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Adoption of appropriate technologies among smallholder farmers in Kenya

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Abstract

The adoption of appropriate technologies in small-scale farming is an important response to the effects of climate change and variability, especially in Africa, a continent characterised by a great vulnerability to the impacts of climate change. This study investigates the levels of awareness and adoption of some appropriate technologies suitable for the changing climatic conditions at two pairs of sites matched for rainfall, but differing in temperature, in semi-arid and sub-humid regions of Kenya. The pairs were also subsequently matched to form cool and warm regions. The study was conducted using participatory methods consisting of 20 focus-group discussions and data from 722 randomly sampled households from the two regions. The descriptive and inferential results show that there was a high level of awareness of appropriate technologies but low rates of adoption in the semi-arid and sub-humid regions, as well as in the cool and warm regions.

The study has identified the fact that even though gender did not influence awareness of the technologies, it has a positive correlation with adoption of the technologies. There was a difference in adoption of appropriate technologies between male-headed households and female-headed households at a 1% level of significance. Technology knowledge and use were higher in the semi-arid and warm regions than in the sub-humid and cool regions with farmer-to-farmer learning being the most prominent source of information. There was a difference in the use of technologies which have a positive impact in regions with high temperatures at a 1% level of significance. A higher percentage of farmers used water harvesting, reduced tillage, crop rotation, green manure and used mulches in the warm regions compared to cool regions. The trend in awareness and adoption assumed a gender and an ecological dimension in favour of males, in both semi-arid regions and warm regions.

Keywords: Climate change and variability, appropriate technology, adoption, gender, semi-arid region, sub humid region

1. Introduction

Smallholder agricultural production systems are the main source of food and income for most of the world's poorest people (GSCCSA, 2011). They produce more than half of the world's food supply, provide up to 80% of food in developing countries and operate around 80% of farmland in sub-Saharan Africa and Asia (Grainger-Jones, 2011). They are in essence, vital to the livelihood of many communities. In Kenya, smallholder farmers account for 75% of the total agricultural output and 70% of marketed agricultural produce (GoK, 2010). In addition, smallholder farming creates opportunities for women, who provide 60–80% of labour in the agriculture sector (GoK, 2010). Therefore, the effects of climate change and variability on the world's 500 million smallholder farmers (IFAD, 2011) cannot be overlooked.

Smallholder farmers are one of the most vulnerable groups to climate change and variability as it adds pressure to their already stressed ecosystems (Grainger-Jones, 2011) and the severe economic constraints they experience. Consequently, investment aimed at reducing the impacts of climate change and variability on small-scale farmers is critical in attaining the objective of global poverty reduction and food security (Wiggins, 2009). However, responding to the effects of climate change and variability requires continuous development of new techniques and improvement of the existing ones and, more importantly, their widespread adoption by farmers. In order to build the adaptive capacity of smallholder farmers, knowledge management is important (Campbell et al. 2010). Smallholder farmers need training on how and why to use technologies and appropriate incentives to adopt them, so as to allow them to maximise the use of water supplies and optimise their production (Filho, 2012). This will require, as a matter of necessity, government support through the formulation of policies that provide incentives either directly or through the markets (Grainger-Jones, 2011).

The global challenges caused by climate change and variability are increasing the value of climate-related information (GSCCSA, 2011) and dissemination (Filho, 2009). However, a survey done in Kenya assessing farmers' needs showed that the most important information required by farmers, such as chemical application rates, control of late blight in potatoes, accessing certified seed and identifying the most appropriate crop varieties for a given location, among others, were not adequately addressed (Rees et al., 2000). It has also been noticed that research work is not often tailored to solve the needs of the farmers (Orotho, 1990). Thus smallholder farmers have devised site specific ways of coping with current environmental and socio-economic conditions over the years. However, most of their coping mechanisms are not documented. In addition, smallholder farmers are also able to contribute to mitigation by adopting agricultural practices that reduce GHGs emissions. Other appropriate technologies adopted have included agroforestry, conservation agriculture, compost production, afforestation and reforestation among others (Seeberg-Elverfeldt and Tapio-Biström, 2010). Among the practices being adopted by the farmers is climate smart agriculture (CSA). The climate smart technologies include mixed cropping, zero tillage, mulching, intercropping, conservation agriculture, crop rotation, integrated crop-livestock management, agro-forestry, improved grazing, and improved water management. CSA also includes innovative practices such as better weather forecasting, drought- and flood-tolerant crops and risk insurance. However, poor smallholder farmers find it difficult to invest in CSA because it takes time before farmers can realise the benefits (Neufeldt, 2011).

In addition, very little is known concerning the specific needs of smallholder farmers in different agro-ecological zones with regard to farmers' on going adaptation to climate change and variability and how that might be affected by factors such as their resource base and gender. The study hypothesizes that geographical location and gender significantly the adaptation strategies of smallholder farmers to climate change and variability.

Current agricultural extension systems in Kenya work closely with farmers and are tasked with the responsibility of initiating and supporting the diffusion of innovations, as well as facilitating exchange of experience between farmers. Apart from extension workers, farmers use radio and television or the observations of other farmers as further sources of agricultural information. However, the use of this information is determined by how the knowledge is passed on, how it works and its benefits to farmers (Muhammad and Garforth, 1995). These matters have largely been overlooked in the past. This study aimed at examining the levels of awareness and adoption of selected appropriate technologies and the modes of information dissemination amongst smallholders in two agro-ecological zones of Kenya. These are semi-arid and sub-humid regions of Kenya. The semi-arid zones are characterised by low, erratic rainfall averaging 300–600 mm per year with shallow and generally infertile soil (Hudson, 1987). The sub-humid region of Kenya receives an average of between 1000–1500 mm of rain annually and the soils are red clay (Orodho, 1996), which makes it vulnerable to climate variability and to the impacts of climate change.

2. Methodology

2.1 Project area

The study was carried out in four important agricultural areas across Kenya, comprising cool and dry, cool and wet, warm and dry, and warm and wet growing conditions. The paired areas represent climate analogues that help people visualise what their climate and environment is likely to look like in the future (Ramírez-Villegas, 2011)**.** The two paired sites have similar rainfall totals and patterns but with a mean annual difference in temperature of 1.5–3 ^{0}C. Detailed descriptions of climatic conditions for the paired sites are given in Table 1.

The study of the semi-arid region was carried out in five villages at Machakos district near KARI (Kenya Agricultural Research Institute) Katumani, which is the cool and dry site, and five villages at Makueni district near KARI Kambi ya Mawe representing the warm and dry site. For the sub-humid region, the study was carried out in five villages in Limuru district representing the cool and wet site, and five villages in Kikuyu district representing the warm and wet site. The differences in climate conditions may influence the agricultural practices that farmers adopt (Bryan et al. 2010). Due to these, different categories of agricultural technologies which assist farmers in adapting rain-fed agriculture to climate change and variability were considered. The selection of these technologies was based on studies of rain-fed agriculture that have consistently shown that soil conservation, rainwater harvesting and drought proofing are essential for adaptation to climate change and variability (Venkateswarlu et al. 2009). Studies show that technologies such as mulching with maize straw lower soil temperature, improve average water use efficiency and increase yields (Liu et al., 2011). This is because mulching reduces soil evaporation and conserves the soil moisture, thus adjusting soil temperature. Soil temperature is an important component in plant growth, since it determines nutrient requirement for plant growth. Temperature also has a direct effect on soil moisture as it influences soil evaporation (Brabson et al., 2011). The technologies were grouped into three categories, named “soil and water management”, “soil fertility management” and “crop management practices”. In addition, the social and economic characteristics of each household were also recorded.

2.2 Data collection methods

Two principle methods of data collection were used in this study: a household survey and Focus Group Discussions (FGDs). In addition, secondary data was obtained from reviews of literature. The study was implemented between July 2011 and June 2012, with data processing taking place in late 2012 and early 2013.

2.2.1 Household interviews

Household interviews were conducted using structured and semi-structured questionnaires to record information on levels of awareness and adoption of technologies and their sources. For each study site, five villages were randomly selected, making a total of 20 villages with the same climatic characteristics as the study sites, which were represented by the village elders (Table 2). From the total of twenty randomly selected villages, 722 households were interviewed as shown in Table 2.

2.2.2 Focus Group Discussions (FGD)

Two sensitization meetings were carried out before the commencement of the FGDs. The date for FGDs was communicated to the participants through the village elders. The participants were stratified randomly selected across the sampled villages with the assistance of the village elders. 209 members who participated in the FGDs were chosen from a sample of 500 randomly selected households. A total of six sessions (three for women and three for men) were conducted per site. The FGDs were conducted with separate groups for men and women with between 6–12 members per group and at the same villages where the household interviews were undertaken. A total of 102 men and 107 women participated. The FGDs were conducted using a checklist. The responses were recorded using an audio recorder and later transcribed to record the themes as they emerged in the discussions.

2.3 Data analysis

The data collected was analysed both qualitatively and quantitatively. Data from household interviews were entered, processed and analysed using two computer programs: Statistical Package for Social Science (SPSS) and Excel. The data used for the analysis was nominal categorical variables. In order to determine trends and patterns of awareness, adoption rate and sources of some agricultural technologies relating to climate change and variability, both descriptive and inferential statistics were used. Specifically, means and frequencies were used to establish trends and patterns while Cramer's V was used to determine the strength and type of association between gender, knowledge and adoption of the technologies (SAS, 1990). Data from FGDs were analysed using content analysis to understand the themes emerging in relation to the study objectives. This was deemed appropriate in establishing a consensus on particular aspects or themes of concern to the study from a wide range of communication, as recommended by Smith, 1992, so as to develop perception and understanding of the data (Cavanagh, 1997).

3.0 Results and discussions

3.1 Description of study sample

The sample was composed of 71.2% and 73.8% male-headed households in the semi-arid and sub-humid regions, respectively. The semi-arid region had 50.6% of household heads with at least a primary level of education as compared to 48.5% from the sub-humid region. 27.8% of household heads reported having secondary education in the sub-humid region, compared to 26.3% in the semi-arid region. Fifty percent of household heads were aged 55 years and above with more older people found in the semi-arid region. At the semi-arid region, KARI Katumani 76.4 % were male-headed households while at KARI Kambi ya Mawe, 71.2% were male-Headed Households. At the sub-humid region, 73.9% of the households at KARI Katumani were male headed households while at KARI Kambi ya Mawe 73.6% were male-headed households. At the semi-arid region, KARI Katumani had higher percentage (57.5%) of household heads with at least a primary level of education as compared to KARI Kambi ya Mawe (53.9%). At the sub-humid region 46.8% of households from KARI Kabete had achieved education at primary level compared to 41.6% of household heads at KARI Limuru.

3.2 Awareness and use of agricultural technologies

3.2.1 Technological expertise and its use in semi-arid and sub-humid regions

A summary of the agricultural technologies suitable for the sub humid, semi-arid, cool and warm regions is shown in Table 3. The analysis showed that there was no significant difference in the knowledge of technologies in the four regions ($\chi2$ = 12.66, df=2, p=0.002, Cramer's V=0.03 for semi-arid and sub humid regions) , ($\chi2$ = 4.42, df=2, p=0.109, Cramer's V=0.023 for warm and cool regions) There was a difference in the adoption of technologies at a 1% level of significance between the sub-humid and semi-arid regions ($\chi2$ =77.84, df=2, p<0.001, Cramer's V=0.1294). Likewise, in the warm and cool regions, the difference is at a 1% level of significance ($\chi2$ =61.58, df=2, p<0.001, Cramer's V=0.1151) (Table 4). Soil and water management technologies were best known and used in the semi-arid and warm regions. This is despite the fact that the use of agricultural practices such as mulching and using compost manure are some of the recommended practices for adapting soil to climate change through C sequestration (Lal, 2010). Likewise, the knowledge and use of soil fertility management technologies were highest in the sub-humid and cool regions. This shows that soil moisture for crop production was not a problem in comparison to soil fertility in the cooler regions. The detailed data from the household interviews on knowledge and utilisation of technology are presented in Tables 5 and 6.

The data in Table 5 showed that there was generally a high level of awareness, with over 50% of the farmers familiar with all the technologies in the semi-arid region. In the sub-humid region, there were only three technologies (seed priming, tied ridges and green manure) of which less than 50% of farmers were aware. Apart from two technologies, row planting and animal manure, the farmers in semi-arid regions showed more awareness of technologies than those in the sub-humid region. This is evidenced by significant statistical differences between the levels awareness and adoption from the semi-arid to the sub humid region as shown in Table 5 ($\chi 2$ = 185.96, df=14, p<0.001, Cramer's V=0.1493). There was also a lower level of awareness and adoption across the two regions for the comparatively more complex technologies that require more financial input and effort such as use of green manure, seed priming and herbicides. This was in line with findings elsewhere that suggest that simple and cheap technologies, such as use of modern maize varieties, are more acceptable (Doss and Morris, 2001), and for adoption of a technology to occur the farmers must be aware of it (Asiabaka et al, 2001; Agwu, 2001; Ajayi, 2002; and Ajayi and Solomon, 2010). From this study, simple technologies such as use of animal manure, row planting and terracing showed the highest awareness and adoption rate from both regions.

The results from the FGDs pointed to the fact that 90% and 84% of farmers from semi-arid and sub-humid regions respectively had less access to information about new agricultural technologies and innovations than indicated, 98% and 88% lacked capital, and 82% and 76% had limited access to extension services. It was also noted that farmers feared the heavy security presence at the entrances of the research centres in their regions. Due to safety reasons the heavy security presence is justifiable, especially where the nature of research requires quarantine to prevent the spread of diseases and avoid harm to human beings and the rest of the flora and fauna.

In the semi-arid region, there were high levels of awareness and adoption of terracing, with all of the farmers being aware of the benefits of terracing. However, only 16.1% of the farmers were practicing terracing in the sub-humid region. This may be attributed to the small areas used, averaging 0.6 hectares per household, and the intensive labour requirement of this technology. The farmers from the sub-humid region, especially from Limuru area, use Napier grass for soil and water conservation.

The level of awareness of row planting was 97.5% and that of both animal manure and pest and disease control 99.2% in the semi-arid region. This high awareness may be due to the promotion of these technologies by the Government of Kenya in the early 1980s (Karanja, 2006). It was encouraging to note that the high levels of awareness of these technologies were also translated into higher adoption rates. The farmers linked the use of the aforementioned agricultural practices to counteracting the increasing temperature ranges and unpredictable rainfall patterns. The higher adoption of pest and disease control linked to climate change and variability was similar to the trends observed in semi-arid regions of Tanzania (Mongi, 2010). The study showed that the emergence of new pests and diseases was associated with the increase in temperatures and number of dry spells, prompting the increase in the use of pest and disease control measures. Other major documented impacts of climate change and variability on agriculture in Tanzania are recurrent droughts, floods, increasing crop pests and diseases and seasonal shifts (URT, 2007).

Conversely, despite the fact that water harvesting technology has been promoted as an alternative to water scarcity in arid and semi-arid regions, the levels of awareness and use stood at 78.8% and 53.3% respectively and were relatively low as compared to levels of adoption of some other technologies (Table 5). Low adoption of other technologies that could be of benefit to farmers in semi-arid regions was also observed for mulching, tied ridges and reduced tillage. Technologies such as reduced tillage, no-till, direct drill, mulch, trash farming and strip tillage have been used for soil and water conservation in semi-arid regions (Hudson, 1987). The barrier to adoption of tied ridges was cited as being the fact that it is labour intensive and only suitable for small land parcels. The low adoption of mulching was associated with termite attacks, meaning the maize stalks are eaten.

The farmers in the sub-humid region showed differing patterns from those in the semi-arid region in awareness of the technologies, with all the farmers reporting awareness of row planting. The levels of awareness of other technologies were also high, with the use of animal manure being mentioned by 99.5% and the application of chemical fertilizer by 98.6% of the farmers. Unfortunately, the high awareness of chemical fertilizer did not translate to high usage with only 35.5% of the farmers reporting using it. This low usage may be due to high input costs (Waithaka et al., 2007). Farmers from the study sites preferred using animal manure since it is easily available. Due to the scorching effect of fertilizer on crops during periods of low rainfall, farmers had a perception that the use of fertilizers hardened their farms. This can be linked to the hygroscopic behaviour of fertilizer (Sharma and Patel, 2000).

Generally, Table 5 demonstrates that technology knowledge and usage is higher in the semi-arid region than in the sub-humid region. This may be contributed to by the average size of land parcel and level of education in the sub-humid region, where the majority of farmers are squatters. The total average area of land per household in the semi-arid region is 2.67 hectares, as compared to 0.6 hectares in the sub-humid region. The area of land cultivated was different in the semi-arid the sub-humid regions at a 1% level of significance. The average area of cultivated land was 1.21 hectares for semi-arid region as compared to 0.4 hectares for sub-humid region. 80% of farmers rented the land to cultivate in the sub-humid region compared to 10% of farmers at semi-arid region. Land ownership was identified as the key factor in the adoption of conservation tillage practices in Morogoro District of Tanzania (Lubwana, 1999). In addition, a higher percentage of household heads (50.6%) in the semi-arid region had primary education as compared to 48.5% in the sub-humid region. A study done in Mozambique showed that where the household heads had an education, those families were more likely to adopt agricultural technologies (Uaiene, 2009). Knight and Weir (2000) also found out that early innovators in Ethiopia tended to be educated. The high levels of knowledge and utilisation of appropriate technology in the semi-arid region is a welcome idea since there is increasing evidence that shows that climate change and variability will strongly affect drier regions (Adger et al., 2007; Kurukulasuriya et al*.,* 2006).

There is a moderate association between the experience of the effects of climate change and variability and utilisation of the climate information (Cramer's V = 0.34). In this study, rainfall, sunny intervals and temperature were the only climate information considered. From Table 5, 86.1% and 88% of farmers are aware of climate information in the semi-arid and sub-humid regions respectively. More interestingly, use of climatic information is high in the semi-arid region with 52.7%, as compared to 30.3% in the sub-humid region. The farmers usually use the weather updates on the radio and TV for agricultural planning, so as to reduce the risk associated with crop failure. The higher percentage of farmers using climatic information in the semi-arid region may be attributed to the variability in rainfall and drought spells witnessed over the last few years. During FGDs, farmers confirmed that climatic information was useful in choosing the type of crops to plant and at what date. However, the percentage of the farmers making use of climatic information is still low despite a lot of talk of climate change and variability in high-level meetings of policymakers, but this has not trickled down to the farmers.

Table 6 gives a summary of results from the cool and warm regions. A higher percentage of farmers from the warm region practiced water harvesting, reduced tillage, crop rotation, mulching, application of green manure and used climatic information for their agricultural production as compared to farmers from the cool region (Table 6). Use of these specific technologies is different between the cool and warm regions at 1% level of significance ($\chi 2$ = 19.654, df=14, p<0.001, Cramer's V=0.485). Technologies such as mulching with straw were found to significantly increase soil moisture and lower soil temperatures (Rioba, 2002), and this is beneficial to crop production, especially to the warm regions. Higher temperatures have also been associated with increased incidences of pest and diseases and the use of crop rotation has been proven beneficial in reducing insect populations, thus increasing yields. Crop rotation also helps farmers to reduce problems associated with reduced tillage such as increased soil compaction and perennial weeds (Roth, 1996). Green manure was also found to conserve water by reducing water evaporation, as well as reducing the need for pesticides (Florentín et al., 2010).

3.3 Appropriate technologies and gender

In the African context, the household head makes decisions on agricultural activities irrespective of whether or not they are present (KIHBS, 2006). Significantly, more male-headed households were aware of technologies than were female-headed households across the two regions (Table 7). The analysis revealed that gender as a whole didn't influence awareness of the technologies (Cramer's V = .0932, p< 0.001, df =1). This adoption of technologies was also significantly different between male-headed households and female-headed households at the 1% level of significance (Cramer's V=0.1308, p<0.001, df=1). Even though gender did not influence the awareness of the technologies, it has a positive correlation with adoption of the technologies. 73.07% and 74.68% of male-headed households from semi-arid and sub-humid regions respectively had adopted the technologies. This may have been contributed to by the fact that in most smallholder farms, technology is mostly at the disposal of men (Lubwana, 1999). In these villages, even in female-headed households, the older son or male relative makes the decisions for the family. If the woman is not the primary decision-maker in the households, her gender-specific needs may not be met (Wakhungu, 2010). Studies also show that women do not possess material assets, thus making it difficult for them to access credit facilities for buying inputs such as fertilizer and seeds. From the study, it was evident that the household head receives the highest percentage of the income accrued from farming. For instance, 68.8% of income accrued from the sale of crops goes to the household head, with the spouse receiving only 25.9%. Similarly, of the income accrued from the sale of livestock, the household head receives 78.7% with the spouse receiving 17.3%. This leaves the women with little income, thus reducing their purchasing power. The ability to afford seed and fertilizer has already been identified as a key component of technology adoption (Wakhungu, 2010). Other factors influencing technology adoption include farm size, level of education, gender, access to extension services and credit facilities (Salasya et al., 2007).

Awareness and adoption of technologies in warm and cool regions were significantly different between male-headed and female-headed households at a 1% level of significance ($p<0.001$, Cramer's V = 0.3079, df=1) (Table 8). The analysis shows a positive correlation between gender and adoption of technologies in the warm and cool regions. 68.93 % and 78.43% of the male-headed households from cool and warm regions had adopted the technologies. This trend is similar to the semi-arid and sub-humid regions, where the adoption of technologies by male-headed households was higher.

Factors contributing to the large disparity in awareness and adoption of these technologies between the male and female-headed households were highlighted during the FGDs. These include heavy workloads as women perform both agricultural and domestic duties such as cooking, fetching water and taking care of children and the sick, among others. Due to this, they have little time to attend community meetings. They also do not have time to listen to the radio, (which is mostly a male possession), or watch TV. This division of roles, which burdens women more than men, is a socially accepted norm in the community. This grossly affects technology adoption by female-headed households. These cultural and traditional beliefs have been seen as a long-standing phenomenon that has negatively affected the adoption of most agricultural technologies (Lubwana, 1999). If women in Kenya are given the same opportunities as men, such as education, information and access to seeds and fertilizers, yields can be increased by 22% (Chelala, 2011) and total agricultural production in developing countries raised by 2.5–4%, as well as the number of hungry people in the world reduced by between 100–150 million (FAO, 2011). Empowering rural women and girls can be a solution to food security, poverty reduction and sustainable development (United Nations Economic and Social Council, 2011).

3.4 Main sources of information about agricultural technologies

There is a general belief that extension workers are the main channel for the adoption of new agricultural technologies and information (Sugimoto and Margono 2011). On the contrary, the study showed that the most frequent source of information in the two regions was learning from other farmers who are already using these technologies, with the exception of climatic information (Table 9). The technologies learnt from other famers may not be new, but they are seen as new by the farmer (Baumüller, 2012). This is consistent with the results of other studies that showed that farmers with experienced neighbours were more likely to devote more land to new agricultural technologies (Abbas, 2003). During the FGDs, farmers confirmed that they imitated the use of technologies and crop varieties from neighbours whose crops were doing well. However, Omotayo et al. (1997) found out that 40–50% of those who had access to radio obtained information on improved farming practices from it. Nevertheless, the study did not show us the extent to which the information was translated into practice.

Farmers in the study signified the importance of electronic media by reporting radio and television as the main sources of information on climate change and variability. This is similar to a study done by Nzeadibe et al. (2011) whereby the mass media was the largest source of information on the phenomenon of climate change in the Niger Delta Region of Nigeria.

3.4.1 Sources of information and gender

A gender analysis of the sources of information showed that there was a difference in the use of all the sources of information between male and female-headed households at a 1% level of significance ($\chi 2$ = 144.67, df=1, $p<0.001$, Cramer's V = 0.2177) in the semi-arid region (Table 10). Government officers and learning from other farmers were the preferred source of information for female-headed households in both regions. This may be attributed to the fact that government officers, especially extension workers, visit farmers groups in their homes on rare occasions, when it is mostly women to whom they offer professional advice. Even though the women indicated that they did not have time for frequent meetings, they have regular women’s groups which meet at predetermined intervals. The NGOs are the main source of information for all (100%) male-headed households in the semi-arid region, while school is the main source of information for male-headed households in the sub-humid region, at 86.26%. This may be due to the fact that men have more time to attend seminars and agricultural-based workshops organised by various organisations. Women attend such events when they are officially nominated and must go. 80% of men from the project site confirmed spending their evening time meeting other men, when they share information at male-dominated markets and hotels. The other 20% preferred helping with livestock-related chores. 32.4% and 27.30% of women mainly get information from their fellow women during women’s groups, which are held after a certain period of time. These percentages seem low, but represent the most significant source of information. This means that they have less exposure time compared to their male counterparts. Extension workers offer professional advice to the women’s groups on crop and livestock production. It has been established that women constitute up to 60–80% of food producers in sub-Saharan Africa. It therefore makes sense to expect that a corresponding percentage of agricultural extension and training services would be directed to women farmers (Doss, 2011). This empowers their families to adapt to agricultural technologies.

There was difference in the sources of information used by male and female-headed households at a 1% level of significance ($p<0.001$) in the warm and cool regions (Table 11). Interestingly, there were similarities in the sources of information used by male-headed households in the warm region and the semi-arid region. For both regions, NGOs were the preferred source of information (Table 10 and 11). The similarity was also apparent between the cool and sub-humid region, with preferred source of information being school for male-headed households. This trend was also replicated between semi-arid, sub-humid, cool and warm regions for female-headed households with government officers and learning from other farmers being the main source of information.

3.4 Extension workers and awareness and adoption of technology

The introduction of the profession of extension officers in Kenya dates back to the early 1900s (World Bank, 1999). Extension services are designed to aid farmers to improve their agricultural productivity and income (Garforth and Oakley, 1997), link the government with farmers and act as the major source of information for farmers on matters related to agriculture and agro-systems (Rees et al. 2000). The FGDs showed that the relationship between extension workers and farmers was poor across the regions with a higher percentage of female farmers having a poor relationship with the extension officers than male farmers (Table 12 and 13). This was in regard to the accessibility of extension workers, their availability, timeliness of the information passed to farmers and the usefulness of that particular information. Poor services are experienced more frequently in the sub-humid than in the semi-arid region. Male farmers from the semi-arid region knew that extension services were available to organised farmers groups but they did not belong to or form such groups that can benefit from these services. The female farmers noted that an absence of extension workers had led to faulty terrace making and increased soil erosion since the 1990s. Generally, extension services for crop production were rare and not accessible. Farmers also complained of the high turnover rate of the officers. The farmers also claimed that the extension workers demand payments for offering their services in order to cover their transport costs. According to Karugia (2012), extension services are extremely limited in Kenya, with the ratio of extension agents to farm households in Machakos and Makueni being 1: 1800 and 1: 1434, respectively. A study carried out in the Rift Valley province of Kenya showed that not all extension workers are motivated to perform their duties (McCaslin and Mwangi, 1994). The male farmers claimed that the extension workers were not cooperative and they were biased towards large-scale farmers who could afford to pay them.

The pattern from the cool and warm regions was different to that from the semi-arid and sub-humid regions. Female and male farmers in the warm and cool regions respectively had poor relationships with the extension officers (Table 13). In most countries, extension services do not give much importance to serving women farmers or wives of male farmers leading to very little accrued benefits to women farmers (Quisumbing et al. 1995). This undermines women as key players in agricultural production, yet they provide 50% of the agricultural labour force in sub-Saharan Africa (FAO, 2011).

4. Conclusions and policy implications

In general, there were no significant differences in the knowledge of technologies between the four sites. However, the adoption of the technologies was higher in the semi-arid region and the warm region, compared to the others. Soil and water management technologies were the best known and used in the semi-arid regions and the warm region. Knowledge and utilisation of soil fertility management technologies was highest in the sub-humid region and the cool region. In this study, simple technologies such as use of animal manure, row planting and terracing enjoyed the highest awareness and adoption rates from both regions. The technologies that were more labour intensive such as terracing and the use of tied ridges had low adoption rates even though most farmers knew about them.

The male-headed households had higher technology adoption levels compared to the female-headed households in all the regions. It was also found that most farmers received information on technologies from other farmers and from electronic media. Therefore, the farmers are generally well informed about the technologies, but have not adopted the technologies that would lead them to adapt to climate change and variability, especially soil fertility management in warm areas and soil and water management in humid areas. This may lead to low production rates. Unfortunately, the extension system and information and awareness-raising approaches in these regions have not been very effective and need to be strengthened. This a need which should be addressed in future studies.

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Table 1. Climatic characteristics of the regions

Characteristics				
	Semi-arid region		**Sub-humid region**	
	Analogue 1		Analogue 2	
	Cool	Warm	Cool	Warm
	Machakos	Makueni	Limuru	Kikuyu
Average annual temperature (^{0}C)	19.2	20.8	15.9	18.2
Mean maximum temperature (^{0}C)	24.7	28.4	20.9	23.3
Mean minimum temperature (^{0}C)	13.7	15.7	10.8	12.5

Average annual rainfall (mm)	673	611	854	1114

Table 2. Distribution of the interviewed households

Regions	Sites	Villages	Frequency (n = 722)
Semi-arid	Machakos District (cool/dry site)	Lower Kwa Kavoo	174
		Upper Kwa Kavoo	
		Upper Kaathi	
		Lower Kaathi	
		Mikuyuni	
	Makueni District (warm/dry)	Kathoka 1	180
		Kathoka 2	
		Kambi ya Mawe	
		Kyemole	
		Mulaani	
Sub humid	Limuru District (cool/wet)	Karara-iti	190
		Maganjo	
		Gatina	
		Gitangu	
		Gatimu B1	
	Kikuyu District(warm/wet)	Mbomboini	178
		Marengeta	
		Kwangera	
		Thiranga	
		Wamoro	
	Total	20	722

Table 3. Summary of knowledge of agricultural technologies in the regions

	Regions (% of farmers and counts)			
Technologies	**Sub-humid**	**Semi-arid**	**Cool**	**Warm**
Soil and water management	44.64	55.36	47.42	52.58
Soil and fertility management	47.94	52.06	50.11	49.89
Crop management	44.37	55.63	49.67	50.33

Table 4. Summary of adoption of agricultural technologies in the regions

Technologies	Regions (% of farmers) Sub-humid	Semi-arid	Cool	Warm
Soil and water management	29.89	70.11	43.2	56.79
Soil and fertility management)	44.74	55.26	57.09	42.91
Crop management	41.08	58.92	49.28	50.71

Table 5: Knowledge and utilization of climate change adaptation technology in the semi-arid and sub-humid regions

Technologies	Semi-arid region (N = 354) Knowledge (%)	Usage (%)	Sub humid region (N = 368) Knowledge (%)	Usage (%)
Soil and water management				
Terracing	100	95.5	92.9	16.1
Climate information	86.1	52.7	88.0	30.3
Reduced tillage	81.3	53.3	58.5	35.5 N=131
Mulching	75.6	34.6	74.6	32.0
Water harvesting	78.8	53.3	57.1	16.7
Tied ridges	64.6	56.4	19.1	10.7
Soil fertility and management				
Animal manure	99.2	87.5	99.5	92.9
Chemical fertilizer	94.6	29.5	98.6	35.5
Green manure	54.4	30.6	25.7	12.0
Crop management				
Pest and disease control	99.2	83.3	94.3	24.3
Row planting	97.5	92.6	100	98.6
Crop rotation	92.9	75.1	88.8	53.0
Seed priming	72.2	14.7	39.9	6.8
Herbicides	64.6	2.8	72.4	5.5

Table 6: **Knowledge and utilisation of climate change adaptation technology in the warm and cool regions**

Technologies	Cool region (N=352)		Warm region (N=370)	
	Knowledge (%)	Usage (%)	Knowledge (%)	Usage (%)
Soil and water management				
Mulching	51.85	43.51	48.15	56.49
Terracing	48.77	46.72	51.23	53.28
Use of climate information	48.08	40.74	51.92	59.26
Tied ridges	46.64	49.58	53.36	50.42
Water harvesting	45.59	33.73	54.41	66.27
Reduced tillage	43.31	41.19	56.69	58.81
Soil fertility and management				
Compost	50.39	54.55	49.61	45.45
Chemical fertilizer	50.22	83.33 N=293	49.78	16.67
Animal manure	48.74	50.08	51.26	49.92
Green manure	46.85	40.13	53.15	59.87
Crop management				
Crop rotation	52.68	60.35	47.32	39.65
Seed priming	51.62	57.14	48.38	42.86
Herbicides	51.52	83.33	48.48	16.67
Pest control	50.22	55.61	49.78	44.39
Row planting	48.17	47.09	51.83	52.91

Table 7. Awareness and adoption of climate change adaptation technologies in semi-arid and sub-humid regions

	Semi-arid region (N=354)		**Sub-humid region (N=368)**	
	(% of farmers per gender)			
Gender of households	**Awareness**	**Adoption**	**Awareness**	**Adoption**
Male	71.87	73.07	73.92	74.68
Female	28.13	26.93	26.08	25.32
	N=100	N=95	N=96	N=93

Table 8. Awareness and adoption of climate change adaptation technologies in warm and cool regions

	Warm region (N=370)		Cool region (N=352)	
	(% of farmers per gender)			
Gender of households	**Awareness**	**Adoption**	**Awareness**	**Adoption**
Male	70.34	68.93	78.74	78.43
Female	29.6	31.07	24.27	21.57

Table 9: Sources of information for the respondents in the semi-arid and sub-humid regions

Technologies	Government officer		NGO		Other farmer		Radio/TV		Demonstration/research station		School	
	SA %	SH %	SA %	SH %	SA %	SH %	SA %	SH %	SA %	SH %	SA %	SH %
Tied ridges	5.0	7.0	2.0	1.0	74.5	61.5	0.5	12.5	10	14.5	6.5	4.0
Water harvesting	7.0	6.0	2.0	1.0	70.0	72.0	5.0	9.5	10.5	6.5	6.0	4.5
Reduced tillage	0.5	5.0	0.5	0.5	86.5	80.0	2.5	8.5	4.0	2.0	5	3.5
Terracing	11.0	12.5	2.5	0.5	67.5	68.0	1.0	4.0	11.0	4.5	6.5	11.0
Mulching	2.5	6.5	1.5	1.0	58.0	66.0	11.0	4.0	9.5	2.5	18	19.5
Animal manure	1.5	2.0	0.5	1.0	88.5	91.5	0.0	0.0	2.5	2.5	7.0	4.0
Green manure	9.5	10.5	4.5	5.0	54.5	37.5	10	18.0	8.0	13.5	12.5	15.5
Crop rotation	6.5	7.5	2.5	0.5	66.0	68.0	2.0	9.0	13.0	6.0	11.0	9.0
Chemical fertilizer	2.5	10.5	1.5	1.5	62.0	57.5	12.5	22.0	14.0	3.0	8.0	5.5
Row planting	2.0	4.5	1.0	0.0	81.5	89.5	2.5	2.0	7.0	1.5	6.5	2.5
Seed priming	0.5	6.0	0.5	0.5	92.5	78.5	2.0	6.5	2.5	3.0	3.0	5.0
Pest control	4.0	6.0	4.0	2.0	63.5	58.0	4.5	23.0	16.0	6.0	7.0	4.0
Herbicides	1.0	4.5	2.5	1.5	55.5	39.5	23	41.5	7.0	6.5	10.5	7.0
Use of climatic information	1.5	0.0	1.0	0.0	11.5	14.0	81.0	86	4.5	0.0	0.0	0.0

Note: SA (Semi-arid region), SH (Sub-humid region), NGO (Non-Governmental Organisation)

Table 10. Sources of information by gender in the semi-arid and sub-humid regions

Source of information	Sub humid region (N=368)		Semi-arid region (N=354)	
	(% of farmers)			
	Female	Male	Female	Male
Government officer	45.16	54.84	32.77	67.23
NGO	15.52	84.48	00.00	100
Other farmers)	32.40	67.60	27.30	72.70
Radio/TV	20.59	79.41	25.74	74.26
Demonstration/research	16.96	83.04	12.70	87.30
School	13.74	86.26	23.40	76.60

Table 11. Sources of information by gender in the cool and warm regions

Source of information	Cool region (% of farmers)		Warm region (% of farmers)	
	Male	Female	Male	Female
Government officer	70.73	29.27	48.45	51.55
NGO	91.13	8.87	89.158	10.85
Other farmer	73.92	26.08	65.73	34.27
Radio/TV	80.35	19.65	74.25	25.75
Demonstration/research station	84.69	15.31	84.7	15.22
School	91.3	8.7	71	29

Table 12. Working relationship with extension workers

	Semi-arid region (n = 140)		Sub-humid region (n = 147)	
	% of farmers			
Type of relationship	Female	Male	Female	Male
Poor	26.43	22.86	51.70	28.57
Good	14.29	12.14	16.33	13.61
Better	2.14	6.43	3.40	9.52
Best	6.43	9.29	2.04	9.52

Table 13. Working relationship with extension workers

	Warm region (N = 124)		Cool region (N =163)	
	% of farmers			
Type of relationship	Male	Female	Male	Female
Poor	41.85	25.26	24.67	46.97
Good	10.14	12.17	7.14	3.65
Better	3.92	3.85	5.21	0
Best	1.96	1.82	7.27	5.10