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A holistic sustainability assessment of organic (certified and non-certified) and non-organic smallholder farms in Kenya

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Abstract

The introduction of organic farm management practices in sub-Saharan Africa could act as a lever for supporting regional sustainable development. In this study, we sought to assess the sustainability performance of organic (certified and non-certified) and non-organic farms in the dry Kajiado County and the wet Murang'a County in Kenya, based on four sustainability dimensions: *Good Governance*, *Environmental Integrity*, *Economic Resilience* and *Social Well-Being*. We collected household survey data from 400 smallholder farms, which were formally characterized into five types (mixed organic and conventional, certified organic, organic, conventional, and subsistence farms). We used multivariate analysis of variance, linear fixed-effects and general linear models to examine differences in sustainability performance. Model results indicate that all farms lack reliable farm management information and that only limited knowledge, skills and social security exist for farmers and farm workers. Comparison of the five farm types indicates no significant differences in their sustainability performance. Nonetheless, certified organic farms had better sustainability performance than non-certified farms due to higher economic resilience, environmental integrity, better support and training for workers. However, except for avoiding the use of agrochemicals in certified farms, there is relatively little difference in the farm management practices across farm types. Our results also indicate that farms in Murang'a were more sustainable than those in Kajiado due to better regional land-tenure security and conflict resolution mechanisms, soil and water conservation measures, and farm commercial viability. Nonetheless, unlike Kajiado, farms in Murang'a showed a tendency toward poor animal husbandry practices which affects overall animal welfare, limited credit uptake and market involvement. The results of this study can support decision making to identify appropriate interventions for improving sustainability in smallholder farms.

Keywords SAFA guidelines · Organic agriculture · Sub-Saharan Africa · Certification · Indicators

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1 Introduction

Agriculture, mainly practiced by rural smallholder farmers, is still the mainstay of most people in sub-Saharan Africa (SSA), and the main driver of socio-economic development (Altieri, 2009; Davis et al., 2017; Salami et al., 2010). Consequently, sustainable agriculture has been identified as a crucial element for promoting sustainable development in SSA (Conceição et al., 2016; Grenz et al., 2009). Smallholder farms, defined by landholding size, constitute the majority of farms in the world, and in SSA around 50% of the smallholders (i.e. cultivating up to 2 ha), live in absolute poverty, despite being primary food producers and managers of natural resources (Altieri, 2009; Salami et al., 2010; Samberg et al., 2016). This study focuses on Kenya where over a third of the population depends on agriculture to sustain their livelihood, and nearly half of the population lives in poverty and is food insecure (GoK, 2009; WFP, 2016).

Supporting smallholder farmers in Kenya and other SSA countries is considered a crucial part of the strategies addressing natural resource depletion and degradation, decreasing agricultural productivity, food insecurity, poverty, and for adapting to population growth, climate change, urbanization and land-use change (De Jager et al., 2001; Giller et al., 2009). However, at present, given the socio-economic, demographic and ecologic constraints, smallholder farms in SSA are showing a tendency toward unsustainable practices (Cohn et al., 2017; Salami et al., 2010).

In the attempt to achieve the United Nations Sustainable Development Goals (SDGs) (UN General Assembly, 2014), smallholder farmers are expected to play an important role through their agricultural and land-use practices (Conceição et al., 2016; Grenz et al., 2009). The definition of sustainable development (used here interchangeably with the term 'sustainability') is generally agreed to be based on three key dimensions: environmental, economic and social (Keeble, 1988; Pretty, 1995; Schaller, 1993). We use the sustainability definition from the guidelines for Sustainability Assessment of Food and Agriculture Systems (SAFA Guidelines) by the Food and Agriculture Organization of the United Nations (FAO) (FAO, 2014), which includes the fourth dimension of good governance (Schader et al., 2016).

1.1 Organic agriculture in sub-Saharan Africa

Organic agriculture (OA) is being promoted as a sustainable farming system in SSA through the "Ecological Organic Agriculture" (EOA) initiative of the African Union (Niggli et al., 2016). Organic smallholder farms in SSA countries can be grouped into certified organic, organic non-certified and mixed organic-conventional. Non-organic farms include conventional and low-input–output systems with no use of agrochemicals at all. The latter are often described as 'organic by default' (Bennett & Franzel, 2013). Certified organic farmers market their products based on standards of international or national certification schemes that follow the general rules of OA. The non-certified organic farmers adhere to many organic principles but are not formally certified as OA (Badgley et al., 2007).

In addition to being promoted by the African Union and other non-state entities, the rise of OA in Africa is being driven by an increasing demand for organically produced products in developed countries. There is also a growing demand for these products in Africa driven by changing local consumer preferences as their living standards improve and concerns about food safety issues grow.

In Kenya, the practice of organic agriculture has gained popularity, triggered by growing demand in organic products in the region as well as internationally. There is also an established regional certification standard in the region called the East Africa Organic Product Standard (EAOPS) (Ayuya et al., 2015; Ndukhu et al., 2016; Schwindenhammer, 2016). Kenyan farmers can grow organic produce through contractual agreements with private companies that facilitate certification and export of the produce. Farmers can also organize themselves in groups such as participatory guarantee systems (PGS) that are supported by local organic initiatives like the Kenya Organic Agriculture Network (KOAN) to get certified. The produce by PGS farmers is mainly sold in local or neighbouring markets, such as the East African region. The products destined for international markets are mainly high value crops like coffee, tea, fruits, nuts and herbs. For the local Kenyan or regional East African market, there is a wide variety of crop and animal products sold including honey, eggs, cereals, vegetables and root tubers (Ayuya et al., 2015; Katto-Andrighetto, 2013; Schwindenhammer, 2016).

Organic and other agricultural certification schemes usually attempt to increase sustainability (Raynolds et al., 2007) by following specific regulations such as those prohibiting the use of chemically treated planting material, genetically modified organisms (GMOs), synthetic fertilizers and pesticides as well as non-organically produced feed and prophylactic use of antibiotics for livestock.

On the one hand, the sustainability of OA is contested. For instance, OA is criticized for generating lower yields, which can translate into lower profitability and inadequate food production compared to conventional agriculture (Meemken & Qaim, 2018). On the other hand, OA has been credited for its potential to increase biodiversity and to improve soil and water quality among other social and ecological benefits (Kamau et al., 2019; Muller et al., 2017). In SSA, organic certification has been found to improve profitability, increase social capital, reduce poverty and improve standards of living (Ayuya et al., 2015; Bolwig et al., 2009; Ndungu et al., 2013). Due to the divergent views on the sustainability of OA in science and practice, better insight into the potential of OA practices in contributing to sustainable development in SSA is needed.

1.2 Agricultural approaches to sustainable development: sustainability assessments and tools

Sustainability assessments based on comprehensive frameworks can support decision making by indicating ways to decrease the negative impacts of agriculture on natural ecosystems, to improve food security and to reduce poverty (Angevin et al., 2017; de Olde et al., 2016). Indicators used in sustainability assessments and tools based on these indicators vary widely in purpose (e.g. research, extension, policy and planning), assessment level (e.g. product/supply chain, farm), dimension (e.g. environmental and/or economic and/or social), intended user, assessment approach (e.g. self-assessment, external auditor), and specificity level (e.g. sector, country or region specific) (de Olde et al., 2016; Schader et al., 2014). Due to this diversity in assessment tools, comparability of data and results is challenging. Although one-size-fits-all solutions are not possible, there is a consensus regarding the need for harmonizing approaches, criteria and indicator sets to enhance the comparability of different sustainability assessment methods (Dantsis et al., 2010; Sachs et al., 2010).

Several frameworks have been developed and used as a basis for selecting indicators to assess sustainability. In agricultural systems for example, the SAFA Guidelines by the

FAO (2014) and the Sustainability Assessment of Farming and the Environment Framework (Van Cauwenbergh et al., 2007) have been used. Further tools and approaches include the Life Cycle Sustainability Assessment (LSCA) (Guinée et al., 2011), and the Response-Inducing Sustainability Evaluation (RISE) (Schader et al., 2014). More tools for sustainability assessment are well documented in literature and their number is rising (Arulnathan et al., 2020; Schader et al., 2014).

The divergent definitions of sustainability, dimensions and indicators in studies of sustainability in smallholder farming in Kenya limits the comparability of their results and conclusions. Sustainability assessments of smallholder farms in Kenya are often based on varying aspects, (sub-) themes and indicators (De Jager et al., 2001; Grenz et al., 2009; Nzila et al., 2012; Onduru & Du Preez, 2008; Shepherd & Soule, 1998; Spaling et al., 2011). For instance, a study comparing low external input and organic management systems to those of conventional smallholders in Machakos County, eastern Kenya, a relatively dry region, used indicators related to environmental and economic aspects of sustainability (De Jager et al., 2001). Other studies in Embu County, also in eastern Kenya (Onduru & Du Preez, 2008), as well as in a relatively humid area in Laikipia County, central Kenya (Grenz et al., 2009), used indicators based on the three main dimensions of sustainability (environmental, economic and social).

In this study, we seek to close the gap in sustainability assessments by demonstrating a comprehensive approach to produce nationally and internationally comparable results along food and agricultural value chains following the SAFA guidelines (FAO, 2014). Additionally, we seek to assess the sustainability of organic and non-organic smallholder farms in two biophysically different counties in Kenya.

Our study was intended to answer the following research questions: (1) What are the characteristic patterns and features of the sustainability performance of Kenyan smallholder farms? (2) Do differences exist in the sustainability performance of smallholder farms practicing organic (certified or non-certified) compared to non-organic (i.e. conventional or low-input 'organic by default') farm management? (3) Do differences exist in sustainability performance between the two biophysically distinct Kenyan counties? We present a farm-level assessment of sustainability in two representative regions in Kenya. Most of the content of this paper is also part of a doctoral thesis (Kamau, 2018).

2 Materials and methods

2.1 Study area

We sought to assess the sustainability of Kenyan smallholder farms while taking into account the heterogeneity of the farms and biophysical differences (e.g. climate and soils), which is recommended in the assessment of agricultural sustainability (Chopin et al., 2017). We chose two counties to represent distinct climatic classifications in Kenya. The first was semi-arid land (ASAL) receiving between 150 and 1100 mm of rainfall annually and represents 80% of the land in Kenya. For this, we chose Kajiado County in south-western Kenya in the ASAL region. The main livelihood activities in Kajiado are pastoralism, conservation of wildlife and crop farming (KCDP, 2013). The certified organic farmers surveyed in Kajiado are members of PGS groups supported by KOAN. These farmers sell their produce at local markets for the prevailing prices, or at premium prices in coordinated markets in Nairobi or other areas within East Africa.

The second category is humid and semi-humid regions receiving between 600 and 2700 mm of rainfall annually. Murang'a County in central Kenya is found in the humid to semi-humid region. The main livelihood activities are crop farming and animal husbandry (MCDP, 2013). The certified organic farms in this county are usually third-party certified by organizations such as the Swiss IMO and others. Certification is regulated through contracts with private companies that obtain and market the farms' produce. These companies pay for the certification costs and facilitate the transformation of the farm through farmer training, hiring labour for harvesting, and marketing the farmers' products at a premium prices (Kamau, 2018; Kamau et al., 2018).

2.2 General approach to the selection of farm and study area

In this study, we applied a typology of smallholder farms (Kamau et al., 2018) that captures farm heterogeneity based on structural, functional and socio-economic aspects. The typology includes five farm types, which can be described as; self-subsistence farms (Type 1), mixed organic and conventional (Type 2), organic non-certified (Type 3), conventional (Type 4), and certified organic (Type 5) (see Table 1). To further study if there was any effect of organic certification, we grouped the farms that were known to be certified organic and compared them to the rest of the farms (i.e. organic non-certified, conventional, mixed and the low-input 'organic-by-default' farms.

We used the results of a multi-stage sampling procedure that had been applied to select the study areas and farms (Kamau et al., 2018) with a sampling frame provided by the agriculture departments of each county. In addition, the national organic initiative KOAN linked us to their local contacts who issued lists of smallholder farmers that were registered with them. Using the Probability Proportional to Size (PPS) sampling procedure (Skinner, 2016), ~33% certified organic farms ($n = 180$) and ~66% non-certified farms ($n = 345$) had been randomly selected for the earlier study (see Kamau et al., (2018) for details). In the present study, about the same ratio of certified organic ($n = 120$) to non-certified farms ($n = 280$) from the Kamau et al., (2018) were sampled. Of the 400 smallholder farms sampled, 211 were in Murang'a, of which ~38% were certified organic, and 189 were in to Kajiado, with ~21% certified organic.

2.3 SAFA guidelines and SMART-farm tool

In this study, we investigated the aspect of sustainability performance based on the SAFA Guidelines that consider four dimensions of sustainability: *Environmental Integrity*, *Economic Resilience*, *Social Well-Being* and *Good Governance*. These four dimensions consist of a total of 21 themes and 58 subthemes. Each subtheme has defined objectives meant to assess the sustainability of operators in the agricultural and food value chain (FAO, 2014), (Fig. 1).

We used the Sustainability Monitoring and Assessment RouTine (SMART)-Farm Tool, which operationalizes the SAFA Guidelines following a similar ordered format of dimensions, themes and subthemes. The tool utilizes an impact matrix with 327 indicators of sustainability. In this matrix, the indicators have 1769 interconnections with the 58 subthemes (Schader et al., 2016). The impact matrix is used to compute the degree of sustainability achievement and measures the degree of goal achievement for each sustainability subtheme described in the SAFA Guidelines on the basis of multi-criteria assessments. Results are normalized to percentage scores ranging from 0 to 100% indicating

Table 1 Characteristics of farms and share of different farm types in Murang'a and Kajiado counties in Kenya

Farm type	Definition of farm type	Share	Household related	Resource endowment	Social networks and information	Development outcome variables
Type 1: Subsistence farms	Poorest, organic-by-default self-subsistence oriented	13%	Small Middle-aged heads of household Less educated heads of household	Low Least land, assets and livestock owned No credit access Lowest income Based on family labour	Weakest social networks Least access to information	Poorest diets Most inequitable
Type 2 mixed organic and conventional	Wealthiest, mixed (organic and conventional) and market oriented	31%	Most educated and literate heads of household	High Based on hired labour Ample off-farm activities Large size of rented land Highest credit access Highest income	Strongest social networks High access to information	Richest diets Equitable households
Type 3 Organic non-certified	Moderately wealthy, mainly organic and market oriented	22%	Highly literate heads of household	Medium Smaller land sizes owned and rented	Strong social networks Highest access to information	
Type 4 Conventional	Poor, mainly conventional and market oriented	9%	Youngest heads of household	Low to medium Rely on rental land Moderate asset ownership Low remittance and pension income	Weakest social networks Poor access to information	Less diverse diets
Type 5 Certified organic	Wealthy, mainly certified organic and market oriented	25%	Oldest heads of household Least educated and literate heads of household Largest families	High to medium Largest farm sizes owned No credit access Few assets and livestock owned High farm income Limited off-farm activities		Moderately diverse diets Highly equitable

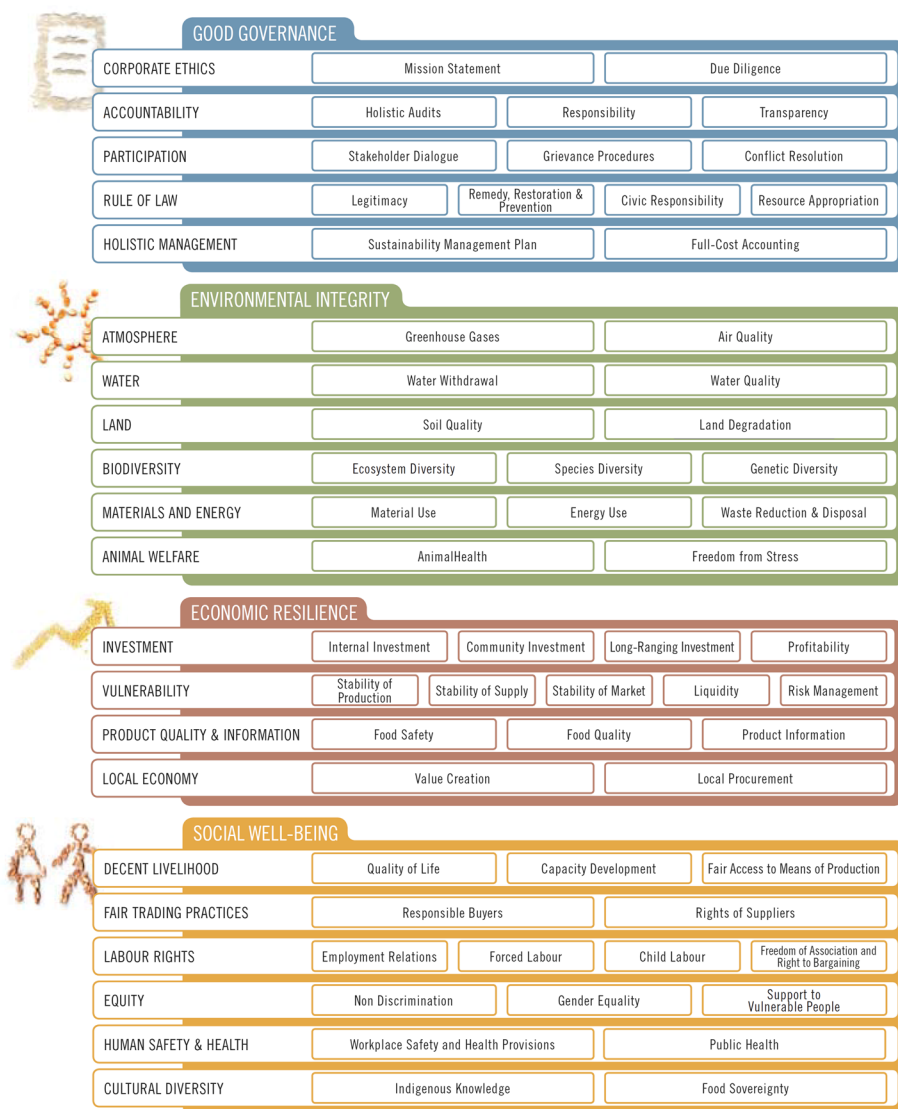*Farm types: Adapted from the farm typology (Kamau et al., 2018)

Fig. 1 Outline of dimensions, themes and subthemes from the guidelines for Sustainability Assessment of Food and Agriculture Systems (SAFA). *Source*: Food and Agriculture Organization of the United Nations (FAO) 2014

worst and best performance, respectively. A relevance check is integrated into the tool to enable automatic selection of relevant indicators for standardizing the questionnaire and thus ensuring comparability between different regions (e.g. temperate, tropical), farm sizes (e.g. large, medium, smallholder) and specific farming systems or components (e.g. crop farming, livestock, arable farming, pesticide or fertilizer use, and labour). Each indicator has a weight on a certain subtheme. These weights are expressed on a scale of −100% to +100% indicating the size of the negative or positive impact of a specified indicator on a

subtheme. The impacts of each indicator in relation to a subtheme were predefined, and experts estimated their magnitude/weight in a Delphi process.

To combine the performance of the different indicators, we aggregated the outcome of the indicator scores up to the subtheme level using a weighted sum algorithm. The sum of the performance rating of respective indicators in relation to the sum of impact weights of respective indicators provides the sustainability score at the subtheme level and is termed as degree of goal achievement (Eq. 1).

$$\mathrm{DGA}_{ix} = \sum_{n=1}^{N}(|\mathrm{IM}_{ni}| \times \mathrm{IS}_{nx})/\sum_{n=1}^{N}(|\mathrm{IM}_{ni}| \times \mathrm{IS}\ \max_{n})\forall\quad i\ \mathrm{and}\ x \tag{1}$$

where DGA_{ix} is the degree of goal achievement of a farm x with respect to a subtheme i; IM_{ni} is the impact weight of indicators n ($n=1$ to N) that are relevant to the subtheme i; IS_{nx} is the performance of a farm x in relation to an indicator n; ISmax_n is the maximum possible performance of an indicator n. The tool generates sustainability reports for each farm (Schader et al., 2016).

To determine the performance of each farm in relation to each relevant indicator and with respect to a given subtheme, we calculated the *RIi* value according to Eq. 2:

$$\mathrm{RI}_i = (|\mathrm{IM}_{ni}| \times \mathrm{IS}_{nx})\forall\quad i\ \mathrm{and}\ x \tag{2}$$

where RI_i is impact rating representing the product of IM_{ni} and IS_{nx}. The *RI* value helped us to understand which indicators contributed to poor performance or large differences in the performance of the subthemes.

2.4 Application of SMART-Farm Tool in data gathering and analysis

The collection of data for this study started in May and ended in June 2016 using the SMART-Farm Tool questionnaire (Version 4.0). Previous to the start of the fieldwork, we chose a group of eight auditors from various institutions in academia and farm extension. All had an agronomic background and no prior knowledge of the SMART-Farm Tool. Together we did a two-week extensive theoretical and practical training program on, the SAFA Guidelines, sustainability assessments, and the process of assessing a farm. We also performed pre-tests and a relevance check of the SMART-Farm Tool questionnaire on a few farms to assist in the interpretation of indicators. Based on the relevance check, between 284 and 318 indicators (from the SMART-Farm Tool pool of 327) were found to be relevant and applied for the sample farms.

We began each farm visit with an introduction by the auditors during which general data about the farm was collected. We followed this with a tour of the farm and concluded with a follow-up interview session. The interview was used to additionally verify and check the plausibility of the observations. To reduce the risk of interviewee fatigue, the interview was punctuated by breaks.

We reviewed the questionnaires to ensure that the interviews were exhaustive and the indicators had been assessed correctly and discussed any inconsistencies or gaps in rating indicators. We followed up and edited where necessary. We also carried out plausibility checks on selected indicators that had divergent responses with the help of an experienced external auditor. In cases where data points were not plausible, the respective auditor was asked to clarify, and if there were data errors, to directly correct them. The SMART-Farm Tool automatically calculated the sustainability performance per subtheme, i.e. *DGA*$_{ix}$

degree of goal achievement. These scores were then analysed further as discussed in the following section.

2.5 Output of SMART-farm tool analyses

This study uses the term 'farm type/s' to refer to the five categories or types of farms identified in the previous study. A distinction is also made between farms that are certified and those that are not certified (i.e. certification status). The non-certified farms include organic non-certified, mixed, conventional and 'organic-by-default' farms (Table 1). Although we refer to the latter as 'organic by default', in this study we do not consider these subsistence low-input–output systems as practicing organic farming. Their farming practices merely have partial resemblance to organic farming.

We analysed the output of the SMART-Farm Tool, which comprises scores of degree of goal achievement per subtheme (DGA_{ix}) as well as the calculated RI values for the indicator scores, in STATA version 14 (StataCorp, 2015). Using multivariate analyses of variance (MANOVA) and multiple linear fixed-effects models, we tested whether farm type (Type 1 to 5) or farm certification status (certified organic versus non-certified) and county (Kajiado versus Murang'a) or the association of the factors had a significant impact on the assessed sustainability subthemes. We chose the preceding multivariate linear approach MANOVA to better control our Type I error rate (Ling, 2011) without the need for any additional adjustment on the 58 succeeding linear models. We used the Pillai's trace test statistic produced by a MANOVA for indication of the influence of the factors on the subthemes.

We conducted two separate MANOVAs: one examining the association between farm type and county and the other examining the association between certification status and county. We also focused on two-way interactions (i.e. farm type×county or certification status×county) because certified organic farms were found across different farm types (Table 1). We tested the multivariate normality of the residuals, as an assumption for the multivariate normality for the MANOVA (Mardia et al., 1979). As the multivariate normality must be tested in each factor, the sample size was not sufficient (i.e. small number of observations per group) to provide the testing of the covariance matrices (singular), which in turn inhibits a global test. Therefore, we corrected for multiple testing and used Bonferroni correction (not trivial covariances). The result did not lead to any rejection of any variable under the normality assumption.

Next, if factors significantly impacted on a specific subtheme, least significant difference LSD pairwise post hoc tests were conducted to compare the means of the different factor levels at $p < 0.05$. Although no adjustments are needed for planned comparison (e.g. comparisons after a preceding global test in our case) (Milliken & Johnson, 2009), Fisher's protected LSD correction was used due to conventional procedures.

A meaningful interpretation of the results of the SMART-Farm Tool requires the identification of the factors driving the sustainability scores in these subthemes (Schader et al., 2016). Thus, in the follow-up step, we revisited the performance of indicators relevant for each subtheme and represented by the RI value. We used generalized linear models (GLMs) with binomial family and logit link to examine the existence of significant differences in sustainability performance of the indicator using average RI scores with respect to farm type, certification status and county. However, since numerous indicators affected the performance of a given subtheme, we only report and discuss indicators with high impact weights (i.e. ≥ 0.6, where 0=least 1=highest).

3 Results and discussion

3.1 Overall sustainability performance

The overall sustainability performance of the smallholder farms (*DGA*) in the two counties followed a similar pattern as shown by averages of results generated by the SMART-Farm Tool (Figs. 2, 3, 4, and 5). The worst performance in all farms was in the dimension *Good Governance*, especially in the themes *Accountability* and *Holistic Management* (Fig. 2). This was mainly due to the disregard of external costs in the accounting procedure, lack of an explicit sustainability plan, lack of farm certification in the use of agrochemicals as well as missing publicly disclosed written sustainability reports (Appendix A, Table S1).

3.1.1 Farm management and accountability

According to the SAFA Guidelines, the *Holistic Management* theme considers the external effects of the farm activities in accounting and decision making, while the *Accountability* theme relates to disclosure and availability of correct and complete information about all aspects of the farm's performance (FAO, 2014).
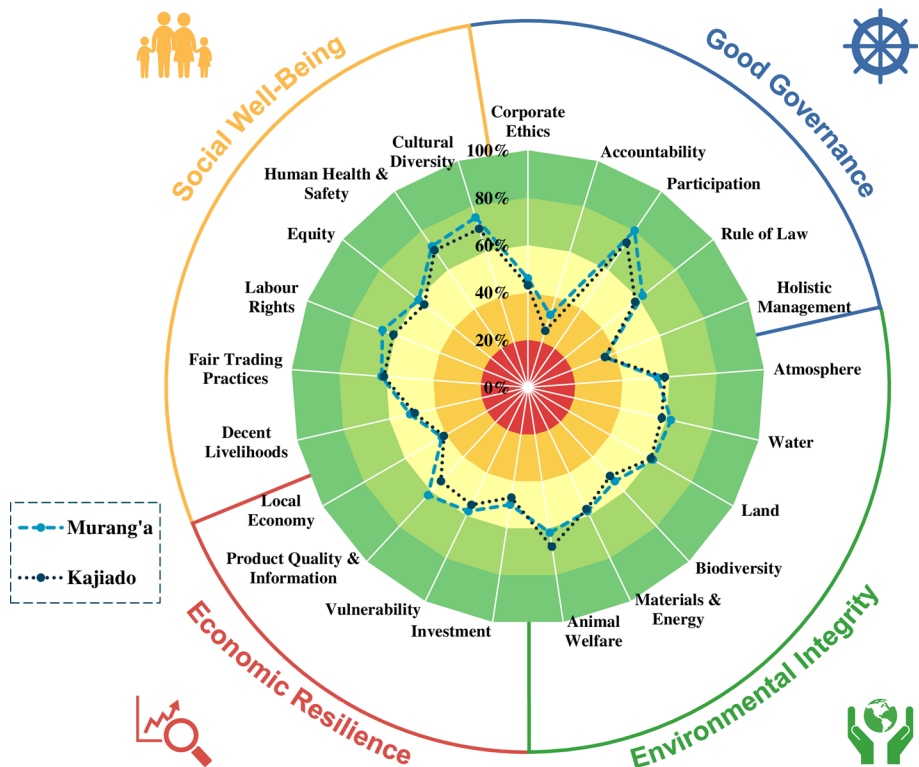

Fig. 2 Overall performance in degree of goal achievement (DGA) from the SMART-Farm Tool across four sustainability dimensions and 21 sustainability themes for 400 farms in Kajiado and Murang'a counties in Kenya

Similarly, other SAFA-based studies found a poor performance in terms of *Accountability* and *Holistic Management* of smallholder farms in developing countries and elsewhere (Landert et al., 2017; Pérez-Lombardini et al., 2021; Schader et al., 2016). A study of non-certified and conventional smallholder coffee farmers in Ethiopia, for example, found that they did not use formal farm monitoring methods (Winter et al., 2020). Poor documentation (e.g. failure to keep records, inconsistent or scanty records, monitoring and evaluation) has been identified as a major challenge for smallholder farms in Kenya, and may limit the economic success of a farm (Muriithi et al., 2014).

The accounting, recording and monitoring of a farm's activities can be knowledge intensive, which is often a challenge especially given that majority of the farmers in this study have no formal education beyond high school with an average of nine years schooling (Kamau et al., 2018). In SSA, this has mainly been attributed to low literacy levels among smallholder farmers, particularly women as reported in South Africa and Kenya for instance (Gyau et al., 2016; Marandure et al., 2017). This gap in knowledge and skills in turn leads to low adoption of sustainable practices that are often knowledge intensive (D'Annolfo et al., 2021). In line with other studies in Kenya and beyond, we consider capacity building in bookkeeping as crucial to improve the sustainability performance of smallholder farms (Gyau et al., 2016; Kabubo-Mariara et al., 2009; Marandure et al., 2020). Although assessing the performance of a farms accountability is challenging in Kenya in terms of monitoring them through some sort of a sustainability reporting system, training farmers in documentation, even for those with limited formal education, can go a long way in increasing transparency and monitoring farm performance. In this aspect, smallholder certification schemes have shown success in improving farm record keeping, tracking and reporting (Kamau et al., 2018; Winter et al., 2020).

3.1.2 Capacity development

Capacity Development in the dimension of Social Well-Being (DGA < 22%) was also relatively weak for smallholder farmers in the areas studied (Figs. 3d, 4d and 5d) due to limited training of farm workers, e.g. in the use of chemical farm products and access to advisory services (Appendix A, Table S1).

There is evidence that capacity development opportunities exist in both Kajiado and Murang'a, and are normally offered by state and non-state actors. However, limited coordination, inadequate technical and personnel capacities and resources remain a challenge for developing capacity (Davis & Place, 2003; Rees et al., 2000). In addition, the gap in technical knowledge in farming as observed in this study in terms of poor handling of chemicals has been reported in various regions of Kenya, for instance with regard to technical information on pest and disease management, use of inputs and irrigation technology (Mati, 2008; Rees et al., 2000). Given that management of farm inputs and soil fertility can be a major barrier to the sustainability of smallholder farms (Grenz et al., 2009; Kamau et al., 2019), there is a need to fill knowledge and skill gaps among farmers and their employees. Better coordination and a stronger role of the national government in extension services without over-reliance on non-state actors have been argued to be imperative (Davis & Place, 2003). In addition, other capacity building initiatives have been claimed to be successful in filling these gaps. For instance, demand-driven extension services (Ngigi et al., 2016) and farmer-to-farmer training approaches (Lukuyu et al., 2012). Strengthening human capacity is a precondition for improving the sustainability of rural livelihoods for communities that depend on rainfed agriculture as was found for example in Azerbaijan

Fig. 3 Average performance in degree of goal achievement (DGA) from the SMART-Farm Tool of 400 ▶ farms in Kajiado and Murang'a counties in Kenya in relation to five farm types across 21 sustainability themes and 58 subthemes in the four dimensions of sustainability (*asterisk after subtheme title represents subthemes with significantly different sustainability performance)

(Aliloo & Dashti, 2021). Despite the existence many avenues to build capacity in Africa including extension, informal education sources like radio, television and mobile phone, Africa's spending on agricultural research and development remains very low, at less than 7% of the gross domestic product, compared to other developing regions in Asia and Latin America (Asenso-Okyere, 2009).

3.2 Comparison of farm sustainability performance with respect to farm types, counties and certification status

In general, summary statistics on the average farm sustainability performance showed hardly any differences across the five farm types (Fig. 3a–d). However, slight differences were observed where farms in Murang'a performed better than those in Kajiado (Fig. 4a–d) and certified farms performed better than non-certified ones (Fig. 5a–d).

Our MANOVA model revealed no statistically significant differences in sustainability performance for the subthemes between the five farm types (Pillai's Trace $= 0.7$, F (232, 1172) $= 1.10$, $p = 0.16$), but significant differences between the two counties (Pillai's Trace $= 0.7$, F (58, 290) $= 10.1$, $p < 0.001$). The interaction between farm types and counties was significant (Pillai's Trace $= 0.8$, F (232, 1172) $= 1.23$, $p = 0.02$) due to a higher level of interaction in some subthemes, which was mainly induced by county differences, as sustainability performance among the five farms types did not differ significantly ($p > 0.05$) (Appendix A, Table S3). However, significant differences were found between certified and non-certified farms (Pillai's Trace $= 0.4$, F (58, 296) $= 3.75$, $p < 0.001$), the two counties (Pillai's Trace $= 0.6$, F (58, 296) $= 8.57$, $p < 0.001$), and the interaction between farm certification and counties (Pillai's Trace $= 0.3$, F (58, 296) $= 1.84$, $p < 0.01$). The outcome of the multiple linear fixed-effects models reveals the effects of the factors for each subtheme (Table 2, Appendix A and B).

Since no major differences in the sustainability performance of the five farm types were found, we do not discuss these results further. For a summary of high-impact indicators that contributed to significant differences (from results of the GLM models) in subtheme scores with respect to certification status, farm type and county (see Tables 3, 4 and 5). In Appendix B, the indicators influencing these results are described in relation to the themes and subthemes and the objectives of the SAFA Guidelines.

3.3 Indicators responsible for differences in the sustainability performance of farms

3.3.1 Differences in land and crop management practices of certified and non-certified farms

The main factor differentiating organically certified farms from non-certified farms was management and use of harmful chemicals (Table 3). Agrochemicals and fertilizers were not used on certified organic farms. Certified farms also performed more soil tests
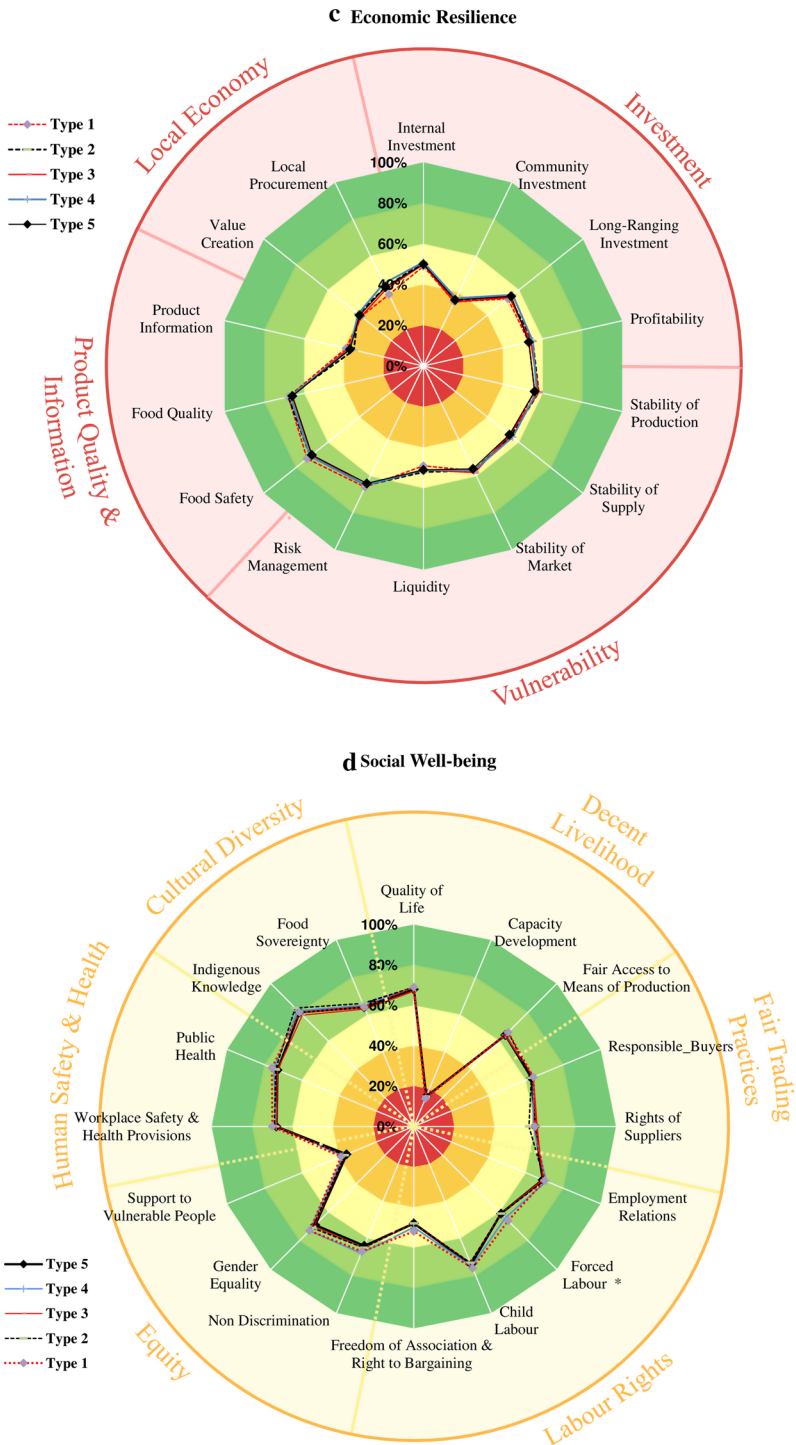
a Good Governance

b Environmental Integrity

c Economic Resilience

d Social Well-being
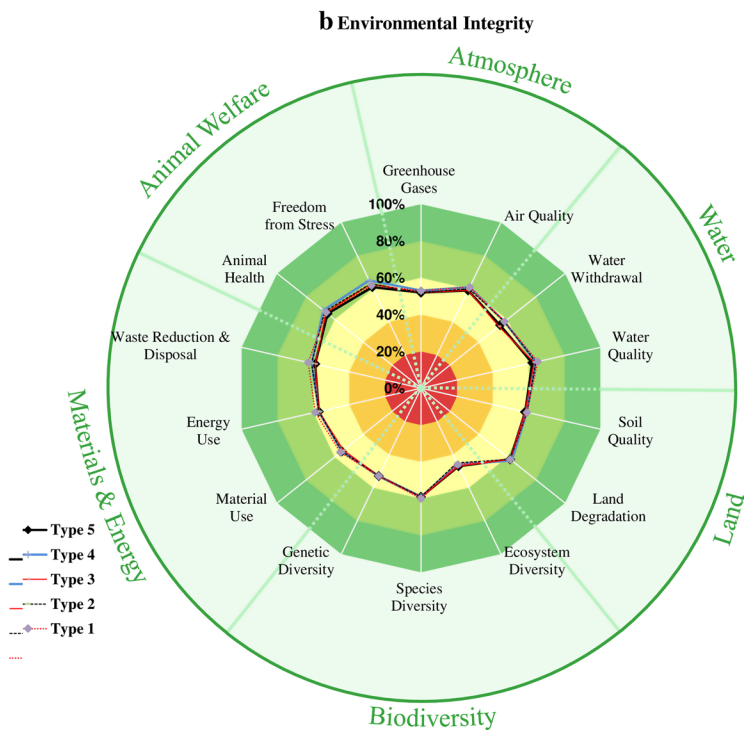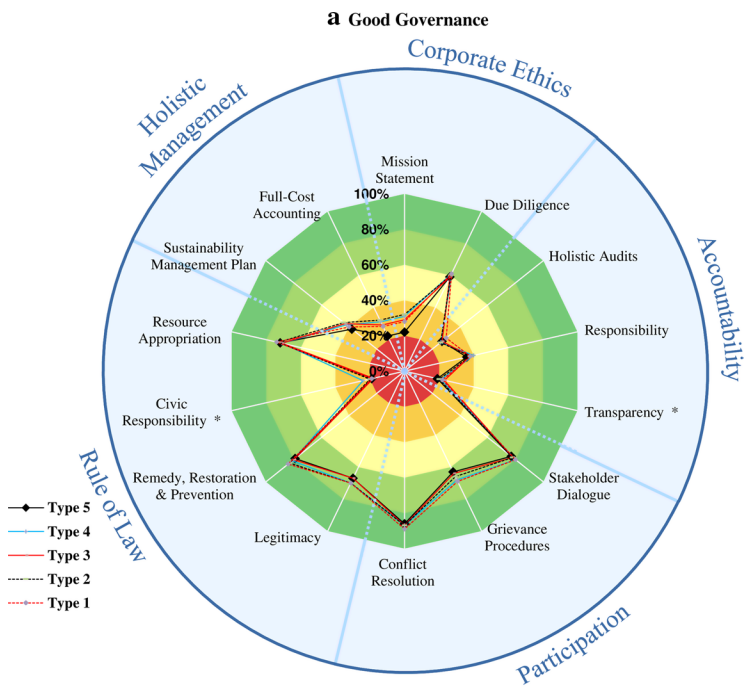
Fig. 3 (continued)

to determine fertilizer requirements and were less likely to apply manure from livestock treated with antibiotics on cultivated areas, and there were more agroforestry systems in certified than in non-certified farms (Table 3), which led to improved performance in sub-themes related to biodiversity and soil quality (Table 4). However, the differences between certified and non-certified farms were not significant in terms of recycling of crop residues, use of compost and farmyard manure, number of perennial crops, yield level, share of legumes on arable land, and share of degraded land (Table 3). The findings imply that the soil management practices of organic farmers therefore do not differentiate them from their non-certified counterparts and they are comparable in terms of soil depletion and yields. However, certified farms were found to enhance agrobiodiversity by avoiding the use harmful synthetic chemicals. This finding is important for Kenya where over 12 million people live on degraded land and degradation of arable land is an ongoing problem (Mulinge et al., 2016).

In terms of soil management practices, these findings are similar to those of previous studies on the sustainability of certified and non-certified organic smallholder farms in Africa. For instance, there was no major difference in the application of 'good' production practices related to soil, pest and disease management between certified and non-certified farms growing coffee in Uganda (Ssebunya et al., 2019). In Ethiopia, expert assessments of smallholder coffee farms concluded that certified farms did not differ from their non-certified counterparts because they were all extensive low external input systems (Winter et al., 2020). In a long-term system comparison of high- and low-input organic and conventional systems in Kenya, results indicated that low-input systems, including organic systems, lead to resource depletion over a long period of time (Adamtey et al., 2016) and could undermine benefits associated with OA.

Nevertheless, the results of this and other studies show the potential of OA to increase biodiversity and improve soil and water quality (Kamau et al., 2019; Muller et al., 2017). For instance, in an earlier independent in-depth assessment of soil fertility and arthropod biodiversity in a subset of the farms used in the current study ($n=20$), it was found that biodiversity was significantly higher in certified organic farms compared to their non-certified or non-organic counterparts, but soil fertility was not significantly different (Kamau et al., 2019). In Colombia, a farm-level sustainability assessment found better environmental practices particularly less use of agrochemicals among organic certified farms (Furumo et al., 2020). In a long-term organic and conventional comparison trial in Kenya, there was a higher termite abundance, activity and diversity in organic systems compared to conventional systems (Anyango et al., 2020). Recent evidence from reviews of literature on agricultural sustainability reiterate that agrochemicals negatively affect soil health; these studies indicate the need to increase agrobiodiversity in farms to make them more resilient to climate change and other shocks (El Chami et al., 2020).

3.3.2 Differences in land and crop management practices on Kajiado and Murang'a farms

There was a poorer sustainability performance of the farms in the drier ASAL Kajiado County compared to the more humid Murang'a County in terms of land and crop management practices. In Kajiado, there were fewer activities to improve soil humus, a lower number of scattered fruit trees and perennial crops as well as limited soil improving or degradation mitigation measures (Table 5 and Appendix A, Table S6).

Similarly, low uptake and use of soil conserving cultivation practices have been reported
in other ASAL regions of Kenya due to limited access to productive assets including land,
inputs and markets (Mutuku et al., 2017). This can be exacerbated by water scarcity and
erratic weather (Njiru, 2012). Despite their associated benefits, the cultivation of peren-
nial crops and fruit trees on small-scale farms in East and Central Africa is constrained
by a lack of improved varieties and markets (Jama et al., 2008). Adverse effects of cli-
mate change pose other threats like yield reduction in key crops if adaptation measures are
not taken (Njiru, 2012; Spaling et al., 2011). The increased use of practices that conserve
resources is crucial for farm sustainability, as agronomic practices affect soil fertility and
productivity (Adamtey et al., 2016). Improved access to productive assets has the potential
to enhance the adoption of these practices.

3.3.3 Farm enterprises

Our results reveal that the economic resilience of certified organic farms was enhanced by
more long-term investments in farm infrastructure and land, and more diversified sales and
income sources, but was reduced by higher yield losses compared to non-certified farms
(Table 5 and Appendix A, Table S4, S5).

Organic agriculture is usually associated with production diversification e.g. in crops
through intercropping and crop rotation, which reduces vulnerability to different economic
and environmental shocks (Pérez-Lombardini et al., 2021; Singh & Maharjan, 2017). In
general, diversification is positively associated with risk reduction and wealth accumula-
tion (Barrett et al., 2001; Davis et al., 2017), but these benefits can be undermined by yield
losses, which can affect farm income and consequently, economic resilience. Investment in
farms could allow them to develop into commercially viable business enterprises, which
could contribute to better economic sustainability (Davis et al., 2017), and diversification
can play an important role.

For the counties in this study, the higher economic sustainability in Murang'a compared
to Kajiado was a result of the higher commercial farm viability, longer customer relation-
ships, and lower product returns from customers. However, lower levels of credit access
and less awareness of future market challenges reduced the economic sustainability of
those farms (Tables 4, 5 and Appendix A, Tables S4, S5).

Previous evidence from Murang'a supports our findings of limited market knowledge
and involvement by farmers in agricultural value chains and agricultural markets that are
poorly developed despite high agricultural potential (Ekbom et al., 2001). Due to locally
poor credit markets, there is also low credit uptake in Murang'a even for farmers with land
title deeds that can be used as collateral (Gyau et al., 2016; Ndukhu et al., 2016). Despite
Kenya's relatively advanced banking sector, banks often view farming as a highly risky
field to invest in. However, access to agricultural financing is vital for pro-poor growth
(Place, 2009). There is a need to provide sound loan products to finance agriculture by
removing barriers to both lenders and borrowers. One way, especially for asset-poor farm-
ers, is through group-based access (Ngigi et al., 2016). Furthermore, collective action has
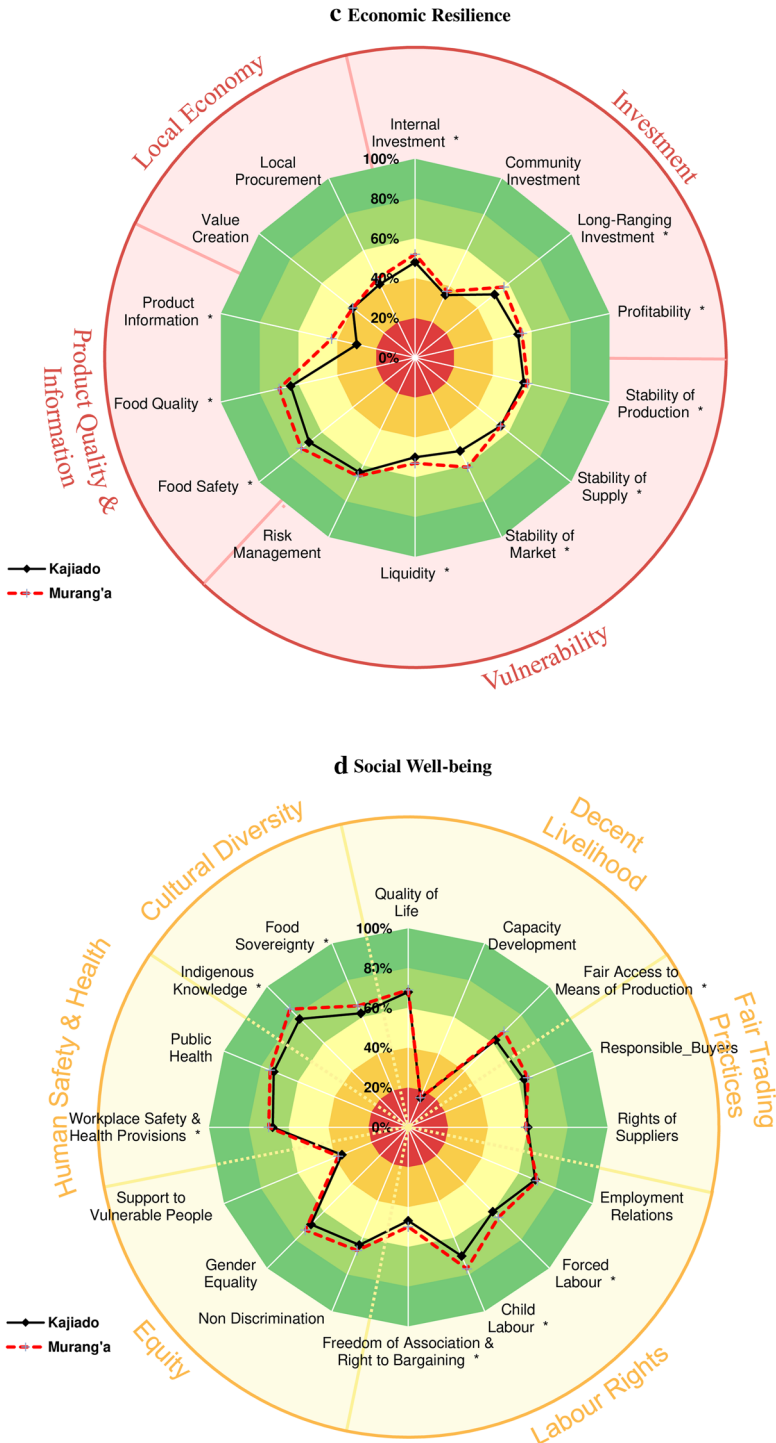been put forward as a strategy to improve farmers' involvement in agricultural value chains

a. Good Governance

b Environmental Integrity

c Economic Resilience

d Social Well-being
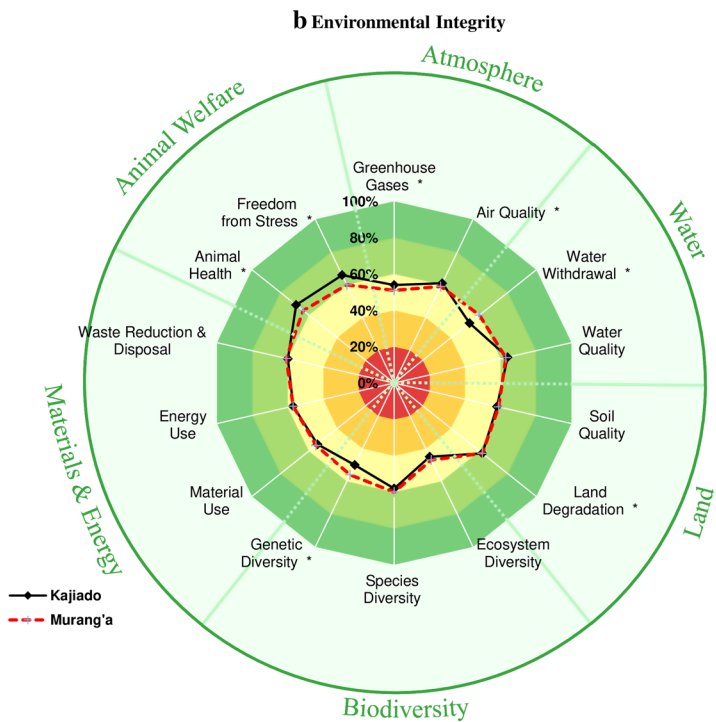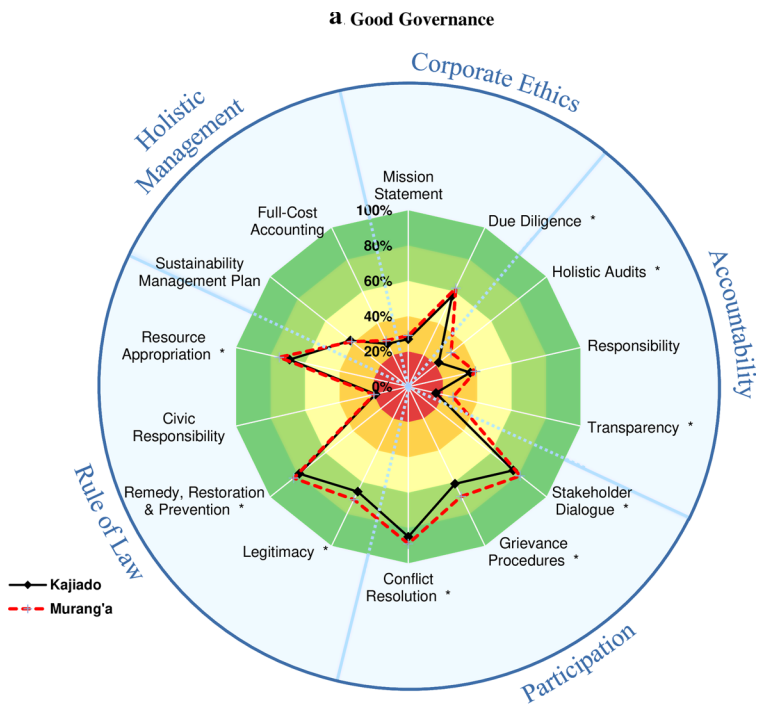
Fig. 4 (continued)

(Gyau et al., 2016). Agricultural insurance is also emerging in SSA as a safety net to protect farmers against climatic and other shocks. For instance, loans and farm inputs can be bundled with other insurance services, thereby shielding both lenders and borrowers (Nshakira-Rukundo et al., 2021).

3.3.4 Farmer and employee welfare

Our results reveal that certified organic farms provided greater support for disadvantaged groups, had more permanently employed workers and workers with social protection than non-certified farms, although the proportion of these workers was very low in both cases. In addition, farms in Kajiado had better support for the disadvantaged although these workers still had poorer access to health care than those on farms in Murang'a (Table 4).

The limited social security in Kenyan smallholder farming observed in the current study (Table 4) was also noted by others (Grenz et al., 2009). Terms of employment are important in determining the level of support to workers. Informal wage workers, who are mostly women and the youth (i.e. below 35 years), make up > 60% of the labour force in rural Kenya, and are largely affected by unemployment, little or no social security, low wages and lack of essential employment rights (Dolan, 2004; Keizi, 2006). Kenya has a national safety net program that targets poor and vulnerable people, those with severe disabilities, older persons, and children (World Bank, 2013). However, poor institutional coordination and management, as well as limited awareness among workers hinders the success of these programs (ILO, 2016; Mathauer et al., 2008). Therefore, stronger linkages between institutions involved in social protection and empowerment of workers have the potential to improve this situation. Moreover, addressing social protection for farm workers as well as tax incentives to induce savings by low-income groups, could enhance workers involvement in the national programmes for medical care and retirement benefits that already exist in Kenya (Dolan, 2004; Keizi, 2006). Agricultural intensification in SSA could increase demand for labour saving technologies (Dahlin & Rusinamhodzi, 2019), which could reduce the already few employment opportunities available in this region. Since agriculture will remain the main source of livelihood in Kenya and other SSA countries in the near future, it is important to improve terms of employment, social protection programmes, and investments in creating opportunities along the agricultural value chain beyond production. This could provide more and better job opportunities and working conditions for the agricultural workforce in Kenya and beyond.

3.3.5 Animal husbandry

Animal welfare, in terms of health and freedom from stress, did not vary significantly between certified and non-certified organic farms (Table 2). However, major differences in animal husbandry practices between counties were observed. In Murang'a, low performance for animal welfare was due to a lack of clean and animal-friendly housing, limited drinking points and outdoor access, lack of quarantine areas, limited access to pasture, and poor animal slaughter standards. In addition, Murang'a farms had more uncovered slurry stores.

These regional differences have been documented before. For instance, studies in Murang'a found that animals were rarely let loose and were mainly confined to their designated housing or tethered. This was attributed to years of land fragmentation and rapid population growth resulting in small land holdings (Ekbom et al., 2001; Ovuka, 2000)

Fig. 5 Average performance in degree of goal achievement (DGA) from the SMART-Farm Tool of 400 ▶
farms in Kajiado and Murang'a counties in Kenya in relation to farm certification status across 21 sustainability themes and 58 subthemes in the four dimensions of sustainability (*asterisk after subtheme title represents subthemes with significantly different sustainability performance)

unlike in Kajiado, where average landholdings are larger and outdoor animal movement is less restricted (Odhong et al., 2014). Poor-quality livestock shelters in Murang'a lead to poor air quality, parasites, infections, dust and mould (Lekasi et al., 2003). Although Kenya has a comprehensive legal animal welfare framework (Masiga & Munyua, 2005), the findings of our study suggest that there is an urgent need to improve animal welfare through better livestock management practices, especially in densely populated humid regions like Murang'a. In addition, the uncovered slurry in the county contributes to anthropogenic greenhouse gas emissions such as nitrous oxide and methane (Mgbenka, 2013), and this suggests a general need to improve animal husbandry practices on farms in Murang'a.

In Kajiado, farms reared far fewer hybrid livestock compared to those in Murang'a (Table 5). Limited rearing of hybrid livestock in Kajiado and other ASAL regions in Kenya has been attributed to preferences for local breeds that are less vulnerable to those environmental stresses more prevalent in ASAL regions, although these local breeds are argued to have lower productivity (Otieno, 2012). In general, agrobiodiversity reduces vulnerability to pests and diseases as well as to other environmental stressors like drought (Altieri, 2009; Di Falco & Chavas, 2006). In making choices about herd diversity, farmers must consider trade-offs in productivity and lasting resilience.

3.3.6 Land-use conflicts and investment

Our results indicate differences in the availability and implementation of mechanisms to prevent resource use conflicts. Conflicts were higher where farm ownership was unclear or disputed (i.e. in Kajiado) compared to areas where more secure land-tenure rights exist (i.e. in Murang'a) (Table 5).

There is evidence of land-use conflicts in Kajiado associated with resource competition between herding, crop cultivation and wildlife. These conflicts are largely the result of regional effects of demographic pressure, land subdivision and climate change on agriculture (Campbell et al., 2000; Njiru, 2012; Ogutu et al., 2014). Land ownership in Kajiado is gradually transforming from communal ownership to privatization and individual ownership as people immigrate from more densely populated areas, driving conflicts in the use of land (Campbell et al., 2000; Kabubo-Mariara et al., 2009). Although our study did not determine an association between conflict and land tenure, malfunctioning land tenure in Kajiado has been found to be associated with resource-use conflicts (Campbell et al., 2000; Ogutu et al., 2014). In Murang'a, however, land rights are overall more secure and based on family and clan affiliation systems, where common resources like woodlands, grazing land and water resources are clearly demarcated and less disputed (Ekbom et al., 2001; Mackenzie, 1989).

Land-tenure insecurity could partly explain the limited long-term investments in soil improvement on the farms in Kajiado (Table 5). Land-tenure insecurity considerably advances food insecurity and poverty in SSA (Radwan, 1995; Salami et al., 2010). Secure land tenure can help in reducing poverty (Radwan, 1995). It can also lead to lasting investments in land conservation (Gebremedhin & Scott, 2003; Shepherd & Soule, 1998), as
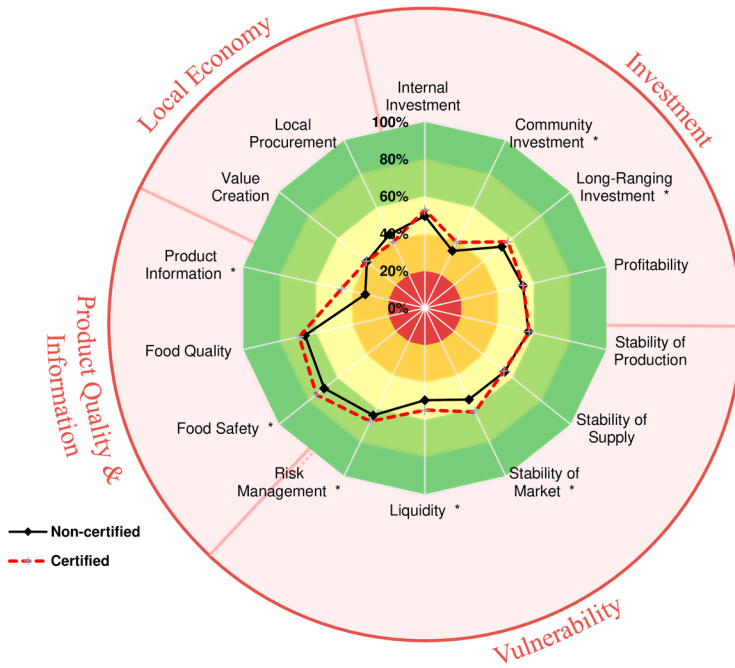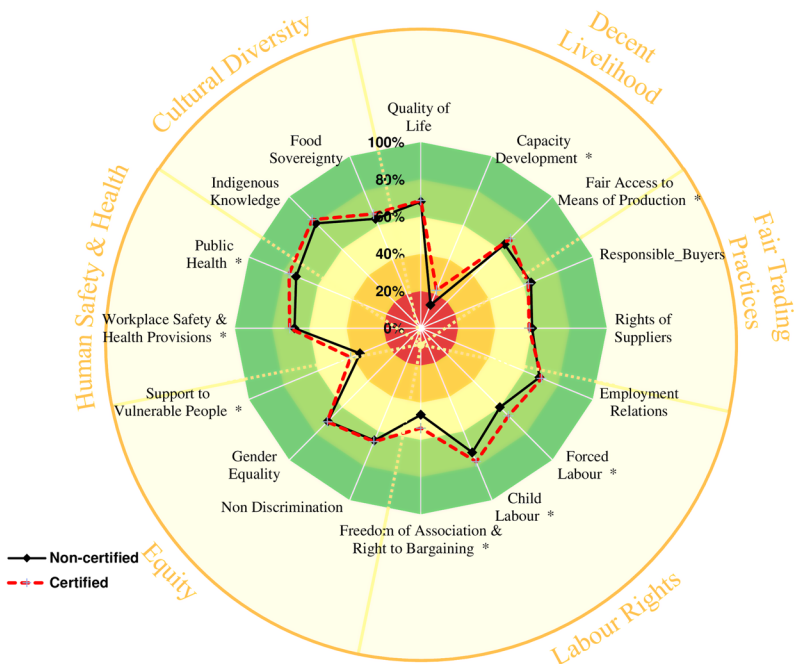
a Good Governance

b Environmental Integrity
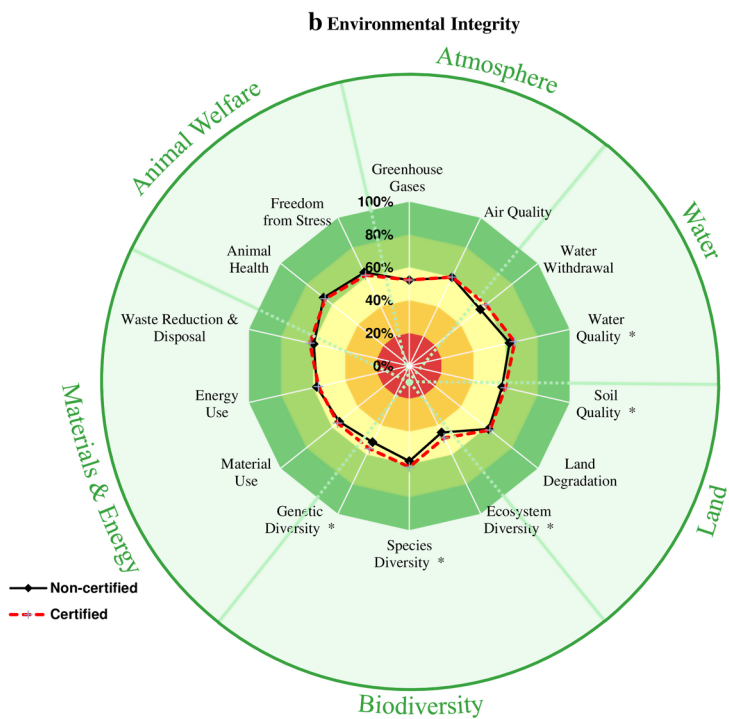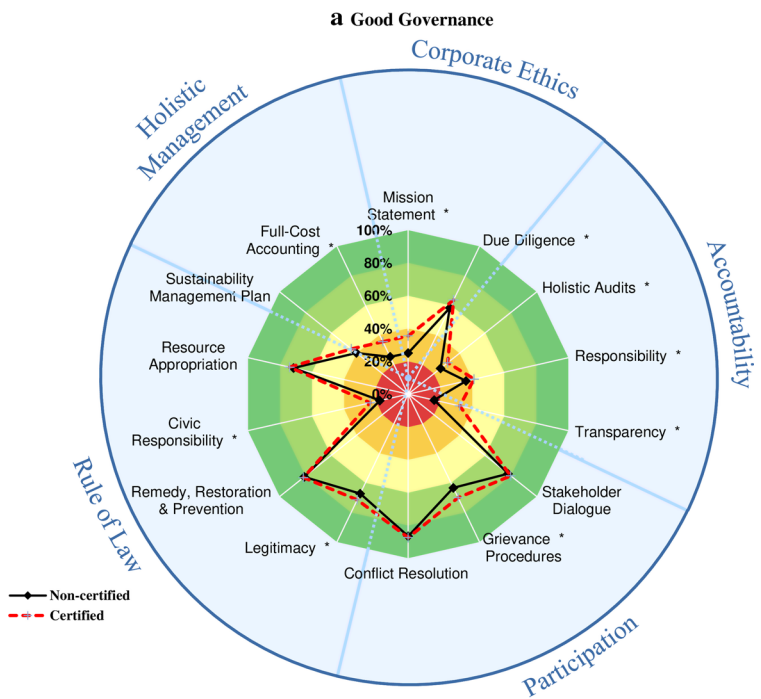
c Economic Resilience

d Social Well-being

Fig. 5 (continued)

Table 2 Mean values of the degree of goal achievement (DGA) from the SMART-farm * tool for each sub-theme by certification status and county for 400 farms in Kenya

Subtheme	p	Certified	Non-certified	p	Murang'a	Kajiado	p	Certified × Murang'a	Certified × Kajiado	Non-certified × Murang'a	Non-certified × Kajiado
		Certification Status			**County**			**Certification Status and County**			
Mission Statement	$p < 0.05$	35.7a	27.1b	ns	30.6a	32.2a	ns	34.1a	37.2a	27a	27.3a
Due Diligence	$p < 0.001$	64.1a	59.2b	ns	62.7a	60.7a	$p < 0.01$	63.3a	64.9a	62.1a	56.4b
Holistic Audits	$p < 0.05$	31.8a	27.1b	$p < 0.05$	31.6a	27.3b	$p < 0.001$	29.7a	33.9a	33.5a	20.6b
Responsibility	$p < 0.01$	42.5a	36.8b	ns	39.1a	40.2a	$p < 0.01$	39a	45.9	39.3a	34.4b
Transparency	$p < 0.001$	31.1a	17.2b	$p < 0.001$	27.9a	20.5b	ns	34.5a	27.7b	21.2a	13.2b
Stakeholder Dialogue	ns	80.7a	78.1a	ns	80.4a	78.4a	$p < 0.01$	79.3a	82a	81.4a	74.8b
Grievance Procedures	$p < 0.001$	69.4a	63.5b	$p < 0.001$	69.6a	63.3b	ns	70.9a	67.9a	68.3a	58.8b
Conflict Resolution	ns	87.8a	86.8a	ns	88.5a	86.2a	$p < 0.05$	86.9ab	88.8b	90.1b	83.6a
Legitimacy	$p < 0.01$	71.3a	67.8a	$p < 0.01$	71.6a	67.5b	ns	72.7a	69.9a	70.5a	65.1b
Remedy, Restoration & Prevention	ns	81.3a	81.5a	ns	82.7a	80.1a	ns	81.4ab	81.3ab	84.1b	78.8a
Civic Responsibility	$p < 0.01$	26.4a	18.2b	ns	20.3a	24.2a	$p < 0.01$	19.9a	32.8	20.8a	15.7a
Resource Appropriation	ns	74a	72a	$p < 0.01$	75a	71b	$p < 0.01$	73.8a	74.1a	76.2a	67.8b
Sustainability Management Plan	ns	44.8a	41.1a	ns	41.6a	44.3a	ns	41.2a	48.4a	42.1a	40.2a
Full-Cost Accounting	$p < 0.05$	35.7a	27.3b	ns	30.6a	32.4a	ns	34.1a	37.3a	27.1a	27.5a
Greenhouse Gases	ns	53.2a	52.6a	$p < 0.001$	51a	54.8b	ns	51.1a	55.3b	50.9a	54.3b
Air Quality	ns	60.8a	60.2a	$p < 0.001$	59a	61.9b	ns	59.2a	62.4b	58.9a	61.4b
Water Withdrawal	ns	58.7a	56.3a	$p < 0.001$	60.4a	54.5b	ns	61.1c	56.3ab	59.8bc	52.8a
Water Quality	$p < 0.01$	66.1a	63.2b	ns	64a	65.4a	ns	65.9a	66.4a	62.1b	64.4a
Soil Quality	$p < 0.05$	60.2a	58.4b	ns	59.3a	59.3a	ns	60.2b	60.1ab	58.4a	58.4a
Land Degradation	ns	63a	62.1a	$p < 0.05$	61.9a	63.1b	ns	62.2ab	63.7b	61.6a	62.5ab
Ecosystem Diversity	$p < 0.01$	49.1a	46b	ns	47.6a	47.5a	ns	48.9c	49.4bc	46.4ab	45.6a
Species Diversity	$p < 0.001$	62.1a	58.8b	ns	60.4a	60.6a	ns	61.6b	62.7b	59.1a	58.5a
Genetic Diversity	$p < 0.001$	56.1a	52.6b	$p < 0.01$	55.9a	52.8b	$p < 0.05$	56.5a	55.8a	55.4a	49.8b
Material Use	ns	56.4a	55.2a	ns	55.8a	55.8a	ns	56.5a	56.2a	55a	55.4a
Energy Use	ns	57.3a	58.2a	ns	57.5a	58a	ns	56.8a	57.7a	58.2a	58.3a
Waste Reduction & Disposal	ns	62.4a	60.4a	ns	61.4a	61.3a	ns	63.3b	61.5ab	59.6a	61.2ab
Animal Health	ns	67.1a	66.7a	$p < 0.001$	63.8a	70b	ns	62.9a	71.3b	64.7a	68.6b

Table 2 (continued)

Internal Investment	ns	52.4a	50.5a	$p < 0.05$	52.7a	50.2b	ns	53.4b	51.5ab	52b	48.9a
Community Investment	$p < 0.001$	39.8a	34.7b	ns	37.1a	37.4a	$p < 0.05$	38.1bc	41.5c	36ab	33.3a
Long-term Investment	$p < 0.05$	57.5a	54.2b	$p < 0.05$	57.2a	54.5b	$p < 0.01$	56.8a	58.2a	57.7a	50.7b
Profitability	ns	53.6a	54.3a	$p < 0.01$	55.2a	52.7b	ns	55.1bc	52.2a	55.3c	53.3ab
Stability of Production	ns	57.8a	58.1a	ns	58.5a	57.4a	$p < 0.05$	57.4a	58.2ab	59.6b	56.5a
Stability of Supply	ns	55.5a	55.2a	$p < 0.05$	54.3a	56.4b	$p < 0.01$	53a	58c	55.5bc	54.9ab
Stability of Market	$p < 0.001$	60.4a	55.3b	$p < 0.001$	61.6a	54b	ns	65.1vv	55.6ab	58.1b	52.4a
Liquidity	$p < 0.05$	53.1a	49.9b	$p < 0.05$	53.6a	49.4b	ns	56.3b	49.9a	50.8a	48.9a
Risk Management	$p < 0.001$	68.3a	64.9b	ns	66.3a	66.9a	$p < 0.05$	67bc	69.5c	65.5ab	64.4a
Food Safety	$p < 0.001$	74.8a	70.3b	$p < 0.05$	73.8a	71.4b	ns	75.4b	74.3ab	72.2a	68.4b
Food Quality	ns	69.1a	67.4a	$p < 0.05$	69.8a	66.8b	ns	70b	68.3ab	69.5b	65.4a
Product Information	$p < 0.001$	44.9a	33.6b	$p < 0.001$	44.5a	33.9b	ns	48.7b	41a	40.3a	26.9b
Value Creation	ns	40.8a	40a	ns	40.1a	40.7a	$p < 0.01$	38.9a	42.6b	41.2b	38.9a
Local Procurement	ns	40.4a	43.9a	ns	42.9a	41.4a	$p < 0.001$	36.9a	43.8ab	48.9b	38.9a
Quality of Life	ns	69.1a	68a	ns	68.4a	68.6a	$p < 0.01$	67.7ab	70.4c	69.2bc	66.8a
Capacity Development	$p < 0.001$	23a	13.6b	ns	17.5a	19a	ns	20.2b	25.7b	14.8a	12.3a
Fair Access to Means of Production	$p < 0.05$	68a	64.6b	ns	67.5a	65.1a	$p < 0.05$	67.2a	68.8a	67.9a	61.4b
Responsible Buyers	ns	63.2a	64.2a	ns	63.9a	63.6a	$p < 0.001$	61.3a	65.2bc	66.5c	62ab
Rights of Suppliers	ns	59.3a	59.8a	ns	58.3a	60.7a	$p < 0.01$	55.9a	62.6b	60.8b	58.8ab
Employment Relations	ns	70.1a	69.1a	ns	70a	69.3a	ns	69.9b	70.4ab	70.1b	68.1a
Forced Labour	$p < 0.001$	66.3a	60.2b	$p < 0.01$	65.1a	61.4b	ns	67.5b	65.1ab	62.6a	57.7b
Child Labour	$p < 0.001$	77a	72.5b	$p < 0.001$	77.8a	71.7b	$p < 0.05$	79b	75.1a	76.5a	68.4b
Freedom of Association and Right to Bargaining	$p < 0.001$	54a	46.8b	ns	51a	49.7a	ns	53.6a	54.3a	48.3a	45.2b
Non discrimination	ns	65.8a	65.8a	ns	66.4a	65.2a	ns	65.6a	66a	67.2a	64.5a
Gender Equality	ns	70.9a	71.5a	ns	72.2a	70.2a	ns	71.1a	70.7a	73.3a	69.7a
Support to Vulnerable People	$p < 0.001$	41.4a	35.6b	ns	38.3a	38.7a	ns	40.1b	42.8b	36.6a	34.7a
Workplace Safety and Health Provisions	$p < 0.01$	71a	68b	ns	69.7a	69.3a	$p < 0.05$	70.1a	71.9a	69.4a	66.7b
Public Health	$p < 0.001$	77a	73.2	ns	75a	75.2a	ns	76.4b	77.7b	73.7a	72.7a
Indigenous Knowledge	ns	82a	80.4a	$p < 0.01$	83.9a	78.5b	ns	83.7b	80.3ab	84.2b	76.6a
Food Sovereignty	ns	66.8a	64.8a	ns	66.5a	65.1a	$p < 0.01$	65.5a	68.1a	67.5a	62.1b

Table 2 (continued)

Details on the standard errors of means and significance levels of subtheme scores for the five farm types in the two counties and interaction effects can be found in Appendix A (Table S2 and S3 and Fig. S1). Means with different letters within columns in each factor category (i.e. certification status, county or their combination) indicate significant differences between factors at $p < 0.05$ based on LSD post hoc test. Cell colours indicate subthemes belonging to the same sustainability dimension

ns = not significant at $p < 0.05$

[*]Sustainability Monitoring and Assessment RouTine (SMART)-Farm Tool

Table 3 Mean sustainability scores (i.e. average RI values) from the SMART-Farm tool of indicators across 4 sustainability dimensions related to land and crop management with significance of differences between certified and non-certified farms according to generalized linear models

Indicator unique ID[x]	Indicator title	p	Certified	Non-certified
34.2	Use of chemical synthetic seed dressings	$p < 0.001$	18.9a	11.4b
202	Agroforestry systems	$p < 0.01$	8.8a	6.4b
222	Permanent grasslands: Share of agricultural area	$p < 0.05$	3.9a	1.9b
229	Ecological compensation areas: Share of agricultural land	$p < 0.001$	15.6a	11.7b
253	Permanent grasslands: Extensively managed	$p < 0.01$	3.4a	11.8b
257.1	Pesticides: toxicity bees	$p < 0.05$	60a	55.1b
257.2	Pesticides: toxicity aquatic organisms	$p < 0.05$	60.7a	54.9b
286	Soil degradation: measures taken to counter	$p < 0.05$	30.5a	27.2b
290	Determining fertilizer requirements	$p < 0.05$	8.4a	6.4b
298	Soil improvement: proportion of formerly degraded land regenerated	$p < 0.001$	26.7a	33.9b
322	Mineral potassium fertilizers	$p < 0.001$	4.6a	16b
377.1	Pesticides: number of active substances	$p < 0.05$	65.3a	59.5b
377.5	Pesticides: chronic toxicity	$p < 0.05$	68.9a	63.2b
710	Harmful substances: phosphorous-fertilizers	$p < 0.05$	11.6a	6.6a
128.1	Yield level	ns	36.1a	39.1a
206	Share of legumes on arable land	ns	21.3a	22.8a
244	Number of scattered fruit trees	ns	22.4a	20.4a
289	Humus formation: crop residues	ns	9.9a	10a
296	Soil degradation: share of agricultural area	ns	60.4a	61.9a
323	Mineral nitrogen fertilizers	ns	32.5a	29.7a
324	Mineral phosphorous fertilizers	ns	31.7a	29.1a
519	Use of GMO crops	ns	36.6a	39.4a
605	Management of riparian strips	ns	30.4a	30.8a
700	Measures to prevent erosion	ns	16.2a	15.9a
740	Growth regulation	ns	58.5a	55.5a
758	Number of perennial crops	ns	47.2a	48.3a

Means with different letters within the same row show significant differences in indicators for farms between certified and non-certified farms at $p < 0.05$

[x]For a detailed description of the indicators, please refer to a detailed described in Supplementary Material A of (Schader et al., 2016)

ns = not significant at $p < 0.05$

Table 4 Average RI values from the SMART-Farm Tool of high impact indicators (weight > 0.6) for certified and non-certified farms and significance levels from generalized linear models (letters indicate significant differences at $p < 0.05$, ns = not significant)

Dimension	Indicator unique ID	Indicator	p	Certified	Non-certified
Good Governance	460	Proactive support of disadvantaged groups	$p < 0.05$	53.6a	46.4b
	0	Professional agricultural accounts	ns	28.5a	28.5a
	423	Workers: Legally binding contracts	ns	59.4a	60.7a
	63	Proportion of environmentally certified products	$p < 0.001$	20.6a	8b
	327	Waste disposal: Pesticides and veterinary medicines	$p < 0.001$	61.4a	48b
	175	Transparency of production	$p < 0.001$	26.6a	8.5b
	322	Mineral potassium fertilisers	$p < 0.001$	4.6a	16b
	375	Animal welfare standards (slaughter)	$p < 0.05$	32a	28b
Environmental Integrity	723	Buying new animals	ns	27.3a	27.7a
	725	Pig keeping: quarantine section	$p < 0.001$	15.5a	8.7b
	253	Permanent grasslands: extensively managed	$p < 0.01$	3.4a	11.8b
	726	Polishing piglet teeth	ns	18.2a	18a
	322	Mineral potassium fertilisers	$p < 0.001$	4.6a	16b
	327	Waste disposal: Pesticides and veterinary medicines	$p < 0.001$	61.4a	48b
	244	Number of scattered fruit trees	ns	22.4a	20.4a
	335.1	Recycling of paper/cardboards	$p < 0.001$	20.2a	13b
	377.05	Wastewater disposal	ns	44.1a	42.1a
	387	Water use efficiency	ns	51.3a	50.7a
	371	Access to pasture for ruminants	$p < 0.001$	4.1a	9.6b
	722	Injuries of pigs	ns	33.6a	33.6a
	357	Mutilation: Use of anaesthetics and analgesics	ns	22.7a	27.4a
	375	Animal welfare standards (slaughter)	$p < 0.05$	32a	28b
	337	Loss of agricultural products (food waste)	$p < 0.001$	40.4a	49.7b
Economic Resilience	63	Proportion of environmentally certified products	$p < 0.001$	20.6a	8b
	175	Transparency in production	$p < 0.001$	26.6a	8.5b
	473	Workers: Training in use of plant protection and animal treatment products	ns	63.3a	60.5a
	72	Further training for farm staff	$p < 0.001$	26.5a	15.1b
	73	Long-term investments	$p < 0.05$	52.5a	44.4b
	158	Diversification of income	$p < 0.001$	46.8a	27.2b
	65	Proportion of products meeting social standards	$p < 0.001$	17.9a	7.2b
	0	Professional agricultural accounts	ns	28.5a	28.5a
	723	Buying new animals	ns	27.3a	27.7a
	83	Diversification of sales	$p < 0.05$	63.4a	53.4b
	371	Access to pasture for ruminants	$p < 0.001$	4.1a	9.6b
	95	Yield loss	$p < 0.001$	25.9a	39.1b
	722	Injuries of pigs	ns	33.6a	33.6a
Social Well-Being	72	Further training for farm staff	$p < 0.001$	26.5a	15.1b
	703	Access to advisory services	$p < 0.05$	57.5a	51b
	423	Workers: Legally binding contracts	ns	59.4a	60.7a
	463.1	Workers: Permanent workforce	$p < 0.001$	5.6a	2.1b
	463.2	Workers: Social protection	$p < 0.001$	17.2a	7.7b
	460	Proactive support of disadvantaged groups	$p < 0.05$	53.6a	46.4b
	327	Waste disposal: Pesticides and veterinary medicines	$p < 0.001$	61.4a	48b
	377.05	Wastewater disposal	ns	44.1a	42.1a
	725	Pig keeping: Quarantine section	$p < 0.001$	15.5a	8.7b

Cell colours indicate subthemes belonging to the same sustainability dimension. Means with different letters within the same row show significant differences in indicators for farms between the certified and non-certified farms at p < 0.05. Cell colours indicate subthemes belonging to the same sustainability dimension

[x]For a detailed description of the indicators, please refer to a detailed described in Supplementary Material A of (Schader et al., 2016) using unique ID (identification) numbers

ns = not significant at $p < 0.05$

has been reported in Kajiado (Kabubo-Mariara et al., 2009). To further reduce conflict, ongoing land reforms in Kenya should seek to secure access to land and other resources for smallholder farmers (WFP, 2016).

Table 5 Average RI values from the SMART-Farm Tool of high impact indicators (weight > 0.6) for farms in Kenya's Murang'a and Kajiado counties and significance levels

Dimension	Indicator unique ID	Indicators	p	Murang'a	Kajiado
Good Governance	67	Prevention of resource conflicts	$p < 0.001$	57.6a	45.2b
	63	Proportion of environmentally certified products	$p < 0.001$	20.1a	3.9b
	65	Proportion of products meeting social standards	$p < 0.001$	17.9a	3.3b
	748	Humus formation: Humus balance	$p < 0.001$	33a	25.8b
	327	Waste disposal: Pesticides and veterinary medicines	$p < 0.001$	56.9a	46.8b
	376.1	Information on water availability	$p < 0.001$	33.7a	24.3b
	175	Transparency of production	$p < 0.001$	21.5a	6.8b
	31	Communication with stakeholder groups	ns	51.8a	63.3a
	460	Proactive support of disadvantaged groups	$p < 0.05$	46b	51.5a
	0	Professional agricultural accounts	ns	20.5a	35.4a
Environmental Integrity	726	Polishing piglet teeth	ns	16.7a	20.2a
	244	Number of scattered fruit trees	$p < 0.001$	28.7a	12.6b
	249	Hybrid livestock (poultry, pigs)	$p < 0.05$	23.4a	18.5b
	332	Electricity consumption per ha	$p < 0.001$	27.8a	18.5b
	376.1	Information on water availability	$p < 0.001$	33.7a	24.3b
	389	Irrigation: Water consumption per ha	$p < 0.001$	52.1a	39.2b
	404	Irrigation: Precipitation measurement	$p < 0.001$	46.5a	28.4b
	200	Covered slurry stores (or stable natural crust)	$p < 0.001$	12.5a	31b
	207	Arable land: Share of direct seeding	$p < 0.001$	14a	33.4b
	371	Access to pasture for ruminants	$p < 0.001$	0.4a	20.8b
	356	Share of dehorned ruminants	$p < 0.001$	11.1a	29b
	361	Cleanness of livestock / housing	$p < 0.001$	36.3a	50.2b
	368.1	Animal-friendly housing system	$p < 0.001$	45a	57.7b

Table 5 (continued)

	369	Number and quality of drinking points	$p < 0.001$	48.5a	58.6b
	370.5	Daily outdoor access for animals	$p < 0.001$	5a	25.4b
	723	Buying new animals	ns	27.8a	27.5a
	725	Pig keeping: Quarantine section	ns	10.5a	11a
	701	Loose-housing system	$p < 0.05$	19.7a	28.3b
	728	Materials to keep animals busy	$p < 0.01$	15.3a	25.2b
	620	Permanent grasslands: mowing frequency	ns	22.9a	20.1a
	63	Proportion of environmentally certified products	$p < 0.001$	20.1a	3.9b
Economic Resilience	146	Product returns	$p < 0.001$	65.5a	39.6b
	170	Food safety standard	ns	5.6a	0b
	175	Transparency of production	$p < 0.001$	21.5a	6.8b
	73	Long-term investments	$p < 0.001$	52a	41.2b
	286	Soil degradation: Measures to counter degradation	$p < 0.001$	32.9a	23.2b
	298	Soil improvement	$p < 0.001$	36.7a	26.1b
	244	Number of scattered fruit trees	$p < 0.001$	28.7a	12.6b
	767	Land ownership (secure tenure rights)	$p < 0.001$	56.6a	49.2b
	65	Proportion of products meeting social standards	$p < 0.001$	17.9a	3.3b
	775	Commercially viable size of main business unit(s)	$p < 0.001$	70.2a	55.8b
	149	Length of customer relationships	$p < 0.001$	40.3a	25.8b
	249	Hybrid livestock (poultry, pigs)	$p < 0.05$	23.4a	18.5b
	758	Number of perennial crops	$p < 0.001$	13.4a	0.4b
	370.5	Daily outdoor access for animals	$p < 0.001$	5a	25.4b
	371	Access to pasture for ruminants	$p < 0.001$	0.4a	20.8b
	723	Buying new animals	ns	27.8a	27.5a
	152	Loan (credit) limit	$p < 0.05$	18.7a	31.3a
	0	Professional agricultural accounts	ns	20.5a	35.4a
	100	Market challenges (farmer information)	$p < 0.001$	41.5a	50.5b
	244	Number of scattered fruit trees	$p < 0.001$	28.7a	12.6b
	207	Arable land: Share of direct seeding	$p < 0.001$	14a	33.4b
	369	Number and quality of drinking points	$p < 0.001$	48.5a	58.6b

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Table 5 (continued)

	67	Prevention of resource conflicts	$p < 0.001$	57.6a	45.2b
Social Well-Being	65	Proportion of products meeting social standards	$p < 0.001$	17.9a	3.3b
	245	Locally adapted livestock breeds	$p < 0.001$	37.2a	31.8b
	249	Hybrid livestock (poultry, pigs)	$p < 0.05$	23.4a	18.5b
	327	Waste disposal: Pesticides and veterinary medicines	$p < 0.001$	56.9a	46.8b
	483	Access to medical care	$p < 0.01$	54.8a	43.6b
	361	Cleanness of livestock / housing	$p < 0.001$	36.3a	50.2b

Means with different letters within the same row show significant differences in indicators for farms between the two counties (Murang'a and Kajiado) at $p < 0.05$

[x]For a detailed description of the indicators, please refer to a detailed described in Supplementary Material A of (Schader et al., 2016) using unique ID (identification) numbers

Cell colours indicate subthemes belonging to the same sustainability dimension

ns = not significant at $p < 0.05$

3.3.7 Water management and quality

Within the *Environmental Integrity* dimension, the water quality subtheme scores were significantly higher in certified organic farms (Table 2), which was explained partly by indicators that showed significantly lower pesticide use and higher information availability about water quality (Tables 4 and 5). The two counties differed considerably in water withdrawal but not in water quality (Table 2). Farms in Kajiado had significantly less information on water availability, used more water for irrigation annually, and they did not measure or record precipitation which helps in calculating irrigation water demand (Table 5).

These results indicate that water quality is reduced in smallholder farms that use agrochemicals and there is poor management of irrigation water particularly in the dry ASAL regions where water is already a limited resource and irrigation is needed. Agriculture is the leading water user in Kenya constituting over 70% of the country's water use per annum (FAO, 2005). However, although the area under irrigated agriculture is still minimal in Kenya, with only ~2.4% of the arable land under irrigation, it accounts for, more than 50% of the water used in agriculture (WRMA, 2013). In Kajiado, the need for irrigation on recently converted land has increased competition for water resources (Adhiambo et al., 2017) and to a reduction in river water quantity and quality over time (Adhiambo et al., 2017; Gichuki & Macharia, 2006). This shows a need for increased awareness on water use, management and storage particularly with ongoing efforts to increase the area under irrigation in Kenya and to improve regulations in water management (WRMA, 2013). Capacity development in irrigation schemes for the Kenyan ASAL regions could decrease regional poverty and food insecurity (Mati, 2008).

3.4 Limitations

The SMART-Farm Tool performs well in comparison with other tools used in decision making at farm level (Arulnathan et al., 2020). To enable comparability of results, the indicators included are broadly defined for different farm types, settings, climatic conditions and socio-economic contexts. This global applicability is important to enable comparability of results (Schader et al., 2016). However, the drawback of this generic approach is that it does not take into account all case- and site-specific factors that may influence sustainability.

One limitation of the approach in this study is the inability to draw general conclusions about the specific impacts of certification or biophysical differences on these farms, without a more targeted assessment. Although our results indicate differences between the two counties as well as certified and non-certified farms, we hesitate to describe the results of in terms of cause-and-effect. The comparability and the explanatory power of such multi-criteria sustainability assessments could increase if they were harmonized and aligned. A first step for such a harmonization could be the agreement on a common framework such as the SDGs translated to goals that are applicable at the farm level.

4 Conclusions

In this study, we assessed the sustainability performance of smallholder farms by applying the SMART-Farm Tool based on the dimensions of *Good Governance*, *Environmental Integrity*, *Economic Resilience* and *Social Well-Being*. We sought to contribute to the ongoing debate on the effectiveness of agricultural systems in contributing to sustainable development and the role of OA in Kenya and beyond. The findings from our case studies in the counties of Murang'a and Kajiado in Kenya demonstrate the need to close the gap in education, knowledge and skills of smallholder farmers, as well as to build job and social safety nets for farmers and farm workers. Our findings indicate that organic certification could play a role in reducing these knowledge gaps thereby contributing to farm-level social sustainability and good governance. OA can also strengthen farms economic resilience through long-term farm investments and diversification.

In addition, our results demonstrate that organic certification is linked to greater biodiversity, soil and water quality levels, which could play a role in tackling the problem of declining soil health in Kenya and possibly elsewhere in SSA, thereby enhancing environmental integrity and climate resilience. However, except for better handling of agrochemicals and a few other practices like more agroforestry systems, the lack of differences in many land and crop management practices of certified farms and non-certified farms implies that the OA attempts to increase environmental sustainability (Raynolds et al., 2007) could be undermined unless certified organic farms adhere to most of the practices required in the practice OA.

Our findings suggest that organic farms can perform better or at least as well as conventional ones in terms of biodiversity enhancement, water management, use and management of agrochemicals, farmer and farm worker well-being and training in farm management even for people with limited or no formal education. Other studies carried out in SSA that reported improvement in profitability, social capital and reduced poverty levels in farms where OA is practiced reinforce our findings that OA is a valid pro-poor growth strategy in SSA.

The sustainability performance of smallholder farms was also shown to be associated with differences in biophysical conditions. This is important for Kenya, a country that is predominantly dry and relying on rainfed agriculture, which exposes farmers to environmental shocks. To advance the sustainability of the farms and overcome low adoption of soil conservation measures and other long-term farm investments in ASAL regions in Kenya, we see a need to increase access to these assets and strengthen land-tenure rights in ASAL regions. Capacity building and fostering regulation and support in water management for farms in ASAL regions could also play a role in improving food security and reducing poverty as the area under irrigation expands in Kenya. For relatively humid areas like Murang'a that tend to have a higher population density than ASAL regions, poor animal husbandry practices should be addressed despite continuing land fragmentation. Farmers also need better linkage to farm input, farm output and credit markets in efforts aiming to advance the sustainability of farms.

To expand on this study, future research could explore topics such as the causal effects of certification in relation to the different themes of sustainability. This will provide more information about the potential of land-use change to address the looming environmental crisis and rapid population growth and exacerbated resource scarcity expected in this region. Further focus on animal husbandry practices (such as manure handling and livestock carrying capacity) on smallholder farms in SSA is also needed, given the negative effects on human and animal welfare and the environment.

5 Implications

Assessing sustainability in smallholder farms is complex, as shown in this and other such studies. Enhancing their sustainability performance is equally complex, given the need to balance different and sometimes conflicting objectives. Nevertheless, we have highlighted some areas that can be strengthened to bring win–win situations across different dimensions.

Strengthening the knowledge and skills among smallholder farmers will enable them to adopt sustainable farming practices. The state can play a vital role through investment in innovation and knowledge development and dissemination. In SSA, this investment remains very low and there is over-reliance on non-state actors. Investments in training on all aspects of the value chain from production to the market could help. This includes soil fertility management, safe use of agrochemicals, bookkeeping, produce marketing, and other relevant technical skills. This training could cover aspects of declining soil fertility and its effects on productivity, yields and food security in SSA. Specific training for OA would allow the adjustment of OA rules to suit the situation not just in Kenya, but Africa as a whole. Even where knowledge and its dissemination mechanisms exist, there is a need for more coordination and investments in technical and personnel capacities.

In addition, these farmers need access to productive assets including capital, credit and secure land tenure to enable them to make long-term investments. They also need access to increased diversified social protection mechanisms. The rapid growth in demand of organic produce internationally, regionally and locally offers a premium market that farmers can take advantage of, with the support of initiatives like the EOA by the African Union, while taking into account all the potential bottlenecks of sustainability of OA highlighted in this study.

This study gives some indication of where gaps in sustainability exist for smallholder farms in Kenya. However, more targeted on biodiversity and soil fertility in smallholder farming SSA, including the role of soil microbiota in different farming systems in SSA could shed more light on sustainability gaps. In addition, the area of the environmental impacts of animal husbandry, particularly in relation of animal welfare and greenhouse gas emissions, needs further scientific exploration. The expansion of intensification of agriculture that is expected in SSA will lead to an increase in the share of land under irrigation as well as agrochemical use, particularly in dry ASAL regions. This will likely have implications on water withdrawal and water quality. Further research that explores this dynamic of agricultural intensification, water use and water quality changes will also be important for understanding and managing these changes. Further research will need to transcend boundaries of academic disciplines to capture the interconnected dimensions and indicators of sustainability.

The findings of our study offer a starting point for a more comprehensive and all-encompassing discourse on farm-level agricultural sustainability. Development interventions, strategies and policies aiming to improve the sustainability performance of smallholder farms in Kenya, similar regions in SSA and beyond, can begin with addressing the gaps in sustainability highlighted in this study.

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