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Farmers' attitudes and perceptions of adoption of agricultural innovations in Kenya: a mixed methods analysis

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Abstract

Attitudes and perceptions are key constructs in decision making. Their nature and influence on agricultural technology adoption among smallholder farmers in Kenya has not been adequately researched. This research applied a mixed methods approach to assess the influence of attitudes and perceptions in adoption of agricultural innovations by smallholder farmers in Kenya. The quantitative phase used a survey (n = 245) while the qualitative consisted of focus groups (n = 28) to elicit subjective farmer views of innovations. A principal component analysis (PCA) technique reduced 14-attitudes statements to five conceptual clusters: challenges in accessing agricultural innovations (explained 19.09 % of the total variance); effectiveness of agricultural technologies (11.88 %); enjoyment of agricultural technologies (10.02 %); social influence in use of technology (9.47 %); and experience with agricultural technologies (8.13 %). Qualitative analysis identified key themes: farmer ambivalence about innovations; economic benefits of innovation use; ease of use of technology encouraged adoption; lack of trust; and limited knowledge of innovations. Farmers' positive evaluation of technology did not encourage widespread adoption of innovations. Farmers were found to be poorly equipped to use innovations due to limited access to agricultural information and training supporting the use of innovations. The lack of trust between the farmers and extension agents aggravated the situation.

Keywords: technology adoption, attitudes, smallholder farmers, principal component analysis, mixed methods, sub-Saharan Africa.

1 Introduction

Kenya is an agrarian economy where smallholder agriculture directly contributes about 21 % of gross domestic product (GDP) and the sector employs 56 % of the total work force (World Bank Group, 2019). Most of the agricultural labor force resides in rural areas and is predominantly dependent on agriculture for both income and sustenance. Specifically, 70 % of Kenya's rural population work directly in the agricultural sector. Small-scale agricultural production contributes disproportionately to the national economy making the agricultural sector pivotal in eliminating food insecurity, reducing poverty (Ndulu *et al*., 2007), and driving the Kenyan economy (Alessandro *et al*., 2015). The importance of agriculture in Kenya's economy makes technology adoption a critical factor in raising crop yields and strengthening overall agricultural growth.

Historically, policy measures to modernize the agricultural sector have targeted the subsector of smallholder farmers, which sustains national food security and contribute to the improvement of rural livelihoods in many developing countries (Kansanga *et al*., 2019). The modernisation of the agricultural sector has taken different forms, but a popular strategy has been to engage both private and public stakeholders to promote the effective use of common inputs (e.g., seeds and fertilisers) among the farmers needing to apply it in their farms, along with mobilizing input market efficiency to guarantee accelerated diffusion of agricultural innovations. In spite of the modest growth witnessed in the agricultural sector in the last few decades, low yield trends have persisted in smallholder agriculture in developing countries, an indication of the limited use of appropriate agri-

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cultural technologies and practices (Akudugu *et al*., 2012). This trend has called into question the efficacy of private and public stakeholders' agricultural innovation diffusion efforts throughout rural economies.

The modernisation of agricultural technology largely remains a function of farmers' efficient leveraging of the innovations that transform farming practices and access of innovation through the most common agricultural extension channels. Adequate use of agricultural innovations enhances the potential to raise agricultural productivity and improve the livelihoods of smallholder farmer households that rely on farm output for food and sustainable income (Asfaw *et al*., 2012; Langat *et al*., 2011; Zeller *et al*., 1998). A review of the literature demonstrates that despite past efforts to market new farming tools and inputs (fertiliser, seeds), the rate of innovation use in developing countries has been slow (Feder *et al*., 1985). In Feder *et al*. (1985), the adoption of innovations was constrained by limited farmer access to sufficient information regarding available agricultural technologies; inadequate farm size; inappropriate transportation infrastructure; and lack of credit (Feder *et al*., 1985). However, efforts to expand the use of new agricultural technologies and practices in sub-Saharan Africa have not substantially improved agricultural production and productivity (Meijer *et al*., 2015).

The literature that focuses on the use and sustained adoption of new agricultural innovations in developing countries has identified both social capital (Hunecke *et al*., 2017) and farmer attitudes (Adrian, 2005; Meijer *et al*., 2015) as key factors that influence the application of technology by farmers. Social capital, defined as trust in social networks, has been found to play a key role in technology adoption, which consequently bolsters agricultural growth. Social affiliations act as a form of social capital in farmer adoption decisions and provide an economic justification in the design of extension services which are key in the diffusion of technologies such as fertilisers (Isham, 2005). Through cooperation and coordination among social networks, farmers are motivated to strive towards achieving the collective social benefits of adopting a new practice (Hunecke *et al*., 2017). Social networks may also influence technology use among farmers in Western Kenya, although there is inadequate literature to support such a claim.

A complementary variable identified as central in promoting technology adoption in developing countries is attitude change. An attitude represents a predisposition to react favorably or unfavorably to a set of objects (Fishbein & Ajzen, 1975), and is composed of a complex array of feelings, desires, fears, prejudices or other tendencies subject to the type of target object. The nature of an attitude combines a series of emotional, motivational, cognitive, or perceptual elements of an individual's experience as well as the physical environment. The acquisition of these attributes occurs over time and are often retained as part of a reinforcing pattern of behavior. The predisposition to react favorably or unfavorably towards an object is a function of individual emotional or perceptual experiences and tendencies. For technology adoption, the evidence in the literature points to a variety of observable and unobservable explanatory factors that influence attitudes towards new practices (Zossou *et al*., 2020). In developed countries, attitudes towards technology adoption have been influenced by perceived benefits of the innovation, adoptive experiences, or perceived difficulty in the implementation of the technology (Kai-ming Au & Enderwick, 2000). These attitudinal factors may not be readily observable, but have been found to be integral in determining farmer decisions in adopting new technologies among smallholder farmers in developing countries.

The formation of attitudes and perceptions about technologies shape individual farmer decisions and their behaviors in the choices they make pertaining adoption of new innovations (e.g., precision agriculture). Specifically, Adrian *et al*. (2005) have shown that a confident attitude towards the use of a variety of technologies, combined with the perceptions of associated net benefits, positively influenced farmers' intentions to adopt novel technologies. However, while farmers' attitudes and perceptions of new technologies have been shown to be key factors in the adoption of these tools in a developed country context, limited research exists that demonstrate the role of attitudes and perceptions in the adoption of yield-improving agricultural inputs, including hybrid seeds and fertiliser in developing country studies.

Given the importance of agricultural technologies in productivity and production growth in agriculture, the present study sought to identify the attitudes and perceptions in the adoption of agricultural innovations among smallholder farmers in Kakamega County, Kenya. The study was exploratory in nature since the research participants were not informed of the study beforehand. Furthermore, a survey questionnaire was prepared to explore the role of social networks that enhance (or hinder) the adoption of agricultural innovation. The administered survey was complemented by focus group discussions that allowed further interrogation of the themes emerging from the survey instrument.

To provide a context for the types of technologies or innovations referenced in the research, the study focuses on basic tools, inputs, and practices applied in the farms. The farm implements can be categorised into traditional and modern agricultural tools. Those used in traditional agriculture often result in low-input husbandry, a practice which is laden with quality products (limited in contamination of the products)

and relies more on traditional and homemade preparations to ward off pests and insects. However, modern agriculture utilizes synthetic pesticides, plant breeding, agronomy, and antibiotics. The modern technologies associated with this form of agriculture also include hybrid seeds, synthetic fertilisers, and the use of agricultural practices that are beyond the reach of most resource-poor farmers. Other farmers use ropes for straight-line planting and sowing, as well as other effective and practical best management practices such as agricultural conservation methods.

Background and conceptual framework

Conceptually, this research draws on the diffusion of innovations theory postulated by Everett Rogers' seminal sociological framework formulated in the 1960s (Rogers, 2003). His theory predicted end-user adoption of agricultural practices by suggesting four key elements that determine the spread of technology: an innovation, a social system, time, and a channel of communication. The theoretical foundation of the theory has remained intact in spite of its dynamic evolution over time. The framework remains foundational in the formulation of new adoption of innovation models, but the communication technologies that surround the spread of innovations have evolved markedly.

Rogers' (2003) theoretical presentation of the diffusion of innovation framework in his seminal work in the 1960s suggested that once opinion leaders in the community begin using new agricultural inputs, they influence their colleagues, who rapidly take up the innovation. However, the introduction of an innovation does not guarantee immediate acceptance by potential users or their peers. Rather, the performance of such new idea is mediated by the relationship between the internal social environment surrounding the innovation and the workings of the entire ecosystem. The proliferation of social innovative activity occurs in environments that foster competition for new practices and the level of need, the system needs, and the type of inherent governance. The diffusion of innovations framework, as postulated by Rogers (Rogers, 2003), has "aged" well because of its adaptability to emerging farming technologies as well as new communication media channels (Tucker *et al*., 2022). In addition to radio and media, common during the theory's introduction in the 1960s, new communication channels have emerged. However, the current study applies the mixed diffusion and reasoned action perspectives in farmer adoption of new practices. The study does not entirely apply the Diffusion Model in its original form.

Review of key factors affecting technology adoption

The decision-making process leading to the adoption of a new agricultural technology is a function of both extrinsic and intrinsic factors which dictate acceptance or rejection of the practice. The current literature on the role of knowledge, attitudes, and perceptions in the adoption of agricultural technologies tends to focus on the extrinsic characteristics, particularly economic considerations (Adrian *et al*., 2005; Nmadu *et al*., 2015).

The dominant socio-economic barriers of adoption among marginalized farmers include the gender of the farmer, the level of education, the cost of inputs, and lack of complimentary inputs. Other studies reveal that infrastructural and economic factors dictate adoption decisions among practitioners (Daramola, 1989). Intrinsic factors may equally influence the adoption of agricultural innovations in some smallholder communities in sub-Saharan Africa (Meijer *et al*., 2015; Zossou *et al*., 2020). Zossou *et al*. (2020) emphasized the inclusion of both intrinsic (e.g. perceptions, knowledge, and attitudes of potential adopters towards the innovation) and extrinsic (e.g. the characteristics of the technology, and attributes of the external environment) as complementing each other in providing a holistic understanding of farmers' views of innovations (Meijer *et al*., 2015).

Intrinsic factors: attitudes and perceptions

The identification of the attitudes of farmers towards new technologies is fundamental in comprehending the uptake of those new agricultural tools and practices. Attitudes are central, intrinsic constructs in social psychology and they are widely applied in the research on human behavior (Edison & Geissler, 2003; Fishbein & Ajzen, 1975). Conceptually, attitudes evaluate whether an object or practice is favorable or unfavorable for use. Thus, attitudes serve as an index of the strength of a person's liking or dislike of an idea, or a concept or views towards others (Ajzen & Fishbein, 1980). Formation of attitudes is shaped by what an individual perceives as true or false (Willock *et al*., 2008). Attitudes are an influence on the behavior of an individual and are informed by beliefs and values. In agriculture, the decision-making process an individual farmer undergoes allows for the evaluation and formation of favorable or unfavorable beliefs about technology use. Attitudinal foundation theories suggest that it is not always possible to measure the process of belief formation, but attitudes can be observed through the choices individuals make (Fishbein & Ajzen, 1975). The formation of these attitudes may be influenced by any given number of social or physical environmental variables. It can be concluded from the foregoing argument that farmers act similarly in the implements they use on their farms based upon the utility

of such technologies (Edison & Geissler, 2003). Therefore, farmer rationality in decision-making is inherently important in the adoption of agricultural tools used. In the literature, other socio-demographic factors, such as age, gender, income or level of education have been suggested to be leading determinants of agricultural tools adopted (Jenkins *et al*., 2011; Nyanga, 2012). In other instances, socio-demographic factors such as gender are not directly associated with the agricultural implements farmers use given the lack of the variable distinction within households (Doss, 2001). For example, even if the female labor share in crop production is high, no clear pattern of adoption of modern agricultural inputs and practices has been established for women relative to men (Palacios-Lopez *et al*., 2017).

Adrian *et al*. (2005) points to other drivers of adoption of precision agricultural technologies beyond the economic benefits that farmers gain. This finding concluded that a confident attitude had a positive effect on technology adoption and that attitudes of confidence towards the use of precision agriculture technologies, the perceptions of net benefits, and farm size positively influenced the intention to adopt agricultural precision technologies. It is evident from this study that economic benefits are not the only reasons that attract farmers to the use of new agricultural practices and tools in technology in developed countries.

The literature exploring the influence of attitudes on adoption in sub-Saharan Africa is limited and highlights the importance of exploring both intrinsic factors – such as farmers' attitudes and perceptions, as well as external factors. In sub-Saharan Africa, one study exploring the adoption of no-till agricultural practices found a positive correlation between a farmer's perception of conservation and higher crop yields-highlighting the importance of intrinsic factors in technology adoption (Ntshangase *et al*., 2018). That study also emphasized the positive role of extension in the promotion of conservation agriculture. A different study from southwest Nigeria found that farmer attitudes had an insignificant impact on technology adoption, but identified that negative perceptions of extrinsic factors, such as constraints on technology training, had a stronger influence on farmers' adoption of novel technology (Kazeem *et al*., 2017).

Extrinsic factors in technology adoption

Farmer uncertainty about adopting a new agricultural practice is influenced by their belief about the technology, experience with the technology, and existing agricultural information networks (Morton *et al*., 2017). Morton *et al*. (2017) further revealed that insufficient information and normative beliefs on the technology strongly influence inherent uncertainty. When the socio-cultural norms are behind the resistance to the introduction of new practices, access to information alone is not sufficient to overcome farmers' uncertainty about novel agricultural practices. In such a circumstance, Morton *et al*. (2017)'s study suggested that scientific information will more likely be accepted when linked to local values and using trusted agricultural networks as a strategy that can improve acceptance of new information.

The contribution of agriculture to food security and economic growth makes a review of the full range of factors enhancing the adoption of agricultural technologies essential in understanding the factors affecting agricultural productivity. Raising the quality of rural livelihoods of smallholder farmers in developing countries cannot be sustained until all the factors inhibiting growth in agricultural productivity are well understood (Odulaja & Kiros, 1996). To shed light on this issue, this exploratory study was conducted to identify the attitudes and perceptions of smallholder farmers in western Kenya.

2 Material and methods

2.1 Methodology

The geographical scope of the study was restricted to the administrative boundaries of Kakamega County, one of the 47 countries of Kenya, located on the western region of the country. It was considered appropriate to conduct face-to-face interviews with household heads who responded to pre-designed questions. The first author and a well-trained interviewer with a good command of the local language and customs administered the data collection. The unit of analysis selected for quantitative data was the household, defined as either an individual person or people who live together under the same housing arrangement and who provide themselves with food and other essentials from the same source. The study applied a sequential mixed method design whereby the survey questionnaire sought to identify the socio-demographic characteristics of the selected households. A simple random selection of the smallholder farm households was conducted to identify the respondents. This resulted in a total of 245 households surveyed across the seven sub-counties, namely: Malava (41), Mumias East/Shianda (30), Ikolomani (35), Lurambi (35), Khwisero (31), Shinyaru (44), and Butere (29) sub-counties. Subsequently, four focus group discussions consisting of purposively selected participants were administered in four of the twelve sub-counties of Kakamega County. The use of a Likert scale to measure the attitudes and perceptions farmers expressed towards the adoption of agricultural tools and inputs was recommended for collecting survey data. The scaled-attitudes and perceptions were analysed through the

principal component analysis whereby 14 identified variables were evaluated.

The entire survey comprised a series of 63 sequential, open-and closed-ended questions with multiple-choice questions probing the socio-demographic characteristics of the households. The survey questions specifically targeted household information pertaining agricultural tools used on the farm, the types of animals raised by the households, and other non-agricultural sources of income for the participating households. Questions 26 through 44 of the questionnaires solicited information regarding attitudes and perceptions towards technologies commonly used by households as well as their attitudes and perceptions of the efficacy of agricultural extension delivery in the area. The design of the study presumed that combing the survey questionnaire and focus group discussions would broaden and deepen understanding of farmer perspectives of technology adoption.

The focus group discussions were facilitated by the first author (a native of Kenya), to explore participants' attitudes and perceptions of agricultural technology, agricultural extension, and their views towards the primary channels of agricultural information. An inductive methodological approach was utilised to allow the research participants to share their personal experiences with agricultural inputs and practices commonly used on their farms. Following inductive exploration, directed questions relating to technology adoption and participants experiences with agricultural extension services, were introduced. The data from the focus groups, which captured the personal accounts of participants, were triangulated with the survey results of the quantitative data. The focus groups consisted of 28 farmers from the sub-counties of Malava (7), Mumias East (5), Ikolomani (7), and Lurambi (9). The selected sub-counties represented observed diversity of the agricultural characteristics of Kakamega County.

The focus group interview protocols were designed to further explore the themes identified in the findings from survey phase of the study. The research participants from the survey phase were instructed beforehand of the follow-up study during the administration of the survey. Those who expressed willingness to participate in the focus group discussion were purposively recruited and they represented the range of age groups, gender, and farming experiences captured in the survey. The peer group discussants included a local opinion leader and smallholder farmers intended to capture a range of views of agricultural tools and practices applied in the community. In their administration, the discussions were limited to verbal behavior and self-reported data as suggested in the literature (Morgan, 2012). This focus group data technique reinforced the quantitative findings by providing more nuanced experiences of local smallholder farmers' views towards agricultural practices applied in the area.

2.2 Statistical data analysis

The primary research question in the study explored farmers' attitudes and perceptions towards agricultural technologies commonly applied in agriculture. To address smallholder's attitudes towards technology adoption, a principal component analysis (PCA) method was utilised to reduce the dimensionality of responses. As a data reduction approach, the PCA technique groups together correlated variables into principal components and simplifies analysis (Olawale & Garwe, 2010). In aggregate, 14 survey statements assessed farmer attitudes and perceptions towards agricultural tech-

Table 1: *Reference table of attitude and perception variables*

	Variable description
Statement 1	I experience challenges in accessing agricultural technology whenever I need it
Statement 2	The use of technology increases effectiveness in my farm activities
Statement 3	The use of technology saves me time in my farming tasks
Statement 4	My use of the commercial inputs increases the quantity of output for the same amount of input
Statement 5	The use of any new farming practices makes me popular among my peers
Statement 6	Modern agricultural inputs are a plausible alternative to traditional agricultural production
Statement 7	Modern agricultural practices influence my practice of agriculture
Statement 8	I receive personal satisfaction from applying modern agricultural production practices
Statement 9	I need the practice of new agricultural production techniques in our small agricultural practice
Statement 10	I will continue to use new agricultural innovations even if the price can sometimes be prohibitive
Statement 11	The main reason for using agricultural innovations is to increase my agricultural output
Statement 12	I enjoy discussing about new agricultural practices currently promoted by the local extension services
Statement 13	My farmer friends who use new agricultural innovations influence me to do the same
Statement 14	I enjoy reading/listening about the different agricultural practices or technologies currently in use

nologies and evaluated their preferences using a standard scaling approach.

In Table 1 the 14 survey statements used to measure the attitudes and perceptions of farmers toward agricultural technologies are listed. The statements were presented in Likert-scale to provide a valid measurement of attitudes in response to questionnaire items using disagree-agree response scale.

These statements measure the attitudes and perceptions, and they provide a holistic view of farmers' opinions of agricultural technologies and are an integral frame of reference.

Table 2 provides the mean rankings of attitudes farmers expressed towards agricultural technologies commonly used on their farms. The variable outcomes represented positive benefits that farmers strongly perceived as important in their use of a variety of agricultural technologies. The variables that emphasized popularity of using agricultural innovations among peers and those related to the enjoyment of discussing agricultural practices are lowly ranked. Farmers appeared to enjoy using agricultural technologies in their small agricultural farms, but there is no indication of whether the technological features influenced their interest, motivation, and acceptance of those innovations.

3 Results

3.1 Principal Component Analysis (PCA)

The PCA technique extracted the most important information from the data and expressed it as a set of orthogonal, principal components. This was achieved through the analysis of a data table representing observations developed utilizing several dependent variables (Abdi & Williams, 2010). The PCA selects the important variables and compresses them into a simplified data form and establishes a pattern if one exists. The resulting components are linear representations of the original variables. The rationale for using a PCA as a data reduction technique is intended to group together the most correlated variables into principal components (Olawale & Garwe, 2010).

The sampling adequacy of the data was measured using Bartlett's Test of Sphericity (.000), and the Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy (.574). These statistics justify further analysis of the data. According to table 3 the KMO test statistic indicates the proportion of variance in the variables that might be caused by underlying factors.

Through the varimax rotation, the PCA technique reduced the original 14 attitude and perceptions statements to five principal component clusters (Table 4). From the survey data, the resulting five components captured smallholder farmer's attitudes and perceptions towards agricultural technologies.

The principal component analysis grouped together the correlated variables into principal components and simplified the analysis (Olawale & Garwe, 2010). The five identified components (Table 4) in the analysis included: 1) I experience challenges in accessing agricultural technologies whenever in need (explained 19.09 % of the total variance); 2) the use of technology increasing effectiveness in farm activities (11.88 % explained variance); 3) the use of technology saves me time in my farming tasks (10.02 % explained variance); 4) effect of commercial inputs on output for the same input (9.47 % explained variance); and 5) the use of new technologies makes me popular among my peers explained (8.13 % of explained variance).

The first component labelled "preferences of modern technologies over traditional practices", had a loading of 2.67 and explained 19.1 % of the variance in technology adoption. This component consisted of three items namely: approval of new technologies over traditional farming techniques (.743); personal satisfaction of innovative agricultural practices (.684); and the influence of agricultural practices on farmers' agricultural experience (.679).

The second component – technical efficiency gains from agricultural technology application - had an Eigen value of 1.67 and explained 11.88 % of the variance. The four items that defined this category were: the use of technology saves me time in the conclusion of tasks (.786); technology use increases effectiveness in my farm activities (.612); technical efficiency (.524); and role of innovations in increasing agricultural output (.501). Items under this component captured views of farmers regarding the application of technologies.

With an Eigen value of 1.40, the third component – enjoyment of agricultural technologies and reliance on social networks in sharing new practices – had three factors on the list namely: level of enjoyment from listening/reading different technologies/practices currently in use (.714); I enjoy discussing new agricultural practices promoted by the local extension services (.559); and I need the practice of new agricultural production techniques in our small farm (.508).

The fourth component – effect of commercial inputs on outputs for the same amount - had an Eigen value of 1.32 and explained 9.47 % of the variance. The two items defining this component are: continual use of agricultural innovations irrespective of the cost (.733) and the influence of farmer friends in the use of new agricultural innovations (.541). This component represents the inspiration that farmers derive from using agricultural technologies and reflect farmers' attitudes and the likelihood to use agricultural tech-

Table 2: *Mean ranking of attitudes towards agricultural technologies.*

	Variable	*Mean*	*Standard Dev.*	*Skewness*	*Kurtosis*
Statement 9	I enjoy applying new agricultural techniques in our small agricultural farm	3.41	1.096	-2.069	3.407
Statement 1	Challenges in accessing agricultural technologies	1.78	.932	.637	.474
Statement 2	Effect of tech use performance of farm activities	1.64	.647	.408	1.708
Statement 10	Influence of high costs to continued use of innovations	1.55	.925	.363	-.089
Statement 3	Effect of tech on time as a resource	1.54	.604	-.488	-.235
Statement 8	Level of satisfaction for application new practices	1.52	.739	.599	.994
Statement 6	Modern agricultural practices versus traditional ones	1.49	.782	.255	.702
Statement 4	Effect of commercial inputs on output for the same inputs	1.48	.591	-.153	-.471
Statement 7	Influence of modern inputs on agricultural practices	1.42	.646	-.037	-.239
Statement 11	On the use of new agricultural innovations	1.41	.866	.477	.596
Statement 13	Main reason for using innovations	1.36	.697	.038	.207
Statement 5	Popularity among peers for improved farming practices use	1.30	.783	-.020	-.280
Statement 14	Level of enjoyment from listening/reading about different technologies	1.29	.770	.145	-.055
Statement 12	I enjoy discussing agricultural practices promoted by extension services	1.27	.836	.551	.686

Table 3: *Kaiser-Meyer-Olkin (KMO) measure and Bartlett's test of sampling adequacy.*

KMO measure of sampling adequacy		.574
Bartlett's test of sphericity	Approx. Chi-Square	549.151
	Df	91
	Sig.	.000

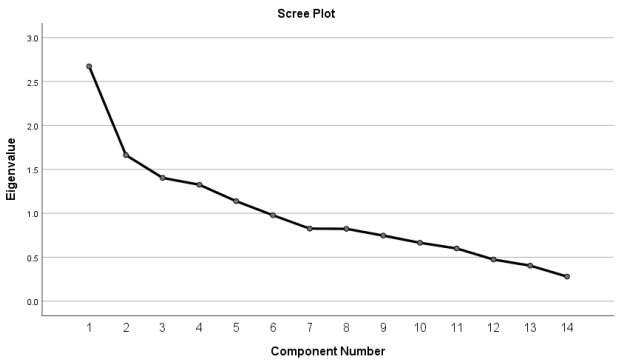

Fig. 1: *Scree plot of principal components.*

nologies and captures potential future attitudes towards a particular agricultural technology.

The last component has an Eigen value of 1.14 and total explained variance of 8.13 %. There are four items in the component namely: experiencing challenges in accessing agricultural technologies (.732); the use of technology increases effectiveness in farm activities (.412); the use of new technologies makes me popular among peers (-.403); and I need the practice of a new agricultural production technique in our small agricultural practices (-.433). The two loadings for the fifth component have negative factor loadings, implying a negative correlation.

The scree plot in Fig. 1 clarifies if there is a clear bend to confirm if the retained factors are still valid as generated by the data on SPSS 24 (IBM Corp. Released, 2017). The scree plot identifies a point on the graph (elbow) where the slope of the graph changes from steep to flat indicating that the components that occur before the elbow should be retained (Abdi & Williams, 2010).

To further confirm the decision to retain the selected factors, a Monte Carlo principal component analysis simulation was run (Table 5) to compare obtained Eigen values with randomly generated Eigen values, which are consequently compared with the retained values in Table 4. The parallel test was conducted via a separate computer software - Monte Carlo PCA for Parallel analysis, a statistical method used to determine the number of components to retain. Table 5 confirms that the five components can be retained since the random Eigen values for the first five components are less than the Eigen values in Table 4.

Table 6 illustrates the extracted factors and their associated loadings, containing the estimates of the orthogonal rotation using the varimax method, indicated that the extracted

Table 4: *Farmers' perception of importance and practising safety regulations.*

	Initial eigenvalues			*Extraction sums of squared loadings*			*Rotation sums of squared loadings*		
Component	*Total*	*% of Variance*	*Cumulative %*	*Total*	*% of Variance*	*Cumulative %*	*Total*	*% of Variance*	*Cumulative %*
1	2.673	19.093	19.093	2.673	19.093	19.093	1.870	13.355	13.355
2	1.663	11.880	30.972	1.663	11.880	30.972	1.847	13.196	26.551
3	1.403	10.024	40.997	1.403	10.024	40.997	1.761	12.582	39.133
4	1.325	9.466	50.463	1.325	9.466	50.463	1.389	9.925	49.058
5	1.138	8.131	58.595	1.138	8.131	58.595	1.335	9.537	58.595

Note: Extraction Method: Principal Component Analysis.

Table 5: *Monte Carlo PCA for random comparison eigenvalues. Number of variables: 14; Number of subjects: 245; Number of replications: 1000*

Eigenvalue#	*Random eigenvalue*	*Standard dev.*
1	**1.4247**	**.0548**
2	**1.3796**	**.0395**
3	**1.2428**	**.0325**
4	**1.1776**	**.0299**
5	**1.1164**	**.0271**
6	1.0629	.0253
7	0.0112	.0232
8	0.9602	.0243
9	0.9093	.0247
10	0.8609	.0240
11	0.8108	.0258
12	07596	.0279
13	0.7053	.0296
14	0.6387	.0353

Comparable PCA factors and eigenvalues:
1. Modern agricultural technologies 2.673
2. Effectiveness of agricultural technologies 1.663
3. Enjoyment of agricultural technologies 1.403
4. Social influence in use of technology 1.325
5. Experience with agricultural technologies 1.138.

factors were not correlated. The loadings, which represent the correlation between a component and a variable, estimate the information they share. The results of the PCA correspond to a fixed effects model (i.e., the observations are the population of interest, and the conclusions are limited to correspond to these observations).

Table 7 offers an assessment of the reliability scale of the survey items, Cronbach's alpha, for the 14 attitude and perception statements, which was 0.6. This statistic was considered acceptable for exploratory research.

In summary, quantitative analysis revealed five attitudinal and perceptual clusters which explained almost 60 % of the variance (58.59) in the smallholder farmers' adoption of agricultural technologies. Most notably, a large part of the variance was accounted for in a cluster identifying that farmer experience challenges in accessing agricultural technologies (19.09) when they needed to use them. Overall, farmers confirmed that technologies increased effectiveness (11.88) saved them time (10.02), effort (9.47) and increased their popularity among peers (8.13). To further explore the challenges farmers reported facing in adopting technologies, qualitative focus group discussions were conducted, and yielded illuminating findings.

3.2 Qualitative findings

Four focus group discussions were conducted to further probe farmers attitudes and perceptions inductively about agricultural technology adoption among smallholder farmers in Kakamega County. The focus group discussions identified five main themes identifying farmer attitudes and perceptions of agricultural technologies. The themes that emerged included 1) farmer ambivalence about agricultural technology; 2) the economic benefits of agricultural technology use; 3) the ease of use of technology facilitated adoption; 4) a lack of trust; and 5) limited knowledge of agricultural technology and practices.

While some focus group participants acknowledged the benefits derived from using different fertilisers and hybrid seeds (the most promoted innovations in this area),other peer discussants expressed doubts over the effectiveness of the technologies promoted by the agricultural extension service providers visiting their farms. Competing views towards agricultural technologies across all the four focus groups emphasized farmer ambivalence about agricultural innovations. Complaints of farmer frustration with currently marketed inputs was observed in the focus group discussions. Other participants cited instances of commercially marketed seeds that never germinated or ineffective herbicides that never controlled weeds on their farms. In a focus group in Malava Sub- County, a farmer expressed these sentiments:

Currently, it is very difficult to differentiate between real seeds and fake ones. There are a lot of businessmen out there who only need money and do not care about farmers. They go on selling fake seeds to us. This really costs us and com-

Table 6: *Factor loadings of the rotated attitude component matrix.*

		Factor components				
	Survey statement	***1***	***2***	***3***	***4***	***5***
6	Modern agriculture practices are a plausible alternative to traditional practices	**.743**				
8	I receive personal satisfaction from applying modern agricultural production practices	**.684**				
7	Modern agricultural practices influence my practice of agriculture	**.679**				
3	The use of technology saves me time in my farming tasks		**.786**			
2	The use of technology increases effectiveness in my farm activities		**.612**			.412
4	Effect of commercial inputs on output for the same inputs?		.524			
11	Main reason for using innovations is to increase agricultural output		.501			
14	Level of enjoyment from listening/reading different technologies/practices in use			**.714**		
12	I enjoy discussing new agricultural practices promoted by the local extension services			.559		
9	I need the practice of new agricultural production techniques in our small agricultural practice			.508		-.433
10	I will continue to use agricultural innovations despite high prices				**.733**	
13	Farmer friends influence me to use new agricultural innovations			.536	.541	
1	I experience challenges in accessing agricultural technologies whenever I need it					**.732**
5	The use of new technologies makes me popular among my peers					-.403

Note: Factors loadings in bold are considered reliable

Table 7: *Reliability analysis of attitude variables.*

Cronbach's alpha	*Cronbach's alpha based on standardized items*	*Number of items*
0.590	0.631	14

promises the yield that we receive from the farms. This is also a challenge most farmers face. In connection to that, I think farmers should buy seeds from the extension officers and not the hawkers.

The regular mention of ineffective inputs was an indication that farmers had mixed perceptions of the contribution of agricultural technologies to agricultural performance. Even when those new technologies, particularly hybrid seeds and commercial fertiliser varieties, were sourced from agricultural extension service providers, the farmers still doubted their effectiveness. In one focus group, a participant stated:*"A lot of seed varieties have been brought to us by extension officers. What we do is try them out first before making them our priority. We've been trying out several varieties but still, opt western seed 614 and 6213."*

Comparatively, there was a broad consensus among the focus group discussants that agricultural technologies resulted in raising economic benefits for farmers who followed the correct guidelines. Improved crop yields increased farmers' output and contributed to sufficient food for household consumption while marketing any surplus. Consequently. innovations stimulated farmer interest in new technology and practices. Farmers found the use of agricultural technologies as important in raising productivity. A participant in one of the focus groups expressed this view in a discussion *"....earlier on, I was not even aware of a variety of farming ideas but with the group, I am now aware. The new maize variety is a good example of the certified seed and it is working well in this zone. Most farmers in this zone are really happy with this because it has resulted in an increase in output..."*

The contribution of agricultural technologies towards economic gains, through yield improvement, was pervasive across the focus group discussions. Even if the utilisation of any kind of technology among farmers may have varied from farmer to farmer, investing in a technology was embraced by farmers due to the potential to increase efficiency and profitability in their farming enterprise.

In addition to the expressed economic advantages of modern agricultural input use in their farms, farmers seemed to enjoy farming because of the benefits resulting from improved crop yields. A female farmer from the Shianda subcounty shared her views on how she enjoyed agriculture: *"On my side, I enjoy farming a lot. I mostly plant maize on large scale and vegetables on a small-scale. I have been renting land, to plant maize and this has really worked well."*

As a result, farmers cherished farming and enjoyed using new agricultural methods.

The ease of use of agricultural technologies, and the familiarity with those innovations influenced the choice of agricultural practices over others. For example, some farmers found planting their maize using a rope efficient and kept crops in a straight line. Other farmers considered limited tillage and no-till planting as "non-traditional" practices; they did not accept these practices because they were not conventional among peers. For farmers, the primary reference point for new practices was familiarity with new practices - those practices that worked well and were prevalent in the community were easily embraced. In input selection, participants opted for specific hybrid seed types or fertiliser brands they were well acquainted with and regularly applied on their farms.

Trust emerged as a central theme in the focus groups. As a key construct in all forms of effective social relationships, the absence of trust undermines meaningful interaction between two or more distinct entities (Ladebo, 2006). Trust was expressed in different forms in farmer relationships with agricultural extension agents and the services they offered. The lack of trust by farmers towards the agricultural extension agents who delivered agricultural training and information services emerged in the focus groups. This relationship was the main cause of farmer rejection of the services intended to improve agricultural practice use and render farmers more productive. That tempered the role of agents working with agricultural communities and imperiled trust-building among the different stakeholders working with local farmers.

Lack of agricultural information and current training emerged as a predominant theme that was identified in the focus group discussions. The discussants intimated the existence of limited organised farmer training and information channels to funnel agricultural techniques crucial in crop yield improvement. There was inadequate knowledge of the most current innovations to use on the farms. Most farmers also lacked information on how to access basic farm services. The public agricultural service delivery infrastructure appeared inhibited by a weak extension system, the predominant source of agricultural information for the resource-poor farmers. A focus group participant from Malava Sub-County expressed views echoed in the other focus group meetings:*"...as Malava farmers, one challenge we face is a lack of awareness of agricultural information. No one is concerned with the idea of farmers being educated with new ideas..."* This statement captured the challenge of limited knowledge of agricultural inputs and practices experienced by many smallholder farmers in the entire county of Kakamega. The current state of agricultural service delivery had resulted in the weak crop yields and overall compromised productivity.

The limited access to a variety of agricultural techniques, including pertinent agricultural information, was a major challenge farmers faced. The low ratio of agricultural extension agents to farmers inhibited faster spread of critical agricultural services. In Ikolomani Sub-County, farmer frustration with information access was expressed by a participant who candidly described the situation in the area: *"I think farmers lack proper education on the new farming techniques...."* The same farmer alluded to the limited number of agricultural agents deployed to support and train farmers in need of services in the area. As the main information diffusion channel, the extension system did not reach the remotest parts of Kakamega County. Consequently, the lack of access to information was a key contribution to the formation of farmer attitudes towards agricultural technologies.

The identified themes partially supported and expanded the conceptual clusters that emerged from the quantitative phase of the research (Table 4). The theme of trust was not captured by the quantitative results, but participants in the focus group discussions emphasized trust as an overarching theme in the adoption of agricultural innovations. The emphasis of trust in the peer discussions provided a new dimension in identifying potential barriers against the adoption of agricultural technologies. The combined interpretation of qualitative and quantitative findings enriches the understanding of the process of adoption.

The prevalent themes in the qualitative phase of the study were: farmer ambivalence about agricultural technology; economic benefits of agricultural technology use; ease of use of technology facilitated adoption; lack of trust; and limited knowledge of agricultural technology and practices. The emerging themes in the qualitative phase of the study complemented the principal component analysis and provided a nuanced view of the attitudes of farmers towards technology adoption by smallholder farmers. The qualitative methodology offered a complementary perspective in explaining factors that enhance or hinder farmer adoption of new technology in region.

4 Discussion

These study findings give a broadened perspective of agricultural technology adoption among smallholder farmers through the lens of a mixed methods approach. The results reconcile the unique role of the qualitative and quantitative approaches in identifying the underlying factors that determine technology choice decisions in smallholder agri-

culture. The principal component analysis identified five key attitudinal components:1) challenges in accessing agricultural technologies; 2) the use of technology in increasing effectiveness in farm activities; 3) the time saving nature of technology; 4) effect of commercial inputs on output; and 5) the use of new technologies as increasing popularity among peers. In the qualitative analysis it was generally evident that people had positive views toward agricultural technologies. In addition to corroborating the variables that the PCA identified as influential in adoption, the qualitative analysis suggested that despite the favorable farmer attitudes, underlying challenges pertaining to technologies access, and use hindered the translation of any positive attitudes to actual adoption.

The qualitative results elicited the nuanced challenges of accessing agricultural technologies beyond the normative socio-economic determinants of adoption. In this regard, the qualitative analysis complements the quantitative findings by broadening the quantitative variables and contextualizing them to the study area. The reduced principal components in Table 4 identified specific farmer attitudes about agricultural technologies. The extension of the key clusters in the focus groups resulted in realistic subjective views that went beyond normative determinants. For instance, the farmer experience of challenges in accessing technologies was reflected in the service delivery bottlenecks highlighted in the ineffective public extension system. The absence of trust between farmers and agricultural extension service providers eroded any positive gains of farmer attitudes towards agricultural innovations.

Even if farmers believed that the use of new technologies could raise crop yields, they were ambivalent about adopting them, due to the lack of trust in their relationship with public and private extension agents. The weak agricultural extension system and the lack of trust in the agricultural extension services weakened farmer willingness to adopt new agricultural practices. Consequently, the issue of trust and lack of information and training would have to be adequately addressed if the slow adoption rates must improve. Regaining the trust of the extension system would take time, which could require a reinvention of service delivery techniques.

The broad interest and positive attitudes of farmers in the use of agricultural technologies in their farms reinforced the PCA findings that demonstrated that they enjoyed using new agricultural practices. The PCA results suggested that social networks could be a reliable channel of cooperation and information sharing across the farming communities. The quantitative and qualitative results concluded that agricultural technology was generally positively valued by smallholder farmers. The focus group discussants stressed the importance of agricultural technologies in improving crop yields and in preventing post-harvest losses. However, a minority of farmers, roughly 20 %, were dissatisfied with the overall effectiveness of agricultural technologies in improving their agricultural performance and livelihoods. These perceptions can be attributed to the widespread marketing of adulterated agricultural inputs by unscrupulous sellers; lack of adequate knowledge and information about agricultural practices; and the unaddressed policy bottlenecks facing the input sub-sector. These combined reasons exacerbated farmer skepticism of agricultural technologies in general; causing some to opt for the use of seeds recycled from the previous harvest instead of adopting hybrid seeds.

Many of the farmers in this study relied on agricultural extension services (private and public) for agricultural information. However, the results indicated farmer dissatisfaction in the delivery of extension services, especially the public extension system. The focus group discussions identified the dislike toward the absence of trust, bordering anger, towards the entire agricultural extension system. The relationship of limited trust between the agricultural extension system and farmers reduced dependence on extension services and eroded farmer confidence in the effectiveness of the entire extension system. The weak agricultural extension infrastructure in western Kenya and the negative farmer attitudes towards it corroborated the quantitative findings of the study. Research participants indicated that agricultural information was insufficient – suggesting the need for improved agricultural training techniques. These results suggest that a focused examination of the delivery of agricultural extension services among smallholder farmers in Western Kenya is necessary.

In their responses, the focus group participants admitted risk-averseness, a characteristic reflected in their expressed input choices. Most of them appeared to prefer the use of recycled seeds from the previous planting season as inputs in the following planting season or using animal manure instead of applying chemical fertiliser on their farms. The marketing of adulterated inputs, which appeared to be a disincentive for the adoption of hybrid seeds, discouraged farmers from using agricultural technologies. In Mumias East and Lurambi sub-counties, research participants complained of the spread of adulterated inputs (especially certified seeds), which the county government of Kakamega had failed to curb. The failure to implement quality control regulations by the county government encouraged the spread of uncertified inputs and resulted in substantial losses to farmers.

This study, which sought to identify the factors influencing agricultural technology adoption among smallholder farmers in western Kenya, makes an important contribution

to the literature on agricultural technology adoption. The PCA results reiterate farmer preference of modern agricultural technology over traditional practices irrespective of the cost of technology. However, current adoption rates in in western Kenya are low, even if the quantitative findings suggest strong farmer willingness to adopt new technology. The findings point to the importance of quantitative and qualitative approaches in understanding adoption. However, the quantitative findings do not proximately capture the nuances that explain the low adoption rates among the smallholder farmers. The qualitative phase, entailing focus group discussions, provides a clear explanation for the low adoption rates and potential reasons that hinder adoption. The personal views of farmers provide deeper and broader justification for adoption trends. These findings warrant the need to consider both quantitative and qualitative approaches when evaluating a phenomenon that includes behavioral considerations, particularly in decision-making.

The diffusion model as postulated by Rogers (2003) focuses on the individual adoption, bust some of the variables analysed in the study are beyond the model. There are also other pertinent behavioral factors that are not captured in the adoption framework. This does not diminish the application of the diffusion of innovation framework in adoption, rather it reiterates how the theory has evolved to incorporate other variables into the model.

Conflict of interest

The authors declare that they have no conflict of interest.

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