Journal of Rural Studies 57 (2018) 171–185

Contents lists available at ScienceDirect

Journal of Rural Studies

journal homepage: www.elsevier.com/locate/jrurstud

Organic and conventional agriculture in Kenya: A typology of smallholder farms in Kajiado and Murang'a counties

Juliet Wanjiku Kamau*, Till Stellmacher, Lisa Biber-Freudenberger, Christian Borgemeister

Center for Development Research (ZEF), University of Bonn, Walter-Flex-Straße 3, 53113, Bonn, Germany

ARTICLE INFO

Keywords:
Diversity
Poverty
Food security
Organic agriculture
Multivariate analysis
Participatory guarantee systems

ABSTRACT

Understanding the diversity of smallholder farms is key for the development of interventions, strategies and policies aimed at addressing the numerous challenges these farmers face as well as for those shaping the future of smallholder farming in Kenya, Africa and beyond. In this study, we developed a typology for smallholder farms in Kenya using survey data from 488 farm households in Kajiado and Murang'a counties. Multivariate statistical techniques (principal component and cluster analyses) were used to group farms into five types differentiated by household characteristics, resource endowment, cropping practices, social networks, access to information, dietary diversity and gender equity. Types 2, 3 and 5 were mostly market oriented, possessed high to medium levels of wealth and had strong social networks. Types 3 and 5, however, mainly practised organic agriculture while Type 2 farms included organic and non-organic cultivated areas. Types 1 and 4 were characterised by low to medium levels of wealth, maintained poor social networks and had low adherence to organic agriculture practices. Yet, while Type 4 farms mainly practised conventional market-oriented agriculture, farms of Type 1 could be defined as organic-by-default and were self-subsistent. The majority of the surveyed farms belonged to Type 2, the wealthiest group of farmers and mostly located in Kajiado county. Murang'a county was dominated by farms of Type 5 practising mainly certified organic agriculture. Overall, the practice of organic agriculture was associated with higher agricultural income, legal ownership of land, older household heads, larger household sizes, stronger social networks, higher access to information, more diverse diets and higher levels of gender equity. In contrast, poorer, younger and less well-connected farmers were less involved in organic agriculture. The results of this study may help to increase efficiency in the implementation of pro-poor and organic agricultural interventions, strategies and policies on the ground and to shape policy instruments accordingly.

1. Introduction

Smallholder farmers are the pillar of the economies of Kenya and other sub-Saharan African (SSA) countries that are heavily reliant on agriculture (Altieri, 2009; Davis et al., 2017; GoK, 2009; Salami et al., 2010). In Kenya, smallholder farms with an area ranging from 0.2 to 3 ha are the source of more than 70% of the of the country's total agricultural produce. In a country where the agricultural sector is responsible for approximately 26% of the gross domestic product (GDP), and 18% of formal and 60% of informal employment in rural areas, the role of smallholder farmers is vital (GoK, 2009). According to different estimates, almost 50% of the population of Kenya lives in poverty. Majority of the poor live in rural areas where there are high levels of food insecurity. In addition, over 65% of the Kenyan population are between 18 and 35 years, and make up over 50% of the unemployed in the country majority (ILO, 2016; Krishna et al., 2004; WFP, 2016).

On the one hand, agricultural growth has been recognised for its capacity to reduce poverty and food insecurity in SSA (Dethier and Effenberger, 2012; Salami et al., 2010; von Braun, 2010), which is essential to achieve the Sustainable Development Goals (SDGs) (UN General Assembly, 2014). On the other hand, hundreds of millions of smallholder farmers continue to face serious challenges such as poor and declining soil fertility leading to large yield gaps for almost all crops, and limited access to financial capital, markets, land, inputs, information and technology. Pre- and post-harvest crop and animal losses due to pests and diseases are still high (GoK, 2009; Salami et al., 2010; Tittonell and Giller, 2013). In addition, because many African countries rely on food imports, they are vulnerable to external influences such as price fluctuations and trade barriers (WFP, 2016). There is a general consensus that for most of the countries in SSA, sustainable development will largely depend on improving agricultural productivity as well as the welfare of smallholder farmers (Dethier and Effenberger, 2012; Salami et al., 2010).

The practice of organic agriculture (OA) is growing among

* Corresponding author. Personal Tel.: +49 152001440960; Office Tel.: +49 228 73 1843.
E-mail address: wanjikuj2003@yahoo.com (J.W. Kamau).

https://doi.org/10.1016/j.jrurstud.2017.12.014
Received 23 February 2017; Received in revised form 28 November 2017; Accepted 10 December 2017

smallholder farmers in SSA and has recently received special attention from policy makers and development experts. It is perceived as a pro-poor and sustainable agricultural production model and therefore promoted as one way to deal with the persistent problems of food insecurity as well as other challenges facing smallholder agriculture in SSA (Bett and Freyer, 2007; Niggli et al., 2016). However, smallholder farmers differ in structural aspects such as financial resources, information access and asset availability and allocation as well as in functional aspects such as agricultural production objectives, livelihood strategies and their dynamics (Kuivanen et al., 2016a; Pacini et al., 2014; Tittonell et al., 2010), diversification approaches (van de Steeg et al., 2010) and other socio-economic aspects (Bidogeza et al., 2009). Given the heterogeneity of smallholder farmers in SSA, any effort aimed at addressing their challenges needs to begin with an understanding of this complex diversity.

One way of addressing the diversity of smallholder farms is classifying them based on their similarities into homogenous groups, i.e. farm types (Kostrowicki, 1977; Kuivanen et al., 2016a). Farm typologies help to identify appropriate and type-specific innovations, to scale them up and to investigate their outcomes (Signorelli, 2016). For instance, farm types have been created for increasing the general applicability of recommendations for farm improvement (Chikowo et al., 2014; Köbrich et al., 2003), identifying reasons for low technology adoption (Bidogeza et al., 2009), supporting policy design, better targeting of agricultural novelties and household resource allocation (Tittonell et al., 2010), as well scaling-up of best-fit options (Alvarez et al., 2014).

One approach for classifying smallholder farms is the consideration of variables of the whole farming system (i.e. household, cropping and livestock systems) as well as their relationship with the ecological, economic and social outside contexts (Alvarez et al., 2014). Variables that have been used in typology studies in SSA include those on household characteristics like age, education and literacy mainly of the household head, and the size of the smallholder household. Resource endowments in terms of availability of land, livestock and other agricultural assets, labour (non-/off-farm versus on-farm), capital (i.e. income, credit access), technology and capacity to invest, are the most common variables of categorising farms. Environmental variables used in typologies include soil and water conservation, land use and management as well as cropping practices. Others variables such as production orientation (i.e. market, self-subsistence), food security and gender equity have also been used in typologies (Bidogeza et al., 2009; Giller et al., 2011; Kuivanen et al., 2016a, 2016b; Mutoko et al., 2014; Pacini et al., 2014; Sakané et al., 2013; Shepherd and Soule, 1998; Signorelli, 2016; Tittonell et al., 2005a, 2005b, 2010, 2010; van de Steeg et al., 2010).

A number of publications used different methods to categorise smallholder farms in Kenya. Shepherd and Soule (1998), for example, grouped farmers in Western Kenya based on their resource endowment and constraints. Tittonell et al. (2005a, 2005b) identified farmer classes based on resource endowment, production orientation, farming constraints and other socioeconomic factors. In the same region, similar criteria of smallholder farm categorization were also used by other researchers (Giller et al., 2011; Mutoko et al., 2014; Valbuena et al., 2008). Household and location factors were used to categorise farmers across various other regions in the Kenyan highlands (van de Steeg et al., 2010) (Sakané et al., 2013). grouped smallholder farmers in wetlands in the Mount Kenya highlands of Nyeri North and Laikipia West based on their livelihood strategies and production orientation.

All of the typology studies mentioned here were carried out in the humid and semi-humid highlands of Kenya with an annual rainfall from 600 to 2700 mm. However, more than 80% of the land in Kenya is classified as arid and semi-arid (ASAL) with an annual rainfall ranging from 150 to 1100 mm (GoK, 2009; Sombroek et al., 1982). To the best authors' knowledge however, no published study have build a typology of smallholder farms in the ASAL regions of Kenya. To capture these two distinct climatic categories, farms from two counties in Kenya were selected for this study, i.e. one humid to semi-humid and one arid to semi-arid county. These counties were also selected due to their proximity to the capital Nairobi where the main market for agricultural produce is located. While studies on smallholder farm typologies of the Kenyan highlands are abundant, the contribution of this study lies in the inclusion of smallholder farms in the ASAL region and comparing them to those of the humid to semi-humid highlands. This study also attempts to provide relevant knowledge on factors driving variability in smallholder farms as well as those that set apart smallholder farms practicing OA from the rest in order to better contextualise and support policy discussions on OA as well as on other agriculture interventions and development strategies in Kenya.

The importance of improving productivity in agriculture and the welfare of smallholder farmers to sustainable development in SSA is undisputed. However, the complexity of smallholder farms poses a threat to the effectiveness of any efforts to achieve this. Past interventions by donors, government and other stakeholders have not fully succeeded in this regard, given the persistent poor productivity and wellbeing of smallholder farms. Typologies of these farms that take into account their complex heterogeneity as well as heterogeneity of their biophysical environment can be a first step to target interventions such as the EOA initiative more effectively. This in turn can contribute to improving their productivity, ultimately contributing to efforts seeking to alleviate of poverty, food insecurity and unemployment particularly in rural areas in Kenya and beyond.

Typology development should be guided by the research objectives, questions and characteristics of the study area (Duvernoy, 2000; Köbrich et al., 2003). This study sought to answer the following two research questions: 1) Which types of smallholder farms can be identified, which factors drive their variability and how are they distributed between the two case counties? 2) What are the main drivers of variability between smallholder farms applying OA and those that do not? To answer the research questions we applied cluster analysis (CA) to the output of a principal component analysis (PCA), a technique known from many other similar studies (Bidogeza et al., 2009; Kuivanen et al., 2016a, 2016b; Mutoko et al., 2014; Sakané et al., 2013; Tittonell et al., 2010).

1.1. Organic agriculture in Kenya

Organic agriculture started in Kenya in the early 1980's as an initiative of non-governmental organisations (NGOs), commercial companies as well as faith- and community-based organisations. It has been suggested that OA is associated with many benefits such as poverty reduction, enhanced food security and gender equity, adaptation to climate variability, access to markets especially through export trade, and provision of other social as well as environmental benefits (African Union, 2011; Amudavi et al., 2014; Ayuya et al., 2015; Bett and Freyer, 2007; Chiputwa and Matin, 2016; Ndukhu et al., 2016; Niggli et al., 2016). Like in other SSA countries, the OA sector in Kenya has developed without formal regulation.

Currently, however, the sector is under legislation through the "Ecological Organic Agriculture" (EOA) initiative by the African Union. This initiative seeks to mainstream OA into national agricultural production systems in Africa by 2025 as a development pathway for the continent to improve agricultural productivity. The definition of the EOA is similar to that used by the IFOAM (International Federation of Organic Agriculture Movements) to describe OA, and is also used in this study (Niggli et al., 2016). According to the IFOAM, 'Organic agriculture is a production system that sustains the health of soils, ecosystems and people and relies on ecological processes, biodiversity and cycles adapted to local conditions, rather than the use of inputs with adverse effects' (IFOAM, 2013). In this study, the terms EOA and OA are used synonymously.

Organic and non-organic smallholder farmers in Africa represent a number of different groups.

Using a classification of smallholder farms in SSA by Bennett and Franzel (2013), that was based on intensity of use of agrochemicals versus use of soil nutrient and pest and diseases management practices, the farmers in Kenya can be grouped into five categories. These include the following: organic certified, organic uncertified, mixed organic-conventional, conventional and organic-by-default farmers. On the one hand, the certified organic farmers market products produced according to specified and verified standards that adhere to the general OA principles. On the other hand, the uncertified organic farmers adhere to many principles of OA, but are not formally certified as OA. Badgley et al. (2007) argued that OA in SSA had been erroneously compared to this subsistence low-input agriculture that is resource constrained (Badgley et al., 2007). The group termed as organic-by-default consists of a low-input low-output system characterised, lack or limited soil conservation or pest and disease management practises. The conventional farmers use agrochemicals and other conservation measures but in varied levels of intensities, while the mixed organic-conventional have less usage of agrochemicals and higher usage of soil and other conservation measures (Bennett and Franzel, 2013; Bolwig et al., 2009).

There has been a rapid growth of the import of organically produced agricultural products from developing countries to developed countries, especially to the European Union (EU), North America and Japan (H. R. Barrett et al., 2001b; Niggli et al., 2016). There is also a growing demand for organic produce in the East African region attributed to improved living standards especially in urban areas and changing food preferences triggered by food safety, among other concerns (Ayuya et al., 2015; Ndukhu et al., 2016). Organic certification is seen as a way to reduce economic barriers for trading organic products by enabling access to high priced markets that reward them for the use (or non-use) of certain production systems and methods (Niggli et al., 2016; Schwindenhammer, 2016).

In Kenya, organic produce destined for the export market is normally certified according to international standards of certification organisations such as Soil Association (UK), Ceres (USA), and IMO (Germany). Local East African certification resulted from a collaborative effort of IFOAM and other national organic initiatives like the Kenya Organic Agriculture Network (KOAN) and its equivalents in Tanzania (TOAM) and Uganda (NOGAMU), which created the East Africa Organic Product Standard (EAOPS), a regional certification standard for East Africa. The same initiative led to the formation of participatory guarantee systems (PGS), which are quality assurance systems built on social networks with emphasis on producer participation and are an alternative to third-party certification. In Kenya, PGS are mainly organised by groups of farmers of organic products under the guidance and support of KOAN. Farmer groups organised as PGS in Kenya are certified by Encert, which is a third-party certification body following EAOPS standards (Ayuya et al., 2015; Katto Andrighetto, 2013; Schwindenhammer, 2016).

2. Materials and methods

2.1. Sampling design

A multi-stage sampling procedure was applied to select counties, sub-counties and farmers. The study was conducted at farm household level. A sampling of farmers was done after preliminary field visits to several counties in Kenya. Two counties, namely Kajiado and Murang'a, were finally selected through purposive sampling based on the general presence of certified organic farmers as well as climatic heterogeneity. The departments of agriculture of each county provided a reliable source to identify smallholder farmers, while contacts provided by KOAN provided lists of certified organic smallholder farmers registered with them.

Since the size of certified organic farmers varied across the counties and sub-counties, and to ensure that every farmer had an equal chance of being included in the sample, farmers were selected through the Probability Proportional to Size (PPS) sampling method. Using this procedure, approximately 33% of the certified organic farmers (n = 180) and 66% of the non-certified farmers (n = 345) were randomly selected.

2.2. Study area

Kajiado county belongs to the ASAL in the southwestern part of Kenya (Fig. 1). It lies between 36° 5′ and 37° 5′ East and 1° 0′ and 3° 0′ South and covers an area of almost 22,000 km^2. Altitudes range between 500 m.a.s.l. at Lake Magadi and 2500 m.a.s.l. in the Ngong Hills. Annual precipitation varies with altitude and ranges from 300 mm to 1250 mm. The county is considered to have low agricultural potential. The main land uses include pastoralism, wildlife conservation, rain-fed and irrigated crop farming as well as livestock farming. Farmers there produce predominantly food crops like potatoes, vegetables and cereals (KCDP, 2013; Ogutu et al., 2014). The surveyed certified organic farmers mainly belong to a PGS groups under the Ngong Organic Farmers Association (NOFA). The NOFA uses the EAOPS as a basis, albeit simplified to an internal standard, and hence they do not have full compliance to the standard. They are self-regulated and monitored with support from the KOAN and sell their produce for a premium price at organised markets in Nairobi or at the prevailing market prices at local markets (Katto Andrighetto, 2013).

Murang'a county is located between 0° 34′ and 1°7′ South and 36° and 37° 27′ East with a total area of about 2500 km^2 (Fig. 1). Altitudes range between 914 and 3353 m.a.s.l. with a humid to semi-humid climate. Annual rainfall is bimodal and varies between 400 mm and 1600 mm (MCDP, 2013). The main land use is crop farming and animal husbandry. Smallholder farmers mainly cultivate tea, coffee, avocado, macadamia, arrowroots, cassava, Irish and sweet potatoes, cereal crops as well as fruits and vegetables (MCDP, 2013). The certified smallholder organic farmers mainly cultivate avocado and macadamia but also cash crops like tea or coffee. They are predominantly certified according to EU standards by international certification bodies such as the Soil Association (UK), IMO (Germany) and EcoCert (France). Private companies who have contractual arrangements with farmers facilitate the certification of farms. These companies finance the certification process aid in the OA transformation of farms through training, labour hiring for harvesting, and buying their products at a premium price above the prevailing market prices.

2.3. Data collection

Empirical data for this study was collected in 2015 through a semi-structured questionnaire, which was pre-tested earlier. Interviews were face to face with the heads of the farm household or, in their absence, with the most senior member of the farm household. The questionnaire included questions on household demographics such as age, occupation, household size, education and income, land tenure rights, livestock ownership, crop production practices and input use, gender equity, dietary diversity, access to credit and information, social networks and asset ownership. The term social networks was used synonymously with group membership representing the membership of a farmer in a cooperative union, crop or seed producer and marketing cooperative, farmers' association, women and youth association, religious association, savings and credit group or any other group of any member of the household. The survey captured a total of 523 smallholder farm households, i.e. 254 in Murang'a and 269 in Kajiado county. The semi-structured questionnaire was administered using Open Data Kit (ODK) (Hartung et al., 2010) installed on Android tablets and administered by trained enumerators. The data were analysed with STATA version 13 (StataCorp, 2015) and R version 3.3.1 (R Core Team, 2014).

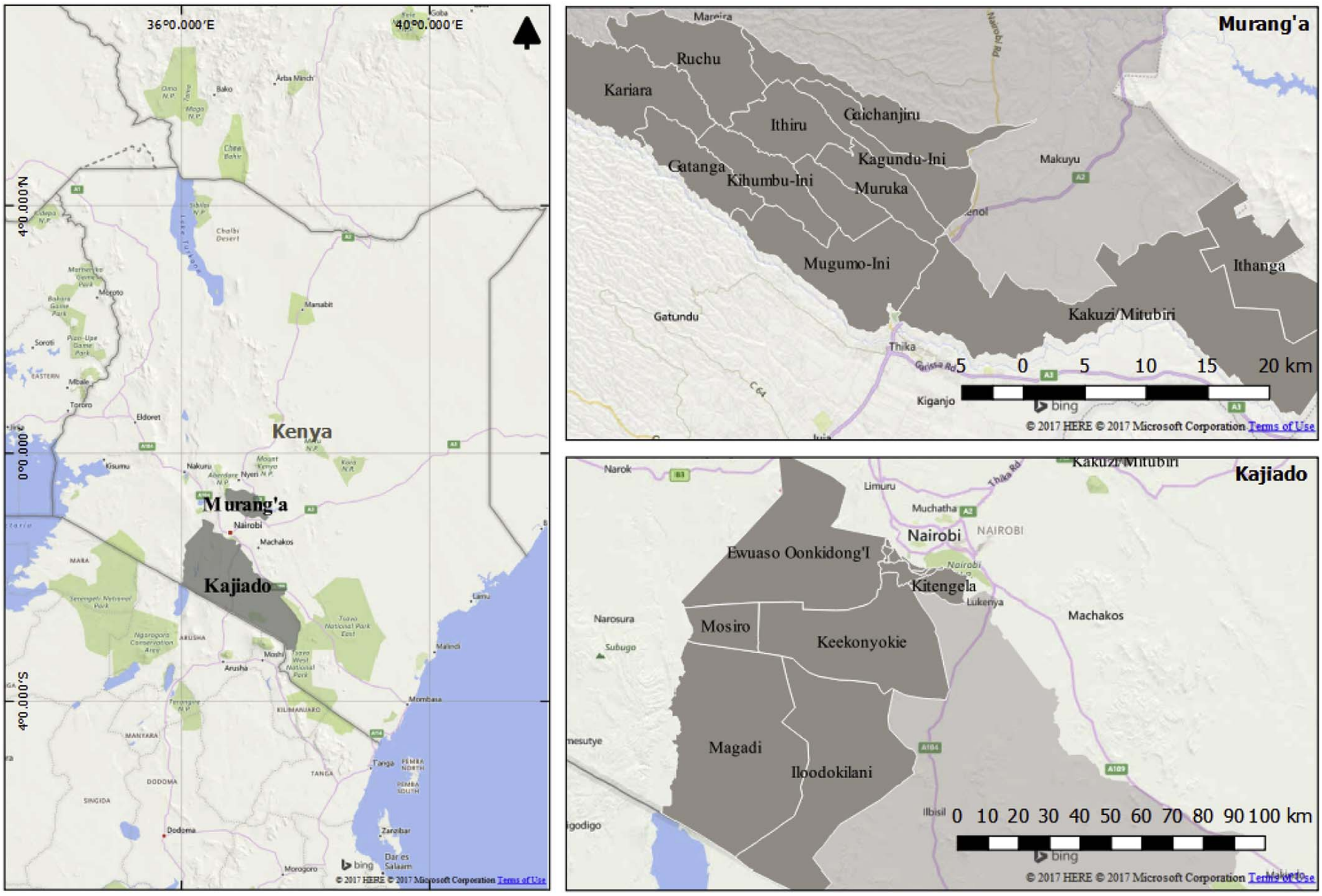

Fig. 1. Map of Kenya (left) showing the location of Kajiado and Murang'a counties and their respective wards (right) that constitute the study area. Data source(GADM, 2015).

2.4. Multivariate data analysis

Prior to categorization, several variables were generated from a consolidation of various items from the questionnaire data. Livestock numbers (tropical livestock units, TLU) were estimated using the conversion factors by Jahnke (1982), where one TLU represents 250 kg live weight. Standardised indices were created for gender equity, dietary diversity and farm productive assets using PCA. The gender equity index was constructed from variables concerned with gender equity in financial decision-making and control over resources as well as sharing of household responsibilities based on 5-point scales (1 = Strongly agree to 5 = Strongly disagree) and 2-point scales (1 = Yes, 2 = No). The dietary diversity index was based on 30-day recalls concerned with the frequency of intake of major food items in different categories including cereals, tubers, vegetables, fruits, pulses, sugars, oils, meat/fish and milk products spread over different time scales in the previous month. A longer reference period has been argued to be better to determine dietary patterns than 24-hour recalls (Ng'endo et al., 2016). This dietary diversity index is similar to the Dietary Diversity Score (DDS), which estimates diversity in diets and represents the number of certain food groups consumed by an individual or a household (Kennedy et al., 2011).

The dataset with 43 variables (Table 1) represents the output of the farm survey designed to capture the whole farming system and its interaction with the outside context. Outliers were defined based on the threshold of 1.5 quartiles above the upper quartile or below the lower quartile, and mostly removed from the dataset prior to further analysis (Hair et al., 2010). However, some outliers were retained as they were deemed sufficiently grouped together to form a farm type (Alvarez et al., 2014). This reduced the dataset from the original 523 to 488 entries. The cluster analysis based on PCA outputs was mainly done according to the method of Alvarez et al. (2014). A functional typology of smallholder farms developed for categorising farms in Kenya by Tittonell et al. (2005a, 2005b) was partly used as a conceptual basis for categorization in this study. The typology was developed based on the outputs of PCA and cluster analyses in R (version 3.3.1) using the ade4 package (Mangin et al., 2012).

PCA can be applied to reduce the multivariate dataset of farm variables to non-correlated principal components (PCs). In this case, however, we used loadings of all variables for the most important PCs as variables for the cluster analysis. Important PCs were selected if the cumulated percentage of explained variability accounted for 90% or more of the total variance (Hair et al., 2010). The Kaiser criterion, which suggests the retention of all PCs with eigenvalues greater than unity, was first considered but given that this criterion has been argued to be less accurate if the number of variables is greater than 30 and a sample size smaller than 250 (Field, 2011), we decided against it. In addition to this, correlations among the variables and the PCs were examined (supplementary material, Table S1). In this study, only loadings greater or equal to 0.03 were considered for interpretation purposes given that the sample size exceeded 300 (Field, 2011; Stevens, 2002).

Hierarchical agglomerative cluster analysis according to Ward's method was used to group the farms into homogeneous types based on the variable loadings of the three retained PCs from the PCA (Ward, 1963). The Ward method initially treats each observation as a separate cluster and merges the two most similar ones in a stepwise process. This procedure continues until all the observations are merged into one single cluster (Kuivanen et al., 2016b). The interpretation of distinct farming types is based on the graphical results from the PCA and cluster

Table 1
Summary statistics for variables used for categorising farm households.

Variable (n = 488)	Code	Unit	Mean	Std. Dev.	Min	Max
Household						
Age of household head (hhh)	age_hhh	Years	54	15	20	94
Total household (hh) size	sizehh	Number	5	3	1	19
Total years of education of hhh	eduyrs	Years	9	4	0	19
Ability of hhh to read and write	readwrite	% hhs[a]	0.88	0.33	0	1
Household labour						
Members working fulltime on-farm	FT_infm	Number	1.3	0.9	0	6
Members working part time on-farm	PT_infm	Number	1.4	1.6	0	9
Members working fulltime off-farm	FT_offfm	Number	0.7	1.4	0	10
Land size and use						
Land legally owned (acres)	Legland	ha[b]	0.84	0.83	0.00	5.26
Land rented in (acres)	Renland	ha[b]	0.07	0.17	0.00	1.01
Legally owned land cultivated (acres)	Cultleg	ha[b]	0.59	0.65	0.00	4.45
Rented land cultivated (acres)	Cultren	ha[b]	0.06	0.15	0.00	0.81
Cropping practices						
Pure stands only	purestd	% hhs[a]	0.15	0.36	0	1
Intercropping only	intercrop	% hhs[a]	0.76	0.43	0	1
Both pure stands and intercrop	pure_inter	% hhs[a]	0.09	0.29	0	1
Organic farming practices of households						
Record keeping	Keeprcds	% hhs[a]	0.29	0.46	0	1
Mulching and cover cropping	mulcovercrp	% hhs[a]	0.58	0.49	0	1
Use of organic soil additions	org_addtns	% hhs[a]	0.94	0.24	0	1
Lack of use of any organic soil additions	non_orgaddtns	% hhs[a]	0.1	0.3	0	1
Use of bio-pesticides	biopest_use	% hhs[a]	0.18	0.39	0	1
Intercropping with legumes	Legintercrp	% hhs[a]	0.68	0.47	0	1
Crop rotation	Crprotn	% hhs[a]	0.63	0.48	0	1
Use of synthetic pesticides	synpes_use	% hhs[a]	0.28	0.45	0	1
Use of mineral fertilizers	minfert_use	% hhs[a]	0.42	0.49	0	1
Access to credit and information						
Accessed credit in the last season	credt_lastsn	% hhs[a]	0.09	0.28	0	1
Accessed credit in the last 2 years	credt_2yrs	% hhs[a]	0.1	0.3	0	1
Accessed information on crop production	inf_crpprdn	% hhs[a]	0.5	0.5	0	1
Accessed information on input use	inf_inptuse	% hhs[a]	0.3	0.46	0	1
Knowledge and practice of organic agriculture						
Heard of organic agriculture	heard_org	% hhs[a]	0.74	0.44	0	1
Practice of certified organic agriculture	prac_corg	% hhs[a]	0.32	0.47	0	1
Group membership (social networks)	grp_membershp	% hhs[a]	0.43	0.5	0	1
Income						
Crop income	inc_crp	Av $ p.a[c]	208	112	0	297
Livestock income	inc_lvstk	Av $ p.a[c]	164	118	0	297
Income from other agricultural employment	inc_othr_agrc_emp	Av $ p.a[c]	27	47	0	297
Income from non-agricultural employment	inc_non_agrc_emp	Av $ p.a[c]	72	106	0	297
Business income	inc_biz_inc	Av $ p.a[c]	87	116	0	297
Remittance income	inc_remit	Av $ p.a[c]	26	61	0	297
Pension income	inc_pens	Av $ p.a[c]	32	70	0	297
Income from other sources	inc_othersou	Av $ p.a[c]	58	101	0	297
Crop gross margin	Totcrpgrossmg	$ p.a	298	571	−1807	3870
Ownership of productive assets (asset index)	asset_index	%	16.7	11.8	1.5	70.0
Dietary diversity (dietary diversity index)	dtry_diver_indx	%	40.4	19.2	0.5	94.5
Livestock ownership in TLU[d]	Tlu	Tlu	2.5	6.2	0	70
Gender equity (gender index)	gender_index	%	74.6	13.4	14.8	96.9

[a] Percentage share of households in a yes/no scale who answered yes.
[b] Conversion factor of 1 ha approximately 2.47 acres.
[c] Average income in the household per annum (p.a). Income variable in an 8-item and 5-item Likert scale (1 = < 25USD, 5 = > 297USD), on different sources of farm household income, and average in each class calculated and converted at a rate of one USD for approximately 101 Kenya Shillings (KES).
[d] Tropical Livestock Unit (TLU): livestock conversion factors based on (Jahnke, 1982).

Table 2
Selected principal components with their respective eigenvalues and percentage variance explained using PCA.

Principal component	Eigenvalue	Variance explained (%)	Cumulative Variance %
1	4.11	82.1	82.1
2	3.14	4.6	86.7
3	2.62	3.7	90.4

analysis and statistical calculations of the mean differences between each cluster and the rest (Alvarez et al., 2014).

3. Results

Summary statistics for all smallholder farmers showed that, on average, the household heads were relatively old (54 years), with family sizes of five members and nine years of education, which represents lower secondary schooling level in Kenya, and that they owned less than one hectare of land (Table 1).

Three PCs were derived from the PCA analysis explaining 90% of the variability in the dataset. The first PC explained the greatest variance of about 82% (Table 2). Variables relating to knowledge and

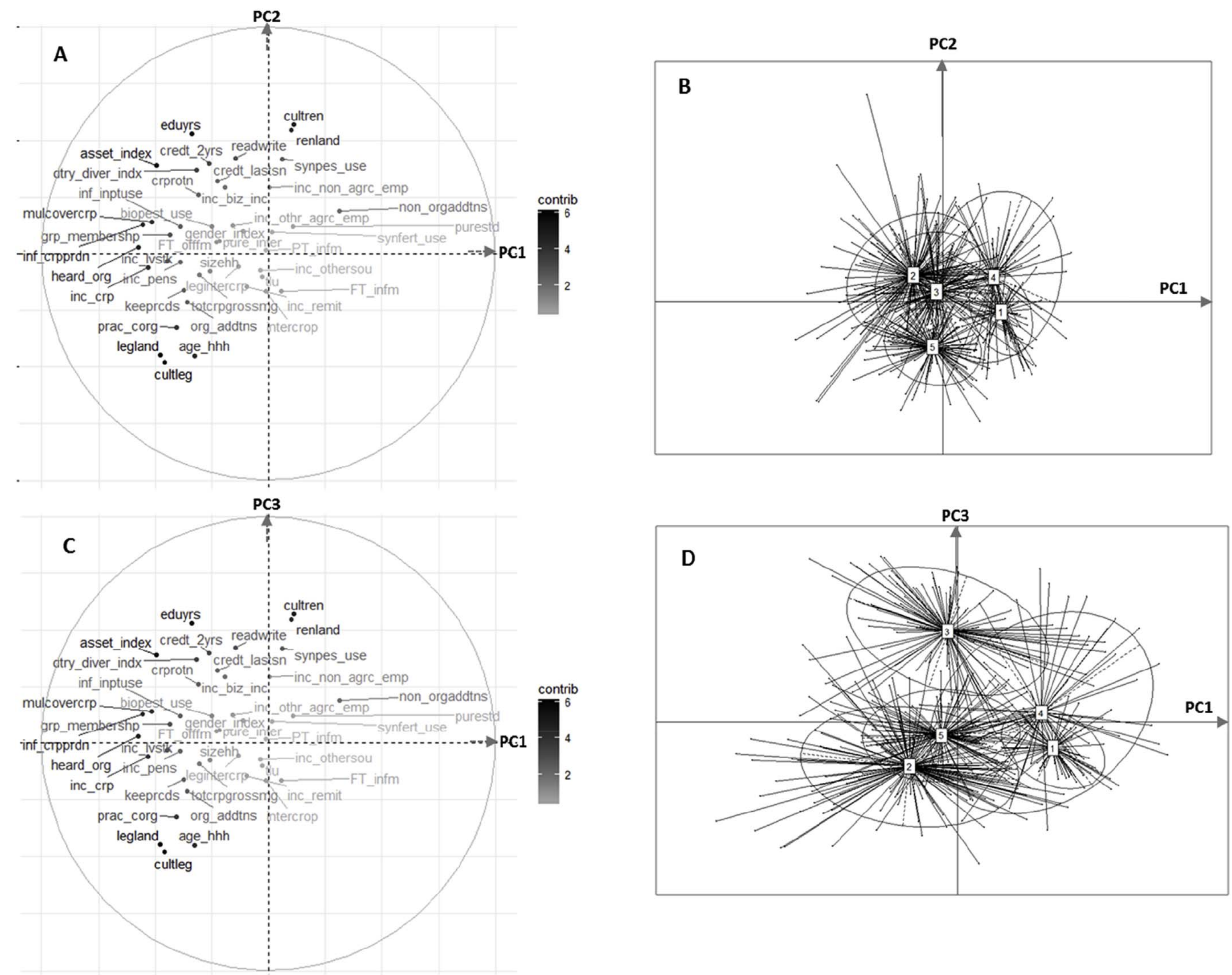

Fig. 2. Output of PCA and cluster analysis: correlation circles (A and C) and farm types 1–5 (B and D) in the planes PC1-PC2, PC1-PC3. The colour of the variable names darkens with increase in the contribution of the variable to the PCs.

practice of organic farming, group membership, information access, crop and livestock income, asset ownership, ownership and cultivation of legally owned land, agricultural employment and pension income were closely related to PC1. Therefore, PC1 appeared to explain agricultural wealth and OA (Fig. 2A and C, supplementary material, Table S1). PC2 was associated mainly with variables of rented land and its cultivation, age, education and literacy levels of the household head, use of synthetic pesticides, access to credit, and non-agricultural income. PC2 appeared to explain non-agricultural wealth and conventional farming (Fig. 2A, supplementary material, Table S1). PC3 correlated with variables related to cropping systems (mainly intercropping) and record keeping (Fig. C, Supplementary Material, Table S1). Variables like TLU, part-time on-farm labour, use of mineral fertiliser and other income sources seemed not to provide much additional information for the PCA but were retained to fulfil the criteria to explain 90% of the variability of the farms (Fig. 2A and C).

The results from the hierarchical clustering procedure suggested a five-cluster cut-off point shown in the clustering dendrogram, and a bar plot showing maximum dissimilarity among clusters with increasing grouping of observations (Fig. 3). This led us to grouping the farm households into five broad farm types (Fig. 2B and D), which will be described according to their characteristics in the following sections. However, variables of part-time on-farm labour and use of mineral fertiliser were excluded from defining the farm types as there were no significant differences ($p < 0.05$) among the five types of farms (Table 3).

3.1. Farm types

The following sub-sections (i.e. 3.1.1–3.1.5) describe the characteristics five farm types in detail while Table 5 gives a summary of the same.

3.1.1. Type 1

Low resource endowment, mainly ‘organic by default’ and self-subsistence oriented, small households, middle-aged less educated heads, least diverse diets and most inequitable (13% of the assessed farms).

This cluster comprised rather small farms with the lowest agricultural and non-agricultural incomes levels, the lowest levels of ownership of productive assets and livestock, and a high dependency on family labour (members worked off-farm the least). The cluster of Type 1 farms was also characterised by rather low adherence to many organic principles with the lowest levels of record keeping, mulching and cover cropping, use of biopesticides and crop rotation. However, they mainly used organic soil additions like manure, compost and recycled

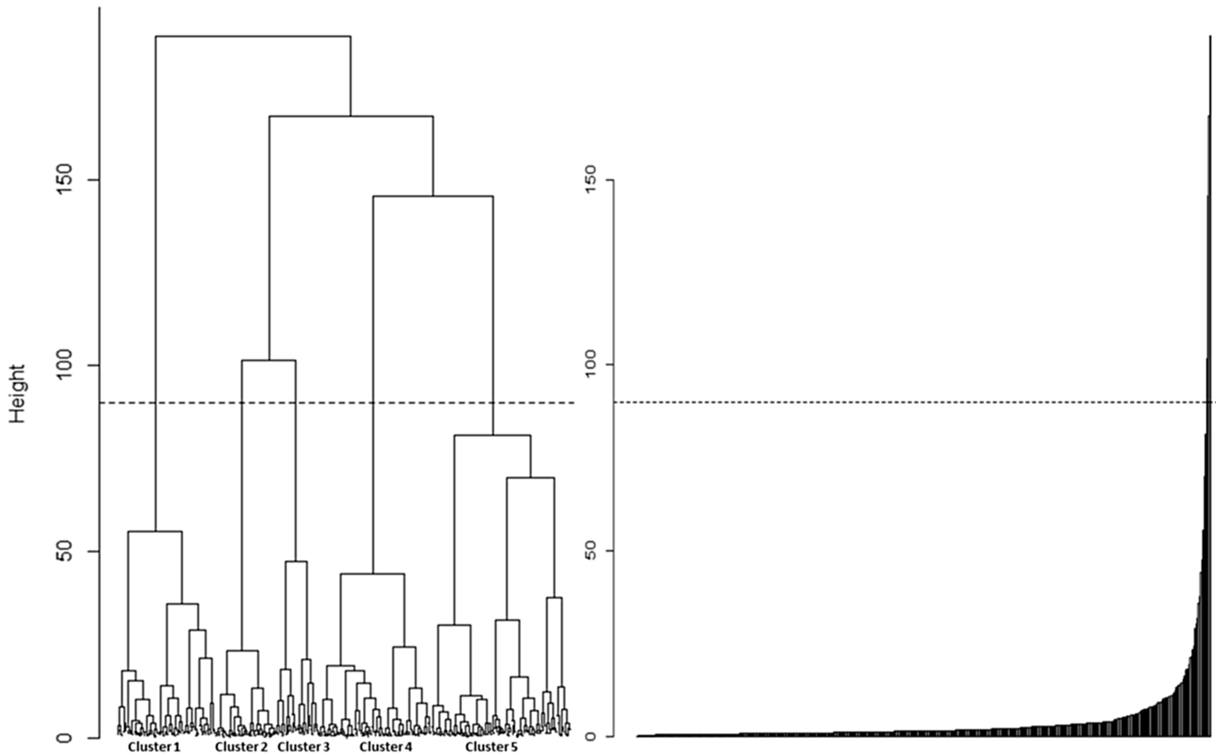

Fig. 3. Dendrogram (left) and associated bar plot (right) illustrating range of cluster solutions resulting from Ward's method of cluster analysis. Dotted line shows selected cut-off points which gave a 5-cluster solution (Types 1–5). Vertical axis represents distance or 'height' between the clusters at each stage.

plant residue with most households adding some form of soil organic amendment while their use of synthetic pesticides was insignificant. These households had the lowest number of members compared to the other clusters, and middle-aged heads with the fewest years of education. They had not accessed credit in the previous season or the previous two years, and had the least access to information on crop production and inputs. In addition, they had the least knowledge of organic farming with a limited practice of certified organic farming, and the poorest social networks with the lowest levels of group membership. Finally, they had the lowest levels of dietary diversity and gender equity (Tables 3 and 5).

3.1.2. Type 2

High resource endowment, mixed conventional and organic market oriented, most educated and literate heads, most diverse diets, equitable and ample off-farm activities (31% of the assessed farms).

The farm households of Type 2 were characterised by highest off-farm income levels from non-agricultural employment, business and pension, as well as the highest livestock and relatively high crop income. In addition to owning large pieces of land, they rented large shares of land and owned the most productive assets. Furthermore, these households adhered to many organic principles with the highest levels of practises such as mulching, cover cropping, use of biopesticides, crop rotation, intercropping, especially with legumes, and high use of organic soil additions with most household adding some form of soil amendment. However, they also had a high usage of synthetic pesticides. This implied that the cluster included a mixture of farms, some practising OA and the rest practising conventional agriculture. The cluster was also characterised by farm households with family members working mainly off-farm (least full-time work on-farm), and by the most educated and literate household heads. They also had the highest level of access to credit in the previous season and previous two years, and a high level of access to information on crop production and input use. They were strongly involved in social networks with the highest membership level in various groups, e.g. farmer cooperatives, church groups, and women and youth groups. Finally, these households had the highest levels of dietary diversity and gender equity (Tables 3 and 5).

3.1.3. Type 3

Medium resource endowment, mainly organic and market oriented households, literate heads, planting mainly pure stands (22% of the assessed farms).

The cluster of Type 3 represented farm households that owned, rented and cultivated relatively small farms and, although not significant, the levels of both agricultural and non-agricultural income, gross crop margins and livestock ownership for these households were moderate. The household heads were highly literate. They adhered to many organic principles with the highest levels of record keeping, as well as high levels of mulching, cover cropping, and use of organic soil additions with most household adding some form of soil amendment. However, they mainly planted their crops in pure stands, and intercropped to a lesser extent with legumes. When intercropping, they did so in different parts of the farm. These households had the highest access to information on crop production and a high knowledge and practice of OA. Finally, although not significantly different from the other farm types, their dietary diversity and gender equity levels tended to be rather moderate (Tables 3 and 5).

3.1.4. Type 4

Predominantly low to medium resource endowment, conventional and market oriented, youngest heads, crop based, reliance on rented land (9% of the assessed farms).

The cluster of Type 4 comprised farms that relied mainly on rented land, most of which was cultivated. They had the lowest levels of income from remittances and pensions. This type also possessed moderate amounts of productive assets and, although not significantly different from other types, had high gross crop margins. These households showed the least adherence to organic principles with low levels of biopesticide usage, mulching, cover cropping and organic soil additions

Table 3
Distribution of characteristics by farm type.

Variable	Type 1	Type 2	Type 3	Type 4	Type 5
	n = 65	n = 150	n = 106	n = 46	n = 121
Age of household head (hhh)	**50****	53	55	**43****	**61****
Total household (hh) size	**4****	5	5	5	**6***
Total years of education of hhh	**8.1****	**11.6****	10	8.7	**7.2****
Share of hhhs that can read and write	0.16	**0.19****	**0.18****	0.16	**0.13****
Number of hh members working fulltime on-farm	1.5	**1.0****	1.3	1.5	**1.5****
Number of hh members working part time on-farm	1.2	1.3	1.6	1.7	1.4
Number of hh members working fulltime off-farm	**0.4****	**1.0****	0.6	0.5	0.7
Size of land legally owned (ha)	**0.33****	0.96	**0.64****	0.79	**1.17****
Size of land rented in (ha)	0.06	**0.12****	**0.04****	**0.13***	**0.01****
Size of legally owned land cultivated (ha)	**0.23****	0.66	**0.43****	0.65	**0.81****
Size of rented land cultivated (ha)	0.05	**0.10****	**0.03****	**0.13****	**0.01****
Share of households (hhs) keeping records	**0.01****	0.05	**0.08****	**0.03****	**0.07***
Share of hhs planting pure stands only	**0.00****	**0.00****	**0.11****	0.03	**0.00****
Share of hhs intercropping only	**0.19****	**0.18****	**0.01****	0.14	**0.19****
Share of hhs planting both pure stands and intercropping	**0.00****	**0.01****	**0.07****	0.02	**0.00****
Share of hhs practicing mulching and cover cropping	**0.04****	**0.14****	**0.12****	**0.07****	0.11
Share of hhs using organic soil additions	**0.19****	**0.19****	**0.19****	**0.06****	**0.19****
Share of hhs not using ANY organic soil additions	**0.00****	**0.00****	**0.01****	**0.16****	**0.00****
Share of hhs using bio-pesticides	**0.01****	**0.05****	0.04	**0.01****	0.03
Share of hhs intercropping with legumes	0.13	**0.18****	**0.03****	0.13	**0.16****
Share of hhs practicing crop rotation	**0.08****	**0.14****	0.13	0.12	**0.10***
Share of hhs using synthetic pesticides	0.06	**0.08****	0.06	0.07	**0.01****
Share of hhs using mineral fertilizers	0.01	0.07	0.07	0.1	0.08
Share of hhs that accessed credit in the last season	**0.00****	**0.03****	0.02	0.02	**0.00****
Share of hhs that accessed credit in the last 2 years	**0.00****	**0.04****	0.02	0.02	**0.00****
Share of hhs with accessed information on crop production	**0.04****	**0.11****	**0.12***	**0.05****	0.1
Share of hhs with accessed information on input use	**0.01****	**0.09****	0.06	**0.01****	0.06
Share of hhs that have heard of organic agriculture	**0.07****	**0.16****	**0.16***	**0.10****	0.16
Share of hhs practicing certified organic agriculture	**0.02****	**0.04****	0.07	**0.00****	**0.12****
Share of hhs belonging to a social network (group, association)	**0.02****	**0.11****	0.1	**0.05***	0.08
Average hh crop income per annum (p.a) in USD	**99****	**223***	222	186	**244****
Average hh livestock income p.a	**82****	**207****	157	147	168
Average hh income from other agricultural employment p.a	**18****	28	31	20	29
Average hh income from non-agricultural employment p.a	**47****	**117****	65	83	**32****
Average hh business income p.a	**37****	**155****	85	90	**30****
Average hh remittance income p.a	19	28	29	**11****	29
Average hh pension income p.a	**7****	**55****	31	**11****	24
Average hh income from other sources	**15****	67	60	79	60
Crop gross margin	**55****	310	321	349	374
Asset index	**10.8****	**23.9***	16.4	**13.5***	**12.5****
Dietary diversity index	**31.7****	**48.5****	42.8	**33.5***	**35.3****
Tropical livestock unit (TLU)	**1.1****	2.1	3.4	5.8	**1.7****
Gender index	**71.0***	**76.0***	73.4	71.2	**77.1****

Note: *represent significant levels of mean differences between the type under consideration and the other four types combined, significant at 5% (*$p < 0.05$) and 1% (**$p < 0.01$).

Table 4
Sample by farm type and county.

Overall sample (n = 488)		Murang'a (n = 246)		Kajiado (n = 242)	
Type	Proportion in survey	Number in type	Proportion in Murang'a	Number in type	Proportion in Kajiado
1 (n = 65)	13%	33	13%	32	13%
2 (n = 150)	31%	50	20%	100	41%
3 (n = 106)	22%	58	24%	48	20%
4 (n = 46)	9%	9	4%	37	15%
5 (n = 121)	25%	96	39%	25	10%

with many households not adding anything to soils at all. Although not significantly different from the other farming types, they had a relatively high usage of synthetic pesticides. In addition, the households had a low level of access to information on crop production and input use, maintained poor social networks with low group membership levels, and their dietary diversity level was moderate (Tables 3 and 5).

3.1.5. Type 5

Predominantly high to medium resource endowment, mainly organic and market oriented, oldest and least literate heads, largest families, highly equitable and limited off-farm activities (25% of the assessed farms).

The farm households in the cluster of Type 5 owned and cultivated the largest farms and relied the least on rented land. They had the highest crop income but the lowest income from non-agricultural employment and business, and although not significantly different from the other types, their crop gross margins were the highest. However, their ownership of productive assets and livestock was low. These households adhered to many organic principles with high levels of record keeping, mulching and cover cropping, crop rotation, intercropping, especially with legumes, and high usage of organic soil additions with most household adding some form of soil amendment. They had the lowest levels of synthetic pesticide usage. In addition, the households were the largest with the oldest and least literate household heads. These farms strongly depended on family labour, and they had not accessed any credit during the previous season or the previous two years. However, they had the highest level of practice of OA and a high knowledge of it. Finally, this type had the highest level of gender equity and a moderate dietary diversity (Tables 3 and 5).

Table 5
Summary of main significant ($p < 0.05$) characteristics of the different farm types.

Farm type	Name of farm type	Share	Household related	Resource endowment	Cropping practice	Social networks and information	Development outcome variables
1	Poorest, organic-by-default self-subsistence oriented	13%	-small -middle-aged heads -less educated heads	low -least land, assets and livestock owned -no credit access -lowest income -based on family labour	mainly 'organic by default'	-weakest social networks -least access to information	-poorest diets -most inequitable
2	Wealthiest, mixed and market oriented	31%	-most educated and literate heads	high -based on hired labour -ample off-farm activities -large size of rented land - highest credit access -highest income	mixed (both organic and conventional)	-strongest social networks -high access to information	-richest diets -equitable households
3	Moderately wealthy, organic and market oriented	22%	-highly literate heads	medium -smaller land sizes owned and rented	mainly organic -planting mainly pure stands	-strong social networks -highest access to information	
4	Poor, conventional and market oriented	9%	-youngest heads	low to medium -rely on rental land -moderate asset ownership -low remittance and pension income	conventional	-weakest social networks -poor access to information	-less diverse diets
5	Wealthy, organic certified and market oriented	25%	-oldest heads - least educated and literate heads -largest families	high to medium -largest farm sizes owned -no credit access -few assets and livestock owned -high farm income -limited off-farm activities	mostly organic certified		-moderately diverse diets -highly equitable

3.2. Distribution of farm types in Kajiado and Murang'a counties

Approximately one third (31%) of all smallholder farms that were analysed belonged to Type 2, which was the wealthiest group. The same proportion of farms belonging to Type 1, which were the poorest farm households, was found in both counties and almost the same proportion of Type 3 farms was also found in both counties. The mainly conventional farm households of Type 4 were a minority, making up only 9% of the total number of households assessed, and were mainly found in Kajiado (15%) rather than in Muranga (4%). Kajiado county was dominated by the wealthier farmers of Type 2 (41%), that were either practising conventional or organic farming. In contrast, Murang'a county was dominated by high to medium resource-endowed households that were mainly organic (Type 5) making up 39% of the farms of this type in the county (Table 4).

3.3. Drivers of variability among farm types and association among variables in relation to organic agriculture

3.3.1. Household-related variables

Farming types differed significantly ($p < 0.05$) in terms of the age of the household heads, their education and literacy levels as well as the farm household size (Table 3). The findings reveal a negative correlation between age and education level of the household heads as well as their ability to read and write (Fig. 2A). In particular, the heads of Type 5 households were the oldest and had the lowest education and literacy levels. Farmers of Type 4, on the other hand, were the youngest, and although not significant, their education and literacy levels were relatively higher than for the other types (Table 3). Nevertheless, the age of the household head was positively correlated to the practice of certified OA as well as ownership and use of legally owned land (Fig. 2A). This indicates that the practice of certified OA was not dependent on the level of formal education but rather on the age and experience of the household head.

In addition, a positive correlation was found between agricultural income from crops, livestock, agricultural employment as well as pension, and the use of land owned legally with the practice of certified OA. At the same time, a positive correlation existed between variables related to non-agricultural income such as that from business and non-agricultural employment with the use of rental land (Fig. 2A and C). Farms practicing certified OA under a certification scheme therefore seem to have higher incomes from these activities and have access to their own land while farmers not practicing OA or at least not under some certification scheme have to rent land and complement income from agriculture with a higher level of non-agricultural employment.

3.3.2. Resource endowment in relation to cropping practices and orientation

The size, ownership and cultivation of land, ownership of productive assets and livestock, as well as agricultural and non-agricultural income, labour and access to credit, were all discriminating factors for the different farm types (Table 3). Variables of agricultural income and legal land ownership and use were correlated with each other. The size and use of rented land and non-agricultural employment income were also correlated with each other. In addition, the practice of OA was positively correlated with size and use of legally owned land as well as age of the household head, while it was negatively correlated with the use of rented land and non-agricultural employment income (Fig. 2A and C). Type 2 and 5 farms, which consisted of certified organic farmers owned larger farm areas. Type 1 farms, which can be classified as organic-by-default, had the least access to legal or rented land, while the mainly conventional Type 4 also owned much smaller farms and relied more on rented land.

Access to credit was strongly correlated to income from business and other sources. Ownership of productive assets correlated to income, both agricultural and non-agricultural (Fig. 2A and C). Farm households that possessed high-income levels from diverse sources, e.g. Type 2, appeared to have a higher level of asset ownership than their counterparts in Type 1 (Table 3).

The variables full-time on-farm and off-farm labour differed significantly among the farm types. While Type 2 farms were mainly based on full-time off-farm family labour, implying a reliance on hired labour, Type 1 and 5 farms relied on full-time on-farm family labour (Table 3). As noted earlier, ownership of livestock was a weak discriminating factor between the farm types (Fig. 2A and C). Nonetheless, it differentiated farm household Types 1 (1.1 TLU) and 5 (1.7 TLU), who owned a relatively smaller number of livestock than the other farm types. In addition, Type 5 farms were larger than Type 1 farms, who relied mainly on rented land (Table 3). Access to credit was positively correlated to the education level and literacy of the household head (Fig. 2A). Farm households Types 1 and 5 characterised by low levels of education and literacy had not accessed any credit in the previous season or even in the previous two years. In contrast, Type 2 households had the highest literacy levels and the highest level of access to credit. Access to credit was, however, not strongly linked to the practice of certified OA (Fig. 2A and Table 3).

3.3.3. Cropping practices

The way in which farm households managed their farms differed significantly between farm types and their levels of resource endowment (Table 3). There was a positive correlation between adherence to OA and management practices like record keeping and the use of organic soil additions according to the practice of certified OA. Farms of Type 3 had similar characteristics but differed from Types 2 and 5 first in their choice to either plant pure stands or both pure and intercropped stands but in separate parts of the farm, and second in their smaller farms sizes. However, farms of Type 2 had a significantly higher usage of synthetic pesticides compared to Type 5 where there was almost no usage of these at all. Both Types 1 and 4 showed a low adherence to OA principles (Table 3), which could be explained by their low levels of wealth.

The practice of certified OA was also strongly and positively correlated with income from agricultural sources especially from the sale of crop harvest indicating market orientation, but also non-agricultural income like pension as well as access to information and group membership (Fig. 2A and C). The association between the practice of certified OA and access to credit was relatively weaker (Fig. C). The correlation tables do not show a marked association between dietary diversity and gender equity for farm Types 1 and 4, which did not practice certified OA and had less diverse diets compared to the other farm types (Table 3).

3.3.4. Social networks and access to information in relation to organic agriculture

There was a strong positive correlation between group membership and access to information on crop production and input use. For instance, participation of farm households Type 1 and 4 in groups and their level of access to information on crop production and input use were low. In contrast, the opposite was true for households Type 2 and 3. Group membership was also positively correlated with agricultural income, knowledge and practice of OA and, to some extent, credit access. Interestingly, it appears that farm types with moderate to high levels of practice of OA had a high level of participation in groups, agricultural income and access to information compared to non-organic farming households (Fig. 2A and C and Table 3). These results indicate the importance of access to information for the dissemination of organic farming practices.

The knowledge and practice of OA was highest in Type 5 and lowest in Type 1. Results indicate that Type 4 farmers had the least knowledge of OA and did not practice it at all. Overall, results largely indicate a connection between the level of resource endowment of a farm household and the knowledge and practice of OA. The farm households that were highly to moderately resource endowed showed high adherence to many OA practices and had more knowledge and experience in practising it. This was in contrast to medium to low resource-endowed households (Table 3).

3.3.5. Dietary diversity and gender equity

Overall, the average score for gender equity in financial decision-making and control over resources as well as for sharing of household responsibilities was high in both counties (> 70%). However, dietary diversity was rather low with an average score of 40% (Table 1). Diversity in diets and gender equity in farm households were correlated with each other as well as variables of high resource endowment. Dietary diversity was strongly correlated to education level and literacy of the household (Fig. 2A and C). These variables did not have a strong association to the practice of certified OA, but they significantly ($p < 0.05$) distinguished farm households (Table 3). Farm households with the lowest levels of resource endowment (Type 1) had the lowest levels of dietary diversity and were the least equitable in terms of gender. Those with medium to high levels of resource endowment (Type 2 and 5) had equally high levels of dietary diversity and gender equity. Dietary diversity differentiated all types from each other apart from Type 3, while gender equity differentiated Type 1, 2 and 5 (Table 3).

4. Discussion

The results of this study show key differences across the five identified farm types. The distribution of the types in terms of the share of each type also varied between the two counties. In the following sections, the factors influencing diversity in smallholder farms and their implications are discussed in relation to the categories of variables that defined the typology, how they relate to each other and to the identified farm types. In addition, we link these categories to the study area and to the practice of OA.

4.1. Household characteristics

The farm household typology reveals the importance of the age, education and literacy level of the household head as well as the size of the household in explaining diversity in smallholder farms in the two case counties. Other studies reported similar findings albeit with variations. For instance, van de Steeg et al. (2010) found that family size and years of education explained heterogeneity in the five farm types they found in the Kenyan highlands. Sakané et al. (2013) observed that household size was a significant discriminant of farm types in Kenya and Tanzania, but that age of the household head was not. In Rwanda, the significant household discriminants were family size, age as well as education and the literacy level of the household head (Bidogeza et al., 2009). The inverse link between age and education as well as literacy level of the household head was also reported by Bidogeza et al. (2009) in Rwanda, where young household heads were more educated. The education level of the household head has been argued to be important for household welfare. Marenya and Barrett (2007) suggested that it was a key determinant of the overall household well-being and productivity. The results of this study show this is true for farm Type 1 and 2, but not for Type 5. Similar findings were reported in Ethiopia where certified smallholder farms were headed by relatively older household heads with a mean age of 48 years who had a low level of education (Jena et al., 2012).

The relationship between resource endowment and the above household variables varied in different studies in SSA. For instance, farm types with a high level of resource endowment were linked to older household heads (Tittonell et al., 2010; van de Steeg et al., 2010) and large household sizes (Kuivanen et al., 2016a; Sakané et al., 2013; van de Steeg et al., 2010). In accordance with this, this study reveals that Type 5 farm households with the oldest household heads were the largest, while Type 1 farms that had middle-aged heads had the smallest household size. However, Signorelli (2016) found that wealthier households headed more by young households with high levels of education.

Generally, however, the results of this study suggest that farming in the sampled households is mainly practised by the older generation. This finding is similar to that of Mutoko et al. (2014) in western Kenya. Majority of the youth lack formal education beyond high school and have no vocational training or professional skills. Due to minimal employment opportunities in the rural areas, they tend to migrate to urban areas where they mainly provide informal labour (ILO, 2016; Njenga et al., 2011).

The low level of youth involvement in agriculture in Kenya has been attributed to the poor transitional pathway from education in agriculture to work in the same, the youth access to land, and a negative perception of farming among the youth, who associate it with long working hours and limited returns. Radwan (1995) argued that employment-intensive growth is a vital strategy for poverty reduction. For agricultural growth aimed at reducing poverty, it is therefore necessary to distinguish the important role of household factors. First, support for youth education beyond high school, and greater emphasis on vocational training can provide these young people with the tools to engage competitively in the formal sector. Investing in human capital through education and training has been argued to help increase productivity and earnings of the poor, as farmers can absorb new ideas and innovations with much more ease and can respond to market opportunities, among other benefits (Radwan, 1995).

Secondly, the older generation that is engaged in farming cannot be ignored. The results of this study indicate that the level of wealth of the oldest, least educated and least literate group with the highest level of practice of certified OA (Type 5) could have been higher had they been able to access credit, which in addition to the reasons given above for low credit access, was also influenced by their education and literacy levels. Basic training, for example in book keeping, financial administration, marketing as well as in technical skills, could benefit them. Moreover, they also seemed to have large families, and other family members, especially the young and their farm workers who are mostly young too, could benefit from formal trainings to support/replace the old household heads. For farm household heads of Type 1, who were relatively younger and literate but with lower education levels, education aimed at enhancing their technical skills would enable them to adopt new technologies.

4.2. Resource endowment and farming practices in relation to organic agriculture

A third of the farms sampled belonged to Type 2 and were well endowed. These farms had diversified livelihood strategies with abundant off/non-farm activities and income, relied on hired labour, had high access to external financial capital and rented land to supplement their own. In contrast, resource-constrained farms belonging to Type 1 who depended on on-farm labour or off-farm employment as casual labourers had self-subsistence orientation. These two types correspond to other typologies for smallholder farmers in Kenya (Mutoko et al., 2014; Shepherd and Soule, 1998; Tittonell et al., 2005a), Uganda (Tittonell et al., 2010), and West Africa (Kuivanen et al., 2016a; Signorelli, 2016). Type 5 farms differed from the other types, as their strategy did not include diversification. Despite being relatively well endowed, they were heavily reliant on farm income mainly from crops and had no access to external financing, which could explain their limited ownership of productive assets as well as livestock. This farm type was similar to a type found in Ghana by Kuivanen et al. (2016a).

In a comparison of several other studies in SSA, a positive association was reported between income diversification and wealth (C. B. Barrett et al., 2001a). Although dependence on on-farm activities is still common in rural Africa, Davis et al. (2017) found that a greater reliance on non-farm sources of income was linked to households being richer in six SSA countries. However, C. B. Barrett et al. (2001a) acknowledged the vicious cycle between the unequal distribution of land and non-farm income, where limited agricultural assets and income hinder investment in non-farm activities. For instance, low credit access has been reported among smallholder farmers in Kenya due to high capital requirements for loan collateral, as lenders try to cushion against non-repayment or delay in loan repayment, poor information access on credit providers, and lack of interest payments (Ayuya et al., 2015; Mutoko et al., 2014).

Land entitlement deeds can be used as loan collateral (Place, 2009). For the farms of Type 1, resource constraint may explain the lack of credit access. Nonetheless, farmers may still not access formal credit even if they have title deeds as evidenced by Type 5 farms, most of which are located in Murang'a, where a general reluctance to obtain formal credit has been reported (MCDP, 2013). This has been attributed to perceived unfavourable terms such as high interest rates, dispossession of land (normally due to failure to pay back loans), and land fragmentation (Ekbom et al., 2001). Despite Kenya's relatively well-developed banking sector, agribusiness is viewed by banks as highly risky, and complex tenure systems and land laws have been argued to accentuate the problem for smallholder farmers (Njenga et al., 2011).

For the poorest farms (Type 1) who are most vulnerable to risks, interventions could first focus on alleviating poverty and food insecurity. Literature suggests that this can be done through measures aimed at increasing their productivity, which depends on many factors such as farm size and access to land as well as on new technologies and their adoption (Dethier and Effenberger, 2012; Kuivanen et al., 2016a; Radwan, 1995). Since these farmers already own or have access to small farms, other measures like promotion of high yielding crop varieties, reduction of post-harvest losses by improving storage facilities, and assistance in access to inputs could address the immediate need of poverty and food insecurity (Kuivanen et al., 2016a). For Type 5 farms, diversification in off/non-farm activities would also generate income (C. B. Barrett et al., 2001a; Kuivanen et al., 2016a), which could be invested in the purchase of more productive assets. In addition, given the large size of farm households in Type 5, technologies that require relatively more labour but are at the same time efficient (Kuivanen et al., 2016a) could be promoted. Development interventions could support the younger farmers in Type 4 in accessing productive assets including land and capital to boost productivity (Radwan, 1995).

4.3. Social networks and access to credit and information

This study reveals a strong positive link between variables of access to information and group membership as well as their association with wealth. Other studies in Kenya and Uganda showed that strong social networks positively influenced information acquisition (Thuo et al., 2014), and also income diversification in India (Davis et al., 2017). High resource endowment was linked with a greater likelihood of group membership for smallholder banana farmers in Kenya (Fischer and Qaim, 2012). The authors also found that these banana farmer groups were avenues of information exchange, and wealthier farmers could overcome some constraints like membership fees.

In addition, information acquisition and utilisation are influenced by literacy, affordability, linkages with external support to farmers (e.g. from extension officers) as well geographical location (Maumbe, 2010; Thuo et al., 2014). Technical information, e.g. on input use, pest and disease management and sources of various inputs, is a major information gap among farmers in Kenya. Poor extension services, long distances to agricultural service providers, especially in the ASAL regions, and weak institutional linkages have been argued to be major impediments to information access among these farmers (Omondi et al., 2014; Rees et al., 2000). Despite these challenges, the information and communications technology sector is well developed in Kenya. For instance, the mobile telephone technology is widely used by farmers not only for communication purposes but also for services like mobile banking. This is an opportunity to provide information to farmers, and could also enable transfer of social grants to poor farmers (Maumbe, 2010).

4.4. Dietary diversity and gender equity

The results of this study also show a positive link between dietary diversity (i.e. proxy food security), gender equity and levels of resource endowment as well education and literacy levels of household heads, and their relevance in distinguishing farm types. These findings are comparable to those in other studies. In western Kenya, wealthier households with better educated women were found to have higher dietary diversity (Ng'endo et al., 2016). In the same region, Tittonell et al. (2010) found a link between food sufficiency, a proxy for food security, and the land:labour ratio (LLR), an indicator of wealth as well as market orientation. The authors found that all households that were food insecure had a lower LLR in contrast to those identified as food secure. In Uganda, high income was associated with improved gender equity as well as improved diets (Chiputwa and Matin, 2016). In Ghana, Signorelli (2016) found that low-endowed households, which were mainly female-headed, had high rates of food insecurity and low literacy rates, while the opposite was true for the wealthy farm households.

The diversity of diets has been argued to be an important indicator of micronutrient adequacy, which is associated with food and nutrition security (Alvarez et al., 2014). Given these linkages, addressing challenges of food insecurity and inequality found for farm Type 1 and 4 could start with improving education levels of women and wealth as well as its distribution. For instance, the measures mentioned above aimed at reducing pre- and post-harvest losses as well as improving education especially of women who prepare the food, would help to increase dietary diversity as well as gender equity. Social protection for the poorest and most food-insecure groups through targeted cash or input transfers can address the problems only in the short term. In the long run, value-chain issues like improved market linkages and access to resources, especially land and capital, could be addressed.

4.5. Organic agriculture in relation to farm types

The adherence to practices associated with OA was high among older and wealthier farm households, but not necessarily the more educated farm household heads. Jena et al. (2012) had a similar finding, which they attributed to the ability of older farmers to earn more because they were more knowledgeable and established than younger farmers. With regard to cropping practices, Type 3 farms planting mainly pure stands could be encouraged to introduce intercropping especially with legumes given the multiple benefits associated with the practice (Mucheru-Muna et al., 2010). The mixed farms in Type 2 farms that are already quite productive and economically well-endowed, as well as Type 4 farms, may need support to manage their soil due to their high usage of agrochemicals (Kuivanen et al., 2016a). Land-tenure security, which represents rights to hold, use and transact land (Adams, 2001), was of particular importance for the practice of certified OA in this study. Organic agriculture is associated with long-term investment in soil conservation measures, which is strongly linked to secure land tenure (Gebremedhin and Scott, 2003). The negative effects of insecure land tenure on soil conservation investments is widely known from the literature (Fraser, 2004; Place, 2009; Shepherd and Soule, 1998).

In Kenya, land tenure can be communal based on traditional ownership with rights to use but not to sell, private with title deeds under freehold, leasehold or government trust land (GoK, 2009). Land rights are overall quite secure in Murang'a, being based on a system of inheritance whereby parents subdivide their land between their children with allocation of title deeds (Ekbom et al., 2001; Mackenzie, 1989). Kajiado county has been evolving from a communal system of ownership to freehold (Campbell et al., 2000; Ogutu et al., 2014). Privatisation of land rights is linked to increased tenure security, which in turn provides collateral for formal credit and increases the incentive to invest in more land or inputs, which ultimately may increase productivity (Place, 2009). However, challenges to land tenure such as uncertainties regarding land rights, unequal distribution of land, and poor mechanisms for the transfer of land rights contribute to poverty and food insecurity (Radwan, 1995; Salami et al., 2010). Radwan (1995) argued that access to land and physical assets can contribute to poverty reduction in SSA. Therefore, the land reform that is already ongoing in Kenya needs to facilitate the access to land as well as tenure security to farmers, the youth and other vulnerable groups (WFP, 2016) especially in the ASAL regions of the country.

The practice of certified OA was also associated with greater access to information, strong social networks, equitable family structures and more diverse diets as well as older household heads. However, this study did not determine causal relationships between the practice of certified OA and these variables. Nonetheless, Chiputwa and Matin (2016) found that organic certification of smallholder organic coffee farmers in Uganda led to improved diets in terms of calorie intake and dietary diversity, mostly due to higher incomes and improved gender equity. They found that organic certification enhanced women empowerment through special training, awareness creation and gender mainstreaming activities encompassed in the process. Since the organic farmers in our study belonged to farm households with medium to high resource endowment, similar reasons of higher economic access enhancing dietary diversity and gender equity could apply.

Organic certification is also associated with several benefits such as access to high-value markets, increased access to credit, increased social capital through extensive training, and increased profitability and it has been reported to reduce poverty (Ayuya et al., 2015; H. R. Barrett et al., 2001b; Bolwig et al., 2009; Jena et al., 2012; Ndungu et al., 2013). However, given the high cost of certification, Barret et al. (2001a,b) argued that smallholder farmers forming groups, obtaining external funding, participating in contract schemes and in some cases seeking national rather than international certification, could help overcome this challenge. For policy makers, direct subsidies on organic inputs similar to those given for mineral fertiliser in Kenya could encourage especially poor farmers to practice OA. In Finland for instance, it was reported that converting to OA was triggered by subsidies especially for farms that had large land areas and low yields (Pietola and Lansink, 2001). Given the importance of social networks for farmer information access, smallholder farmers and the youth, even if these are not involved in farming, could benefit from becoming involved in existing groups or from forming new ones.

This study also reveals differences between the two counties in terms of how the five farm types were distributed. Kajiado was dominated by mixed conventional and organic high-resource endowed farms with quite diversified livelihood strategies (Type 2), while Murang'a was mainly dominated by certified organic farms whose livelihoods seemed to be reliant on agriculture (Type 5). Farms of Type 1 and Type 3 were equally abundant in both counties, while farms with the youngest household heads (Type 4) were mainly located in Kajiado. It was beyond the scope of this study to prove if this varying distribution of farm types is because of climatic heterogeneity. However, from the findings it is reasonable to assume that the overall greater reliance on agricultural activities and income in Murang'a is due to its higher biophysical agricultural potential. Kajiado on the other hand, being an ASAL region, is prone to erratic weather conditions including recurrent drought and floods (Campbell, 1984), and with a need for irrigation to supplement rainfall for crop cultivation. Hence, diversified livelihoods would cushion farmers against these environmental shocks.

4.6. Limitations of the study

Because of time and financial resource constraints, this study was subject to a number of limitations. A participatory approach, as recommended by Kuivanen et al. (2016b), was thus not possible. However, various informal meetings with farmers and other local stakeholders were conducted in both counties and in Nairobi. The sample size of the study also had to be limited to approximately 500 farms. In addition, the study did not capture the spatial distribution of biophysical factors, which could have helped to explain the distribution of the farm types as well as the adoption of organic farming practices based on geographical and environmental conditions. However, we decided to classify farms mainly from a socio-economic point of view and tried to include a diversity of environmental conditions through the selection of two biophysically different counties. Although typologies are useful to understand the diversity of smallholder farm households, they are limited in their ability to accurately capture every aspect of dissimilarity. In addition, this categorization is based on a one-time measurement giving a snapshot of the situation on the farms at the time the study was conducted. However, smallholder farms are dynamic and production systems can rapidly change, hence farm typologies need to be constantly updated (Alvarez et al., 2014). Nevertheless, this study endorses findings by previous farm typology studies carried out in Kenya, as well as in other countries in SSA, where similar patterns were observed. This was a cross-sectional study and its results should be interpreted with caution as it did not determine causal relationships between the variables. Finally, despite its attempts to capture climate heterogeneity, this study falls short in representing the whole diversity of Kenya's biophysical conditions.

5. Conclusions

In this study, smallholder farms in Kajiado and Murang'a counties in Kenya were characterised and classified into five distinct types. The characteristics of the farms were analysed with a focus on aspects influencing the transformation of farms to OA in the country. With regards to the first research question, a typology was found with significant differences among five farm types. The distinguishing characteristics were based on resource endowment, household-related factors, cropping practices, production orientation, social networks, information access, dietary diversity and gender equity. Wealthier smallholder farms practising both organic and non-organic (conventional or organic-by-default) agriculture dominated Kajiado while Murang'a was dominated by farms practising OA with medium to high wealth levels. Concerning the second question, farmers practising certified OA were wealthier but not necessarily better educated than those who did not, which was attributed to higher experience and greater access to productive resources unlike their younger counterparts. The practice of OA (certified and uncertified) was more likely to be found in smallholder farms that had legal land tenure rights, moderate to high income levels, especially from agricultural sources, with older household heads that were well informed with strong social networks, a large number of household members, and equitable family structures and highly diverse diets. However, this study did not determine causal relationships between these factors and the practice of OA.

The characteristics of typical farm households found in an area and identified through typology construction can form a basis for understanding current practices as well as for targeting future interventions. Programs aiming to address agricultural growth in Kajiado and Murang'a as well as in similar regions in Kenya need to take into consideration the challenges and opportunities associated with the farm types identified in this study, which are similar in many aspects to others identified by farm typology studies in the region. The significant role of resource endowment in reinforcing the cycle of imbalance through a system that benefits wealthier over poorer, older over younger or men over women farmers, suggests the need to address this inequality in order to reduce their vulnerability to different shocks and aid in wealth accumulation, which will enhance their spending power. Empowering women has been shown to translate to better diets for the household and increase their control of resources and decision-making capacity.

Based on this typology, effective pro-poor development strategies seeking to improve productivity and welfare of smallholder farms and farmers respectively should be systematically targeted. For instance, resource constrained farms in Type 1 and 4 could benefit from interventions that target access to capital particularly land, low-input technologies, high yielding and biofortified crop varieties. They could benefit from participation social networks in their communities, especially where no barriers of entry like membership fees exist, as these networks have been shown to be ideal places for information sharing. Type 5 farms could benefit from efforts towards income diversification into non- and off-farm activities, increased credit access as well as improving their literacy levels. The wealthier conventional farms in Type 2 could be encouraged to use more improved technologies, inputs and farming practices that are environmentally friendly including certified OA, and since both Type 2 and 3 are highly literate, they could benefit from more knowledge intensive technologies. Finally, Type 3 farms could be encouraged to adopt more intercropping, and assisted to gain greater access to productive resources.

Given the growing local and international markets of organic produce and the benefits associated with OA, as well as policy interest in these sector, efforts aiming promote certified OA in the study area and other parts of Kenya should also seek targeted and problem oriented strategies. For certifiers, purchasers and traders of certified products and development stakeholders, this may include local or other cost-effective certification strategy such as group certification in contract schemes or PGS systems to overcome barriers of entry to the organic market, particularly for farmers already practicing uncertified OA like some in Type 2 and 3. Increase in knowledge about OA and its benefits could also encourage farmers to adopt this practice. However, further research, particularly in studies with larger samples; including spatial distribution factors, in-depth participatory techniques and qualitative methods is needed.

Acknowledgements

The authors would like to thank the Right Livelihood College (RLC) Campus Bonn Program, the German Academic Exchange Service (DAAD) and the Dr. Hermann Eiselen Doctoral Program of the Foundation *fiat panis* for providing the funds for this research. The authors' gratitude extends to the International Centre for Insect Physiology and Ecology (*icipe*) and Dr. Hippolyte Affognon (formerly of *icipe*, now with the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Mali) for providing guidance and a base from which the fieldwork was conducted. Finally, the authors would like to thank Guido Lüchters of the Centre for Development Research, Bonn, for his valuable guidance in data analysis.

Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.jrurstud.2017.12.014.

References

Adams, M., 2001. Tenure security, livelihoods and sustainable land use in Southern Africa. In: SARPN Conference on Land Reform and Poverty Alleviation in Southern Africa 4th and 5th June.

African Union, 2011 African Union, 2011. Decision on Organic Farming. Doc. EX.CL/631 (XVIII). Executive Council- 'Eighteenth Ordinary Session 24–28 January 2011. Ethiopia, Addis Ababa The document is available online at: http://www.au.int/en/sites/default/files/decisions/9646-council_en_24_28_january_2011_executive_council_eighteenth_ordinary_session.pdf.

Altieri, M.A., 2009. Agroecology, small farms, and food sovereignty. Mon. Rev. 61, 102.
Alvarez, S., Paas, W., Descheemaeker, K., Tittonell, P., Groot, J., 2014. Typology Construction, a Way of Dealing with Farm Diversity: General Guidelines for Humidtropics.
Amudavi, D.M., Ombati, J.M., Nkurumwa, A.O., Ngigi, M., others, 2014. Technical, economic and social gaps and information needs among smallholder farmers in practice of ecological organic agriculture in Kenya. Int. J. Agric. Innov. Res. 3, 198–209.
Ayuya, O.I., Gido, E.O., Bett, H.K., Lagat, J.K., Kahi, A.K., Bauer, S., 2015. Effect of certified organic production systems on poverty among smallholder farmers: empirical evidence from Kenya. World Dev. 67, 27–37. https://doi.org/10.1016/j.worlddev.2014.10.005.
Badgley, C., Moghtader, J., Quintero, E., Zakem, E., Chappell, M.J., Avilés-Vázquez, K., Samulon, A., Perfecto, I., 2007. Organic agriculture and the global food supply. Renew. Agric. Food Syst. 22, 86–108. https://doi.org/10.1017/S1742170507001640.
Barrett, C.B., Reardon, T., Webb, P., 2001a. Nonfarm income diversification and household livelihood strategies in rural Africa: concepts, dynamics, and policy implications. Food Pol. 26, 315–331.
Barrett, H.R., Browne, A.W., Harris, P.J.C., Cadoret, K., 2001b. Smallholder farmers and organic certification: accessing the EU market from the developing world. Biol. Agric. Hortic. (BAH) 19, 183–199.
Bennett, M., Franzel, S., 2013. Can organic and resource-conserving agriculture improve livelihoods? A synthesis. Int. J. Agric. Sustain. 11, 193–215. https://doi.org/10.1080/14735903.2012.724925.
Bett, K.E., Freyer, B., 2007. Recognizing and Realizing the Potential of Organic Agriculture in Kenya.
Bidogeza, J.C., Berentsen, P.B.M., De Graaff, J., Oude Lansink, A.G.J.M., 2009. A typology of farm households for the Umutara Province in Rwanda. Food Struct. 1, 321–335. https://doi.org/10.1007/s12571-009-0029-8.
Bolwig, S., Gibbon, P., Jones, S., 2009. The economics of smallholder organic contract farming in tropical Africa. World Dev. 37, 1094–1104. https://doi.org/10.1016/j.worlddev.2008.09.012.
Campbell, D.J., 1984. Response to drought among farmers and herders in southern Kajiado district, Kenya. Hum. Ecol. 12, 35–64.
Campbell, D.J., Gichohi, H., Mwangi, A., Chege, L., 2000. Land use conflict in Kajiado district, Kenya. Land Use Pol. 17, 337–348. https://doi.org/10.1016/S0264-8377(00)00038-7.
Chikowo, R., Zingore, S., Snapp, S., Johnston, A., 2014. Farm typologies, soil fertility variability and nutrient management in smallholder farming in Sub-Saharan Africa. Nutrient Cycl. Agroecosyst. 100, 1–18. https://doi.org/10.1007/s10705-014-9632-y.
Chiputwa, B., Matin, Q., 2016. Sustainability standards, gender, and nutrition among smallholder farmers in Uganda. J. Dev. Stud. 1–17.
Davis, B., Di Giuseppe, S., Zezza, A., 2017. Are African households (not) leaving agriculture? Patterns of households' income sources in rural Sub-Saharan Africa. Food Policy. Agriculture in Africa – Telling Myths from Facts 67, 153–174. https://doi.org/10.1016/j.foodpol.2016.09.018.
Dethier, J.-J., Effenberger, A., 2012. Agriculture and development: a brief review of the literature. Econ. Syst. 36, 175–205. https://doi.org/10.1016/j.ecosys.2011.09.003.
Duvernoy, I., 2000. Use of a land cover model to identify farm types in the Misiones agrarian frontier (Argentina). Agric. Syst. 64, 137–149.
Ekbom, A., Knutsson, P., Ovuka, M., 2001. Is sustainable development based on agriculture attainable in Kenya? A multidisciplinary case study of Murang'a district. Land Degrad. Dev. 12, 435–447. https://doi.org/10.1002/ldr.460.
Field, A., 2011. Discovering Statistics Using SPSS: (And Sex and Drugs and Rock "n" Roll), 3. ed., reprinted. ed. Sage, Los Angeles, Calif (2011).
Fischer, E., Qaim, M., 2012. Linking smallholders to markets: determinants and impacts of farmer collective action in Kenya. World Dev. 40, 1255–1268. https://doi.org/10.1016/j.worlddev.2011.11.018.
Fraser, E.D., 2004. Land tenure and agricultural management: soil conservation on rented and owned fields in southwest British Columbia. Agric. Hum. Val. 21, 73–79.
GADM, 2015. GADM Database of Global Administrative Areas: Version 3.
Gebremedhin, B., Scott, M.S., 2003. Investment in soil conservation in northern Ethiopia: the role of land tenure security and public programs. Agric. Econ. 29, 69–84. https://doi.org/10.1016/S0169-5150(03)00022-7.
Giller, K.E., Tittonell, P., Rufino, M.C., van Wijk, M.T., Zingore, S., Mapfumo, P., Adjei-Nsiah, S., Herrero, M., Chikowo, R., Corbeels, M., Rowe, E.C., Baijukya, F., Mwijage, A., Smith, J., Yeboah, E., van der Burg, W.J., Sanogo, O.M., Misiko, M., de Ridder, N., Karanja, S., Kaizzi, C., K'ungu, J., Mwale, M., Nwaga, D., Pacini, C., Vanlauwe, B., 2011. Communicating complexity: integrated assessment of trade-offs concerning soil fertility management within African farming systems to support innovation and development. Agric. Syst. 104, 191–203. https://doi.org/10.1016/j.agsy.2010.07.002.
GoK, 2009. Agricultural sector development strategy (ASDS), 2009-2020.
Hair, J.F., Black, W.C., Babin, B.J., Anderson, R.E., Tatham, R.L., 2010. Multivariate Data Analysis, (seventh ed.s.), seventh ed. Pearson, NY.
Hartung, C., Lerer, A., Anokwa, Y., Tseng, C., Brunette, W., Borriello, G., 2010. Open data kit: tools to build information services for developing regions. In: Proceedings of the 4th ACM/IEEE International Conference on Information and Communication Technologies and Development. ACM, pp. 18.
IFOAM, 2013. Productivity and Profitability of Organic Farming Systems in East Africa.
ILO, 2016. labour organisation. Kenya Decent Work Country Programme 2013-2016. International.
Jahnke, H.E., 1982. Livestock Production Systems and Livestock Development in Tropical Africa. Wiss. Verl. Vauk, Kiel.
Jena, P.R., Stellmacher, T., Grote, U., others, 2012. The impact of coffee certification on small-scale producers' livelihoods: evidence from Ethiopia. In: Presentation at the International Association of Agricultural Economists (IAAE) Triennial Conference. Foz Do Iguaçu, Brazil, pp. 18–24.
Katto Andrighetto, 2013. Participatory Guarantee Systems in East Africa: Case Studies from Kenya, Tanzania and Uganda.
KCDP, 2013. Kajiado County Integrated Development Plan 2013–2017.
Kennedy, G., Ballard, T., Dop, M.C., 2011. Guidelines for Measuring Household and Individual Dietary Diversity. Food and Agriculture Organization of the United Nations, Rome.
Köbrich, C., Rehman, T., Khan, M., 2003. Typification of farming systems for constructing representative farm models: two illustrations of the application of multi-variate analyses in Chile and Pakistan. Agric. Syst. 76, 141–157.
Kostrowicki, J., 1977. Agricultural typology concept and method. Agric. Syst. 2, 33–45.
Krishna, A., Kristjanson, P., Radeny, M., Nindo, W., 2004. Escaping poverty and becoming poor in 20 kenyan villages. J. Hum. Dev. 5, 211–226. https://doi.org/10.1080/1464988042000225131.
Kuivanen, K.S., Alvarez, S., Michalscheck, M., Adjei-Nsiah, S., Descheemaeker, K., Mellon-Bedi, S., Groot, J.C.J., 2016a. Characterising the diversity of smallholder farming systems and their constraints and opportunities for innovation: a case study from the Northern Region, Ghana. NJAS - Wagening. J. Life Sci. 78, 153–166. https://doi.org/10.1016/j.njas.2016.04.003.
Kuivanen, K.S., Michalscheck, M., Descheemaeker, K., Adjei-Nsiah, S., Mellon-Bedi, S., Groot, J.C.J., Alvarez, S., 2016b. A comparison of statistical and participatory clustering of smallholder farming systems – a case study in Northern Ghana. J. Rural Stud. 45, 184–198. https://doi.org/10.1016/j.jrurstud.2016.03.015.
Mackenzie, F., 1989. Land and territory: the interface between two systems of land tenure, Murang'a district, Kenya. Afr. J. Int. Afr. Inst 59, 91–109. https://doi.org/10.2307/1160765.
Mangin, B., Siberchicot, A., Nicolas, S., Doligez, A., This, P., Cierco-Ayrolles, C., 2012. Novel measures of linkage disequilibrium that correct the bias due to population structure and relatedness. Heredity 108, 285–291.
Marenya, P.P., Barrett, C.B., 2007. Household-level determinants of adoption of improved natural resources management practices among smallholder farmers in western Kenya. Food Pol. 32, 515–536. https://doi.org/10.1016/j.foodpol.2006.10.002.
Maumbe, B.M., 2010. International Journal of ICT Research and Development in Africa: an Official Publication of the Information Resources Management Association. v. 1, no. 1, January-March 2010.
MCDP, 2013. Murang'a County Integrated Development Plan 2013–2017.
Mucheru-Muna, M., Pypers, P., Mugendi, D., Kung'u, J., Mugwe, J., Merckx, R., Vanlauwe, B., 2010. A staggered maize–legume intercrop arrangement robustly increases crop yields and economic returns in the highlands of Central Kenya. Field Crop. Res. 115, 132–139. https://doi.org/10.1016/j.fcr.2009.10.013.
Mutoko, M.C., Hein, L., Shisanya, C.A., 2014. Farm diversity, resource use efficiency and sustainable land management in the western highlands of Kenya. J. Rural Stud. 36, 108–120. https://doi.org/10.1016/j.jrurstud.2014.07.006.
Ndukhu, O., Onwonga, N., Wahome, G., Kironchi, G., Jensen, H., 2016. Assessment of organic farmers' knowledge and adaptation strategies to climate change and variability in Central Kenya. Br. J. Appl. Sci. Technol. 17, 1–22. https://doi.org/10.9734/BJAST/2016/16270.
Ndungu, S.K., Macharia, I., Kahuthia-Gathu, R., Wahome, R.G., 2013. Impact of organic vegetable production system in kiambu and Kajiado counties of Kenya. J. Environ. Sci. Eng. 2, 256.
Ng'endo, M., Bhagwat, S., Keding, G.B., 2016. Influence of seasonal on-farm diversity on dietary diversity: a case study of smallholder farming households in western Kenya. Ecol. Food Nutr. 55, 403–427. https://doi.org/10.1080/03670244.2016.1200037.
Niggli, U., Willer, H., Baker, B., 2016. A Global Vision and Strategy for Organic Farming Research.
Njenga, P.K., Mugo, F., Opiyo, R., 2011. Youth and Women Empowerment through Agriculture in Kenya. VSO Jitolee.
Ogutu, J.O., Piepho, H.-P., Said, M.Y., Kifugo, S.C., 2014. Herbivore dynamics and range contraction in Kajiado County Kenya: climate and land use changes, population pressures, governance, policy and human-wildlife conflicts. Open Ecol. J. 7.
Omondi, S.P., Kidali, J.A., Ogali, I., Mugambi, J.M., Letoire, J., 2014. The status of livestock technologies and services in the Southern Maasai rangelands of Kenya. Afr. J. Agric. Res. 9, 1166–1171.
Pacini, G.C., Colucci, D., Baudron, F., Righi, E., Corbeels, M., Tittonell, P., Stefanini, F.M., 2014. Combining multi-dimensional scaling and cluster analysis to describe the diversity of rural households. Exp. Agric. 50, 376–397. https://doi.org/10.1017/S0014479713000495.
Pietola, K.S., Lansink, A.O., 2001. Farmer response to policies promoting organic farming technologies in Finland. Eur. Rev. Agric. Econ. 28, 1–15. https://doi.org/10.1093/erae/28.1.1.
Place, F., 2009. Land tenure and agricultural productivity in Africa: a comparative analysis of the economics literature and recent policy strategies and reforms. World Dev., The Limits of State-Led Land Reform 37, 1326–1336. https://doi.org/10.1016/j.worlddev.2008.08.020.
Radwan, S., 1995. Challenges and scope for an employment-intensive growth strategy, in: employment for poverty reduction and food security. Intl Food Policy Res Inst 21–45.
R Core Team, 2014. R: A Language and Environment for Statistical Computing.
Rees, D., Momanyi, M., Wekundah, J., Ndungu, F., Odondi, J., Oyure, A.O., Andima, D., Kamau, M., Ndubi, J., Musembi, F., 2000. Agricultural Knowledge and Information Systems in Kenya: Implications for Technology Dissemination and Development. Overseas Development Institute (ODI). Agricultural Research & Extension Network (AgREN).
Sakané, N., Becker, M., Langensiepen, M., van Wijk, M.T., 2013. Typology of smallholder production systems in small east-african wetlands. Wetlands 33, 101–116. https://doi.org/10.1007/s13157-012-0355-z.

Salami, A., Kamara, A.B., Brixiova, Z., 2010. Smallholder Agriculture in East Africa: Trends, Constraints and Opportunities. African Development Bank, Tunis.
Schwindenhammer, S., 2016. Authority pooling and regional organic agriculture standard-setting: evidence from East Africa. J. Environ. Pol. Plann. 18, 102–120. https://doi.org/10.1080/1523908X.2015.1053109.
Shepherd, K.D., Soule, M.J., 1998. Soil fertility management in west Kenya: dynamic simulation of productivity, profitability and sustainability at different resource endowment levels. Agric. Ecosyst. Environ. 71, 131–145.
Signorelli, S., 2016. Typology Characterization of Farmers in West Africa.
Sombroek, W.G., Braun, H.M., Van der Pouw, B.J., 1982. Exploratory Soil Map and Agro-climatic Zone Map of Kenya, 1980. Scale 1: 1,000,000. Kenya Soil Survey, Kenya.
StataCorp, 2015. Stata Statistical Software: Release 14.
Stevens, J., 2002. Applied Multivariate Statistics for the Social Sciences, fourth ed. NJ, Erlbaum., Hillsdale.
Thuo, M., Bell, A.A., Bravo-Ureta, B.E., Lachaud, M.A., Okello, D.K., Okoko, E.N., Kidula, N.L., Deom, C.M., Puppala, N., 2014. Effects of social network factors on information acquisition and adoption of improved groundnut varieties: the case of Uganda and Kenya. Agric. Hum. Val. 31, 339–353. https://doi.org/10.1007/s10460-014-9486-6.
Tittonell, P., Giller, K.E., 2013. When yield gaps are poverty traps: the paradigm of ecological intensification in African smallholder agriculture. Field Crop. Res. 143, 76–90. https://doi.org/10.1016/j.fcr.2012.10.007.
Tittonell, P., Muriuki, A., Shepherd, K.D., Mugendi, D., Kaizzi, K.C., Okeyo, J., Verchot, L., Coe, R., Vanlauwe, B., 2010. The diversity of rural livelihoods and their influence on soil fertility in agricultural systems of East Africa – a typology of smallholder farms. Agric. Syst. 103, 83–97. https://doi.org/10.1016/j.agsy.2009.10.001.
Tittonell, P., Vanlauwe, B., Leffelaar, P.A., Rowe, E.C., Giller, K.E., 2005a. Exploring diversity in soil fertility management of smallholder farms in western Kenya: I. Heterogeneity at region and farm scale. Agric. Ecosyst. Environ. 110, 149–165. https://doi.org/10.1016/j.agee.2005.04.001.
Tittonell, P., Vanlauwe, B., Leffelaar, P.A., Shepherd, K.D., Giller, K.E., 2005b. Exploring diversity in soil fertility management of smallholder farms in western Kenya: II. Within-farm variability in resource allocation, nutrient flows and soil fertility status. Agric. Ecosyst. Environ. 110, 166–184. https://doi.org/10.1016/j.agee.2005.04.003.
UN General Assembly, 2014. Open Working Group Proposal for Sustainable Development Goals. United Nations General Assembly, Geneva.
Valbuena, D., Verburg, P.H., Bregt, A.K., 2008. A method to define a typology for agent-based analysis in regional land-use research. Agric. Ecosyst. Environ. 128, 27–36. https://doi.org/10.1016/j.agee.2008.04.015.
van de Steeg, J.A., Verburg, P.H., Baltenweck, I., Staal, S.J., 2010. Characterization of the spatial distribution of farming systems in the Kenyan Highlands. Appl. Geogr. 30, 239–253. https://doi.org/10.1016/j.apgeog.2009.05.005.
von Braun, J., 2010. Food insecurity, hunger and malnutrition: necessary policy and technology changes. N. Biotech. 27, 449–452. https://doi.org/10.1016/j.nbt.2010.08.006.
Ward, J.H., 1963. Hierarchical grouping to optimize an objective function. J. Am. Stat. Assoc. 58 (236). https://doi.org/10.2307/2282967.
WFP, 2016. Comprehensive Food Security and Vulnerability Survey: Summary Report Kenya.