' perception on the SR season affected adoption of ISFWM technologies negatively and highly significantly (P≤0.01). It had a negative coefficient (-0.258) indicating that the variable October-November SR season is important thus as the short season becomes more unreliable, farmers will be more hesitant to adopt the ISFWM technology. This is evidenced by the study of Mutuma (2013) reporting that most smallholder farmers' practicing more ISFWM technologies such as improved seed, inorganic fertilizer and in particular the farmers' who were found to apply organic fertilizers in their farms only during SR season. These findings are also in conformity with earlier reports by Recha *et al.* (2013) who showed that on average, 18% of the farms were left fallow during the SR season while 34% land were left fallow during the March-April long rain (LR) season, reflecting the general perception that the short rain season are more reliable compared to LR season. Consequently, farmers in lower eastern Kenya perceives October-December season as more reliable season thus tend to increase the acreages under crop, planting of late maturing crops varieties and agro-forestry species. Likewise report by Mutuma (2013) showed that farmers use technologies that they perceive as profitable such as use of inoculants (Biofix®) on Soybean *(Glycine Max)* to boost production in western Kenya during the most reliable season.

Smallholder farmers access to agricultural extension services was reported to be statistically significant (P≤0.05) in relation to adoption of ISFWM technologies. The positive sign (0.675) indicates that access to information on new technologies is crucial to creating awareness and attitudes towards technology adoption (Kassie *et al.,* 2009). In addition, Adolwa (2012) reported that extension services, agricultural institutions of learning and/or research, farmer unions or cooperatives, input dealers or stockiest, mass media, information communication technologies (ICTs) such as internet, mobile telephony and faxes were reported as means of creating technology awareness. In addition, the modern community and print based channel networks employed by extension agent and researchers were stated to some of the means of promoting technology adoption (Adolwa, 2012).

Economic characteristics

Inaccessibility to agricultural credit negatively (-0.028) influenced adoption of ISFWM technologies statistically significant (P≤0.05). This indicated that the smallholder farmers in the study region were not able to get credit or they were reluctant to access the credit probably due to high interest rate the financial institutions in Kenya charge. According to Nobeji *et al*. (2011), smallholder farmers in developing countries have limited access to financial loans and credits and so they depend on savings from their low incomes, which limits opportunities to adopt certain practices such as ISFWM technologies. The results were in line with Demeke (2003) who reported a systematic association between farmers' participation in credit access and adoption of conservation structures. Chiputwa *et al*. (2011) found that lack of access to cash or credit/ cost of capital (interest rate) may hamper smallholder farmers from adopting new technologies that require initial investments. Access to credit by farmers enhances their purchasing power and this in turn may increase purchase of improved seeds, inorganic fertilizers with consequent adoption (Nyamai, 2010; Oluyede *et al.,* 2007; Humphreys *et al.,* 2008).

The costs of inputs were highly significant (P≤0.01) and showed a negative coefficient of -1.307. This implies that the more the cost/price of inputs increases, more farmers become unwilling to purchase the inputs. Thus as the prevailing prices of improved seed and mineral fertilizers increases, the farmers in ASALs are reluctant to adopt e.g. seed price of the staple (maize), cost and level of subsidy on fertilizer have been reported (Oluyede *et al.,* 2007; Humphreys *et al.,* 2008) to be the key determinants of financial attractiveness and the potential adoptability of the different soil fertility options.

Radio access was found to significantly (P<0.01) influenced adoption of ISFWM technologies positively (0.066). The results imply that the more smallholder farmers are exposed to radio information, the more they are likely to choose best alternatives to use in their farms without even considering their long term impacts. These results agree with those reported by Lwoga *et al.* (2011) who found that 96.3% of the farmers used radios to access information and knowledge in farming systems. Lwoga *et al.* (2011) noted that radio was an appropriate channel for acquiring information for large numbers of farmers in rural areas probably due to its oral nature, low costs and availability to farmers without electricity.

Cost of labor affected the adoption of ISFWM technologies highly significantly (P<0.01). The coefficient of labor was positive (0.645) implying that availability of labor augmenting implements increases adoption of ISFWM practices. A study by Mutoko *et al.* (2015) in North-Western Kenya indicated that an increase in availability of labor enhancing machines and implements increases adoption of ISFWM practices. These findings are also consistent with the findings by Odendo *et al.* (2010) who observed that labor constraints had a significant impact on the adoption decision of use of tree fallows which are a relatively labor-intensive. In addition, Drechsel *et al.* (2012) and Gichangi *et al.* (2007) pointed out that labor availability and labor bottlenecks were two of the most important types of diagnostic information that aid in selecting appropriate technologies and in defining target groups with high adoption potential.

Out-put market access was established to significantly (P<0.01) affect the ISFWM adoption negatively. This negative coefficient (-2.55) indicates that farmers are unwilling to adopt a technology that its market structure is poor. The economic theory clearly shows that the incentive to invest in a new technology increases in the induced change in output (i.e. through higher yields and /or relative prices) and decreases in the relative cost of investment thus relative cost or price and technology is very important for adoption of ISFWM technologies (Barrett *et al.*, 2002).

Similarly, Nambiro and Okoth (2013) found that distance to input and output markets had a negative influence on use of inorganic fertilizer in maize production. Likewise, market access for agricultural products often facilitate commercialization of production and adoption of commercial inputs such as fertilizers, improved seeds, pesticides and therefore improved market access can be the driving force for sustainable intensification of agriculture (Odendo *et al.,* 2010).

Machinery related factors

The study found that availability of farm machinery affects adoption of ISFWM technologies highly significantly (P<0.01). Inappropriate farming machinery especially implements used in making the soil conservation structures was established to be a major constraint in ISFWM technology adoption. Lack of appropriate machinery was positive (0.025). The positive coefficient shows that as the appropriate farm machinery becomes more accessible, farmers will be willing to adopt that ISFWM technology. This is in line with earlier findings by Gichangi *et al.* (2007) who reported that farmers in the ASALs of Kenya indicated that they were impressed by water harvesting techniques especially using tied ridges but noted the need for a suitable implement that could be invented to make the work easier. Besides, Mati (2005) and Dorward *et al.* (2008) noted that, use of labor saving machinery was a prerequisite for the use of modern agricultural inputs (fertilizer, selected seeds, agro-chemicals) in ASALs of Kenya and in West Africa, respectively.

Comparison between adoption levels among project and non-project areas.

There were significant differences in the household heads who adopted different levels of technology combinations between project and non-project areas (Table 4). Majority of the respondents (93.9%) in the project areas adopted tied ridges, organic fertilizer and improved seed compared to only 6.1% in the non-project area. There was significantly (P<0.01) higher adoption (76.5%) of tied ridges, combined fertilizer and improved seed in the project area in contrast to only 23.5% in non-project area. Adoption was also significantly higher (P<0.01) for household heads who majority (80%) were reported adopting a combination of zai pit, combined fertilizer and improved seed improved in the project area as compared to non-project areas households heads who stated only 20%. However, a combination of open ridges, organic fertilizer and local seed was adopted by a significantly (P<0.05) higher percentage (78.6) in non-project area compared to project area with only 21.4%.

It is our recommendation that the policy makers to focus mainly on availability of affordable: input-output markets, credit service facilities, labor and ease access of information. When this happens, farm productivity will be boosted with consequent improved food and nutrition security for enhanced livelihoods of the smallholder farmers' in ASALs of Kenya.

Table 4: ISFWM technology adoption levels among project and non-project areas

Levels of ISFWM technologies	Project area %	Non-Project area %	t-ratio	p value
Or+Org+Local seed	21.4 (3)	78.6 (11)	9.833	0.027*
Or+Org+Improved seed	30 (21)	70 (49)	24.773	.000**
Or+Inorg + Local seed	50 (1)	50 (1)		Ns
Or+Inorg+ improved seed	33.3 (2)	66.7 (4)		Ns
Or+combined fert + Local	33.3 (2)	66.7 (4)		ns
Or+Combined fert+Improved seed	39.3 (24)	60.7 (37)	25.474	.000**
Tr+Org+Local seed	71.4 (5)	28.6 (2)		ns
Tr+Org+Improved seed	93.9 (31)	6.1 (2)	3.187	0.004**
Tr+Inorg+ improved seed	100 (3)	0 (0)	0.458	0.017**
Tr+Combined fert+ Local	100 (1)	0 (0)		Ns
Tr+Combined fert+Improved seed	76.5 (26)	23.5 (8)	6.671	0.001**
Zp+Org+Improved seed	33.3 (1)	66.7 (2)		ns
Zp+Inorg+Improved seed	0 (0)	100 (1)		ns
Zp+Combined fert+ Local seed	33.3 (1)	66.7 (2)		ns
Zp+Combined fert +Improved seed	80 (4)	20 (1)	6.978	0.006**

*Key, : Or=Open ridges, Org=organic fertilizer, Inorg=Inorganic fertilizer, fert=fertilizer, Tr=Tied ridges, Zp=Zai pits, Figures in parenthesis indicates frequencies, * significant at 5% level, ** significant at 1% level*

CONCLUSION

The study sought to understand factors that influence the integrated soil fertility and water management (ISFWM) technologies in Yatta and Mwala Sub-Counties in Machakos County, Kenya. Thus factors that impede adoption of ISFWM technologies by smallholder farmer in ASALs were identified. The results reported in the study demonstrates that low adoption of ISFWM technologies by the smallholder farmers' is the major factor that causes low agricultural productivity. Consequently, more frequent food insecurity, nutrition and negative transformation of livelihoods in these regions.

There was clear evidence from the study that the following variables affected adoption of ISFWM technologies either positively or negatively thus gender, group membership, radio access, cost of labor, availability of appropriate farm machinery and access to agricultural extension showed a negative coefficient. Household head: age, education, costs of inputs, access to credit services and out-put markets and household perceptions on seasons gave a negative coefficient regarding ISFWM technology adoption.

We have found that majority (93.9%) of the household heads in the project area had adopted a combination of tied ridges, organic fertilizer and improved seed compared to only 6.1% in the non-project area, one of the recommendation practices advocated by the project team.

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