Sustainability performance of organic and conventional farming systems in Kenya:
Murang'a, Kirinyaga and Machakos Counties

DISSERTATION

zur Erlangung des Grades

Doktor der Agrarwissenschaften (Dr. Agr.)

der Landwirtschaftlichen Fakultät

der Rheinischen Friedrich-Wilhelms-Universität Bonn

von

John Mwaniki Ndungu

aus

Kiambu, Kenya

Bonn 2022

Referent: Prof. Dr. Christian Borgemeister

Koreferent: Dr. Christian Schrader

Tag der mündlichen Prüfung: 2. November 2021

Angefertigt mit Genehmigung der Landwirtschaftlichen Fakultät der Universität Bonn

Acknowledgment

I express my gratitude to my supervisor Prof. Dr. Christian Borgemeister, for his highly valuable guidance and scientific advice during the study. My gratitude extends to my doctoral co-advisor, Dr. Christian Schader (FiBL) for his guidance and insight into this research. I thank my tutors Dr. Oliver Kirui and Dr. Lisa Biber-Freudenberger from the Center for Development Research (ZEF) for their research recommendations, inspiration and encouragement. My sincere gratitude goes to the doctoral program team at ZEF especially to Dr. Günther Manske and Mrs. Maike Retat-Amin for a well-organized and smooth stay in ZEF, Bonn and Germany. I appreciate the team from the Research Institute of Organic Agriculture (FiBL), in particular, Dr. Irene Kazdere the overall ProEcoAfrica and OFSA project coordinator, for the smooth running of the research activities. I am also grateful to Mr. Johan Blockeel, Miss. Anja Heidenreich and Mr. Bernhard Schlatter, all from FiBL, for their support and advice on research and data collection and management guidance. I appreciate Dr. Anne W. Muriuki, the Centre Director, KALRO Food Crops Research Centre, Kabete and ProEcoAfrica project Kenya Country Coordinator, for inspiration and guidance in this research. I also appreciate Dr. Rahab W. Muinga and Dr. Lusike Wasilwa for their encouragement and mentorship.

Funding for this study was made available by the Dutch Humanist Institute for Cooperation with Developing Countries (Hivos), the Swiss Agency for Development and Co-operation (SDC) and the Mercator Foundation Switzerland through the ProEcoAfrica and OFSA projects (www.proecoafrica.net) led by the Research Institute of Organic Agriculture (FiBL), Frick, Switzerland. I also acknowledge the German Federal Ministry of Education and Research (BMBF), and the University of Bonn for its administrative support during my stay in Germany. I am grateful to Dr. Eliud Kireger, the Director General, Kenya Agricultural and Livestock Research Organization (KALRO) for logistical support. I appreciate the International Centre of Insect Physiology and Ecology (ICIPE) for their collaboration in the overall ProEcoAfrica/OFSA research in Kenya and the Project Advisory Committee for their overall guidance to the project.

Finally, I express my sincere thanks to farmers in Murang'a, Kirinyaga and Machakos counties, who willingly participated in this study. Thanks to the enumerators who were part of the team on data collection. I thank my ZEF colleagues and friends who tirelessly supported and inspired me during the study. I am grateful to my family for the care, support and sharing my difficult moments. Above all, I am grateful to the Almighty God for making this journey possible.

Table of Contents

List of Tables

List of Figures

Abbreviations/ Acronyms

AESIS	Agro-Environmental Sustainability Information System
APOLA-NOVORURAL	The System for Weighted Environmental Impact Assessment of Rural Activities
ARBRE	Arbre de l'Exploitation Agricole Durable (The tree of sustainable farming)
AVIBIO	AVIculture BIOlogique (A program for evaluating requirements that meets increasing demand for organic poultry towards sustainable production)
BMBF	German Federal Ministry of Education and Research
COSA	Committee on Sustainability Assessment
DELTA	An Integrated Indicator-Based Self-Assessment Tool for the Evaluation of Dairy Farms Sustainability
DSI	Dairyman Sustainability Index
DSR	Driving Force State Response
FiBL	Forschungsinstitut für Biologischen Landbau (Research Institute of Organic Agriculture)
GAP	Good Agricultural Practices
Hivos	Humanistisch Instituut voor Ontwikkelingssamenwerking (Dutch Humanist Institute for Cooperation with Developing Countries)
IBM SPSS	Statistical Package for the Social Sciences
ICIPE	International Centre of Insect Physiology and Ecology
IDEA	Indicateur de Durabilité des Exploitations Agricoles (farm sustainability indicators
ISAP	Indicator of Sustainable Agricultural Practice
KALRO	Kenya Agricultural and Livestock Research Organization
LCA	Life Cycle Assessment
MAUT	Multi-Attribute Utility Theory
MESMIS	Marco de Evaluación de Sistemas de Manejo incorporando Indicadores de Sustentabilidade (Framework for Assessing the Sustainability of Natural Resource Management Systems)
MMF	Multiscale Methodological Framework
MOTIFS	Monitoring Tool for Integrated Farm Sustainability
OFSA	Organic Farming System Africa
PAC	Project Advisory Committee
PG	Public Goods Tool
RAD	Réseau d'Agriculture Durable (Sustainable agriculture network)
RISE	Response-Inducing Sustainability Evaluation 2.0
SAT	Sustainability Assessment tool
SAFA	Sustainability Assessment of Food and Agriculture Systems
SAFE	Sustainability Assessment of Farming and the Environment
SDC	Swiss Agency for Development and Co-operation
SMART	Sustainability Monitoring and Assessment RouTine
ZEF	Zentrum für Entwicklungsforschung (Center for Development Research, University of Bonn)

Abstract

The concept of sustainable farming systems focuses on the need to develop techniques and practices that have positive effects on social outcomes, the environment, and food productivity. In Africa, there are limited empirical studies that compare agronomic practices on organic and non-organic farms. The current comparative study assesses the productivity and profitability of organic and conventional farming systems, their sustainability performance, and farmer perceptions on sustainability gaps for improved intervention in Kirinyaga, Murang'a and Machakos counties of Kenya. Empirical data collected from 849 farms was used to perform i) a productivity analysis to assess the yield and profits of ten common crops; ii) and an assessment, using an indicator-based multi-criteria approach (SMART-Farm Tool), of sustainability performance comparing organic and conventional farming systems at the farm and county levels. Thirdly, farmer feedback workshops and in-depth discussions analyzed farmers' views on the challenges and options available to improve their sustainability performance in the areas in which they were found to have critical sustainability scores. The yields, costs, revenues and profits of twenty crops evaluated and some crops grown under organic farming were found to be better than those under conventional farming. The effect on yields for four crops compared by using the nearest neighbor, kernel matching and radius matching showed that there was a significant increase in yields in organic farming systems. Organic farming significantly increased average yields in four crops: common beans (increased by 49.6%) macadamia nuts (36.6%), coffee (37.3%) and mango (43.1%). The average profits of field/common beans increased by US$ 994/ha (equivalent to an increase of 35.3%). Similarly, the profits for macadamia nuts increased by US$ 5,263/ha (equivalent to a 44.4% increase). The propensity score matching sensitivity analysis shows that the reduction in the median bias were all greater than 19% for the yields (field/common beans 19%, macadamia nuts 87%, coffee 88%, and mango 32%), and greater than 21% for the profits (field/common beans 21% and macadamia nuts 61%). The large reduction in median bias improves the quality of matching.

The sustainability assessment found that, overall, organic farms performed significantly better than conventional farms with regard to the sustainability dimensions of environmental integrity, economic resilience and governance. The fourth sustainability dimension, social, showed lower degree of goal achievement scores for organic than conventional farms e.g. employment relations Among the sustainability sub-themes and indicators, some degree of goal achievement scores were similar for both organic and conventional farming systems but others lower for organic. The study identified sustainability challenges among the smallholder farms that need to be addressed. The challenges of high importance facing both organic and conventional farmers in the study area can be summarized as; limitations to technical and physical inputs, market-related challenges, agronomic skills and limited institutional support. The intervention areas and strategies suggested by farmers included biodiversity conservation, water resource use and management, soil fertility management, farmer group establishment and maintenance, diversification and alternative markets, and record keeping. Other strategies suggested by farmers included capacity development and public health and safety measures. The low indicator and sub-theme scores found in the sustainability assessment need to be addressed. The identified constraints in the sustainability assessment can be addressed by improving farming practices in both organic and conventional farming systems, such as by enhancing farmers' knowledge in correct use of synthetic fertilizers and manure, and correct use of plant protection products, such as the recommended dosage required and observance of pre-harvest intervals to ensure production of safe and nutritious foods. Capacity building of farmers requires that a program for regular training and extension support for farmers be implemented to take into account the continued improvement and maintenance of the set of evolving organic standards. Since organic farming systems have significant positive impacts on the yield and profitability of some crops, these should be promoted among small-scale producers as a way of improving their livelihoods. It is strongly recommended that the government create, using benefits, tax breaks and other incentives, an enabling environment for organic farming as such policies that will encourage more farmers to join organic farming groups and motivate already existing members to continue. The use of knowledge dissemination, product diversification, and value addition using agricultural technologies should be adopted to enhance organic farming systems.

Zusammenfassung

Das Konzept der nachhaltigen landwirtschaftlichen Systeme konzentriert sich auf die Notwendigkeit, Techniken und Praktiken zu entwickeln, die positive Auswirkungen auf soziale Ergebnisse, die Umwelt und die Nahrungsmittelproduktivität haben. In Afrika gibt es nur wenige empirische Studien, die agronomische Praktiken auf ökologischen und nicht-ökologischen Farmen vergleichen. Die vorliegende vergleichende Studie bewertet die Produktivität und Rentabilität ökologischer und konventioneller Anbausysteme, ihre Nachhaltigkeitsleistung sowie die Wahrnehmung der Landwirte in Bezug auf Nachhaltigkeitslücken bei verbesserten Maßnahmen in drei Bezirken Kenias. Empirische Daten wurden auf 849 Farmen gesammelt. Diese kamen zum Einsatz, um i) eine Produktivitätsanalyse durchzuführen, welche die Erträge und Gewinne von zehn gängigen Nutzpflanzen bewertet und ii) eine Bewertung der Nachhaltigkeitsleistung unter Verwendung eines indikatorbasierten multikriteriellen Ansatzes (SMART-Farm Tool) ermöglicht. Letzterer wird herangezogen, um ökologische und konventionelle Anbausysteme auf Farm- und Bezirksebene zu vergleichen. Drittens wurden Feedback-Workshops und intensive Gesprächsrunden mit Landwirten durchgeführt. In diesen Veranstaltungen wurde der Prozess der Optimierung der Nachhaltigkeitsleistung in Bereichen behandelt, welche kritische Werte aufwiesen. Die Sicht der Landwirte auf die Herausforderungen und Chancen im Prozess der Steigerung der Verbessrung der Nachhaltigkeitskriterien stand dabei im Vordergrund. Die Erträge, Kosten, Einnahmen und Gewinne von zwanzig Nutzpflanzen wurde untersucht. Bestimmte Nutzpflanzen, die im ökologischen Landbau angebaut wurden, erwiesen sich als vorteilhafter als die im konventionellen Landbau angebauten Pflanzen. Die Auswirkung auf die Erträge für vier Kulturen, die mit Hilfe des nächsten Nachbarn, des Kernel-Matchings und des Radius-Matchings verglichen wurden, zeigten, dass es eine signifikante Steigerung der Erträge in ökologischen Anbausystemen gab. Der ökologische Landbau steigerte die durchschnittlichen Erträge bei vier Feldfrüchten signifikant: Ackerbohnen (Steigerung um 49,6%), Macadamianüsse (36,6%), Kaffee (37,3%) und Mango (43,1%). Die durchschnittlichen Gewinne von Ackerbohnen/Gartenbohnen stiegen um US$ 994/ha (entspricht einer Steigerung von 35,3%). Ähnlich stiegen die Gewinne für Macadamia-Nüsse um US$ 5.263/ha (entspricht einer Steigerung von 44,4%). Die Propensity-Score-Matching-Sensitivitätsanalyse zeigt, dass die Reduktion der Medianverzerrung bei allen Erträgen größer als 19 % war (Ackerbohnen 19 %, Macadamianüsse 87 %, Kaffee 88 % und Mango 32 %) und bei den Gewinnen größer als 21 % (Ackerbohnen 21 % und Macadamianüsse 61 %). Die starke Reduzierung der Medianverzerrung verbessert die Qualität des Abgleichs.

Die Nachhaltigkeitsbewertung ergab, dass ökologisch wirtschaftende Betriebe bei den Nachhaltigkeitsdimensionen ökologische Integrität, wirtschaftliche Belastbarkeit und Unternehmensführung insgesamt deutlich besser abschnitten als konventionelle Betriebe. Die vierte Nachhaltigkeitsdimension, Soziales, zeigte eine niedrigere Zielerreichungsgrade für ökologische gegenüber konventionellen Betrieben. Bei den Unterthemen und Indikatoren der

Nachhaltigkeit waren einige Werte für ökologische und konventionelle Landwirtschaftssysteme vergleichbar, andere jedoch niedriger für Ökobetriebe. Die Studie identifizierte Nachhaltigkeitsherausforderungen bei den kleinbäuerlichen Betrieben, die angegangen werden müssen. Die wichtigsten Herausforderungen, mit denen sowohl ökologische als auch konventionelle Landwirte im Untersuchungsgebiet konfrontiert sind, lassen sich wie folgt zusammenfassen: Einschränkungen bei technischen und materiellen Inputs, marktbezogene Herausforderungen, mangelnde agronomische Fähigkeiten und begrenzte institutionelle Unterstützung. Zu den von den Landwirten vorgeschlagenen Interventionsbereichen und Strategien gehörten die Erhaltung der Artenvielfalt, die Nutzung und das Management von Wasserressourcen, das Management der Bodenfruchtbarkeit, die Gründung und Aufrechterhaltung von landwirtschaftlichen Verbänden, Diversifizierung, das erschließen alternativer Märkte sowie die Führung von Betriebsbüchern. Andere von den Landwirten vorgeschlagene Strategien beinhalteten Kapazitätsentwicklung und Maßnahmen zur öffentlichen Gesundheit und Sicherheit. Die niedrigen Werte für Indikatoren und deren Subthemen, die in der Nachhaltigkeitsbewertung gefunden wurden, müssen beachtet werden. Die in der Nachhaltigkeitsbewertung identifizierten Einschränkungen können durch die Verbesserung der Anbaupraktiken sowohl in ökologischen als auch in konventionellen Anbausystemen angegangen werden, z. B. durch die Verbesserung des Wissens der Landwirte über die korrekte Verwendung von synthetischen Düngemitteln und Dung sowie die korrekte Verwendung von Pflanzenschutzmitteln, wie z. B. die empfohlene Dosierung und die Einhaltung der Intervalle vor der Ernte. Dadurch wird die Produktion von sicheren und nahrhaften Lebensmitteln sichergestellt. Der Aufbau von Kapazitäten der Landwirte erfordert, dass ein Programm zur regelmäßigen Schulung und Beratung der Landwirte implementiert wird, um die kontinuierliche Verbesserung und Aufrechterhaltung der sich entwickelnden ökologischen Standards zu gewährleisten. Da ökologische Anbausysteme signifikante positive Auswirkungen auf den Ertrag und die Rentabilität einiger Nutzpflanzen haben, sollten diese bei Kleinproduzenten als Möglichkeit zur Verbesserung ihrer Lebensgrundlage beworben werden. Es wird dringend empfohlen, dass die Regierung durch Vergünstigungen und Anreize ein günstiges Umfeld für den ökologischen Landbau schafft. Mehr Landwirte müssen motiviert werden, sich ökologischen landwirtschaftlichen Verbänden anzuschließen und bereits bestehende Mitglieder sollten zur Fortsetzung ihres Engagements ermutigt werden. Die Verbreitung von Wissen, Diversifizierung von Produkten und eine Steigerung der Wertschöpfung durch Einsatz von landwirtschaftlichen Technologien sollte genutzt werden, um ökologische Anbausysteme zu verbessern.

1. Chapter General information

1.1 Motivation

Sustainable agriculture is directly or indirectly emphasized in connection to food production in 12 of the 17 United Nations Sustainable Development Goals (SDGs) (Röös *et al.*, 2019; UNEP-UNCTAD, 2008). Food production while maintaining biodiversity and the ecosystem is one of the biggest constraint facing humanity (Ehrlich, 2008). About 40% of the earth's surface is utilized for agricultural production (Foley *et al.*, 2011). The management of huge tracts of land and the natural resources harvested from them, by farmers and pastoralists, shapes ecosystems, habitats, and landscapes (Bosshard *et al.*, 2009; Dale *et al.*, 2019). To conserve biodiversity and ecosystem services for future generations, agricultural farming methods such as conservation agriculture, precision farming, intensification farming, agro-ecological farming, and organic agriculture have been proposed as alternative, more sustainable farming practices as compared to conventional farming (Latruffe *et al.*, 2016; Pretty & Bharucha, 2014). Since organic production targets the development of a sustainable cultivation-based system, it is a relevant tool to advance the United Nations SDGs on sustainable agriculture, sustainable production and consumption, climate change, and ecosystem management (UNEP-UNCTAD, 2008).

Interactions between farmers (perceptions and goals), the physical environment (land, animals, plants, technology, and climate), and the socio-economic environment (norms, markets, policy) bring about the formation of specific farming systems (Darnhofer, 2005). Information from the ecological, social and economic situation is processed and resolutions are made and applied at the farm-level (Malcolm *et al.*, 2005). Studying productivity, profitability, and sustainability of the complex heterogeneity of agricultural systems brings better understanding and knowledge of these systems (Gaviglio *et al.*, 2017), especially when utilizing revised and improved interpretive methods (Bennet & Franzel, 2013; De Olde *et al.*, 2016). Analysis of the factors that help build the resilience of organic farms that pursue ecologically, socially, and economically sustainable practices can help farmers to redirect their development paths to become even more sustainable (Majewski, 2013; Malcolm *et al.*, 2005). Such an analysis can also help demonstrate to non-organic farmers that they can redirect their development paths to become sustainable.

Farms of different sizes and commercial orientation coexist in any location, and further differentiation over time is driven by the interaction of demographic and economic change

(IFOAM, 2018; Taylor, 2006; Weidmann *et al.*, 2004). Sub-Saharan countries need to devote their efforts to science-based, actionable solutions that are tailored to local situations, and support structural transformations of whole food systems (Taylor, 2006; Weidmann *et al.*, 2004). In Africa, there are limited empirical studies on various aspects of organic agriculture, like environmental sustainability, economic resilience, profitability, and productivity, including production, marketing, and post-harvest management (Lee & Fowler, 2002). In Kenya, only limited information exists on the economic benefits of organic farming and this partly hinders farmers' ability to make decisions in favor of adopting organic production systems. At the same time, organic farming receives limited support by the government and other development agencies (Ndungu *et al.*, 2013; Taylor, 2006; UNEP-UNCTAD, 2008).

1.2 Organic farming in Africa

Africa has a large number of non-certified organic farms that are mainly subsistence farms or provide products to local markets. Such farms are often termed 'organic by default'. Africa also produces organic food (e.g. olives, coffee, cotton, cocoa and palm oil) and non-food products (cotton and medicinal plants) for export, with the European Union as the main procurer (Bouagnimbeck, 2011; Tung, 2018). In 2018, about 2 million ha of agricultural land was under organic farming in Africa, which constituted about 0.2% of the continent's total agricultural area (Willer *et al.*, 2020, pp. 185-200). About 30% of the organic farmland was used for arable crops and there were an estimated 788,858 organic producers in Africa (ibid., pp. 185-200).

1.2.1 Organic farming defined

There is no universally accepted definition of organic farming, but a majority of authors consider it to be a specific production system that aims to avoid the use of synthetic and harmful fertilizers, pesticides growth regulators and livestock feed additives. Organic farming can be defined as an ecological production system which promotes and enhances biodiversity, biological cycles and soil health, and utilizes limited off-farm inputs and farming practices that restore, maintain, and enhance ecological harmony (De Ponti *et al.*, 2012; Lee *et al.*, 2015; Weidmann *et al.*, 2004 ; UNEP/UNCTAD, 2008). IFOAM (2014) defines organic farming as a production system that sustains soil health, ecosystem and humans. The system relies on an ecological processes, biodiversity and locally adapted cycles rather than the use of external inputs with adverse impacts. Organic farming brings together traditions, innovations and science and promotes fair interactions and a good quality of life to all (IFOAM, 2014; Schrama *et al., 2018*). Organic agriculture considers the environment holistically, including its natural cycles and complex food chain (Luttikholt, 2007; Mugivhisa *et al., 2017*). Weidmann *et al.,* (2004) classify organic farming under four main principles, which are the health of soils, plants, animals, and human beings; that every farm is embedded in an ecological context; fairness for all relationships; and care and precaution. Traditional farming practices are low-intensity agricultural production systems. Many traditional farming systems have been replaced with more intensive and mechanized forms of farming, particularly on more productive land (FAO, 2019).

Organic farming is a process that involves adding organic matter (compost, farmyard manure, green manure, and plant residues in the fields as mulch) to maintain soil fertility (Luttikholt, 2007; Pinthukas *et al., 2015*). Organic pest and disease management through strict crop rotation and use of resistant crops and crop varieties is the preferred practice (Rodrigues *et al.,* 2016). The use of beneficial insects and natural enemies of plant and diseases, and mineral or botanical extracts of insecticides and fungicides is promoted (Herath & Wijekoon, 2013). The practice of organic weed management incorporates early weeding adapted soil preparation, crop rotation, plant cover crops, green manures, mulching and maintains plant residues in the fields (Luttikholt, 2007; Malcolm *et al.,* 2005). Organic livestock husbandry includes the use of fodder grasses and legumes, which apart from feed also build soils (nitrogen addition) and aid soil water retention for plant growth (Rodrigues *et al.,* 2016).

Another approach considered alongside organic farming is agro-ecology. According to the FAO (2019), agro-ecology is a set of farming practices (seeking to boost resilience and the ecological, socio-economic and cultural sustainability of farming systems), a social movement (a new way of considering agriculture and its relationship with society), a scientific discipline (the holistic study of agro-ecosystems), or all three as one. The core principles of agro-ecology include planning, resource use, and field and landscape management.

The main supporting ideas and debates surrounding organic agriculture is that whatever the farming system, it shares the common goal of striving for sustainability, which includes environmental aspects and socio-economic considerations for the benefit of present and future generations (Oberč, & Arroyo, 2020).

1.2.2 Farming systems in Kenya

Farming systems are a complex mix of farm enterprises to which farmers allocate their resources in order to efficiently utilize the existing enterprises for increasing the productivity and profitability of their farms (Goswami *et al.*, 2017; FAPDA & FAO, 2014). Farming systems involve the organization of farms and all the enterprises in relationship with each other (FAO & World Bank 2001, pp. 8-10).

Types of farming systems

- Extensive farming systems: - Involves farming using very little inputs to produce the desired products (Dixon *et al.*, 2001).
- Intensive farming systems: - Involves usually commercial production of crops and livestock using large amounts of external inputs on predominantly large farms (Dixon *et al.*, 2001.

The above extensive and intensive systems can be carried out under large scale or small scale farming, depending on the level of technology, availability of land, capital, and skilled labour (Dixon *et al.*, 2001; FAO 1999).

Farming methods practiced in Kenya

- Mixed farming: - Involves growing crops and keeping animals on the same piece of land (Dixon *et al.*, 2001; FAO 1999).
- Nomadic pastoralism: - The moving of livestock from one place to another in search of fresh water and pasture (Dixon *et al.*, 2001; FAO 1999).
- Organic farming: - Involves the growing of crops and rearing of livestock without using agricultural chemicals while observing four principles - health (of soils, plants, animals, and human beings), ecology, fairness, and care (Luttikholt, 2007; Seufert, Ramankutty, & Mayerhofer, 2017).
- Agroforestry: - an integration of land-use systems and technologies where trees, shrubs, palms, bamboos, etc. are used on the same land management units as agricultural crops and livestock crops. i.e. involves the growing of leguminous trees and crops and keeping livestock on the same piece of land (Dixon *et al.*, 2001; FAO 1999).

Crops are either annual crops (grown every year) or perennial crops. The crops found in Kenya can be broadly classified as starchy staples, starchy roots, sugars and sweeteners, stimulants and spices, timber trees, oils and nuts, fruits, fodder/foliage, vegetables, legumes, grains, and fiber (GOK, 2019). Livestock found in Kenya include cattle, sheep, goats, donkeys, camels, ducks, geese, horses, pigs, rabbits, quails, turkey, fish and crabs (ibid.).

1.2.3 Organic farming in Kenya

Organic farming initiatives and organizations that promote organic agriculture began in Kenya in the 1980s. The Kenya Institute of Organic Farming (KIOF) was founded in 1986. In the 1990s, the Kenya Organic Farmers Association was created to support smallholder farmers, while the Kenya Organic Producers Association (KOPA) was created for medium and large-scale farmers engaged in the export market. The Kenya Organic Agriculture Network (KOAN) was established in 2004 as an organic stakeholders' platform to coordinate the organic sector. Along with private sector companies (producing for local and export markets), an ever-growing number of civil society organizations has led to the growth of the organic sector in Kenya.

The organic movement in Kenya has the potential for growth and expansion. The organic potential areas including a lack of capital to invest in external inputs that are often expensive, the ability of farmers to grow crops without external inputs, a rapid emerging local market for organic products, an ever-increasing export market for organic products, and an awareness of the possible negative effects of chemical residues in food (Walaga, 2004). Agricultural land comprises about 48.5% of Kenya's total land area of 569,140 square kilometers (GoK, 2019; KNBS, 2019a, 2019b). Organic farming in Kenya has increased steadily as smallholder farmers shift cultivation practices (Tung, 2018). The total hectares under organic management increased from 4,894 ha in 2014 to 276,113 ha in 2018 (Willer & Lernoud, 2015, 2016, 2017, 2018, 2019; Willer *et al.*, 2020). In 2018, organic farming was practiced on 0.6% of the country's agricultural land with about 37,295 organic producers, including 154,488 hectares under wild collection (Willer & Lernoud, 2019). The wild collections are described in the IFOAM Norms 2014 as wild harvests from a system that is sustainably managed and does not surpass the sustainable return of the ecosystem or impend existence of plant, fungal or animal species, including those not directly exploited (IFOAM, 2014).

1.2.4 Organic markets and certification in Kenya

Organic markets in Kenya are largely formal and export-orientated, requiring certified and labeled products. Organic products range from vegetables, fruits, essential oils, nuts, spices, dried and fresh herbs, plus products for the cosmetic and pharmaceutical industry (Herath & Wijekoon, 2013; Weidmann *et al.*, 2004). The certification process is essential in organic farming. A certification body/organization assesses the product to verify its production as per the rules of the organic standard followed (Herath & Wijekoon, 2013; Weidmann *et al.*, 2004). The standard describes in detail how a product must be produced, processed, and packaged for it to be labeled and sold as organic. In Kenya, the main standard regulatory authority is the Kenya Bureau of Standards (KEBS). It has recognized the National Organic Standard of Processing and Production and the East African Organic Products Standards (EAOPS) as standards that guide the organic sector (Tung, 2018; UNEP-UNCTAD, 2008). Certified organic products are sold at a premium price. The standards regulate the control and certification process that farmers or groups of farmers go through to acquire organic certification labels. Training of farmers is necessary for the certification of the product.

East Africa Organic Products Standard (EAOPS) 2007

The EAOPS is a multi-country organic standard for Burundi, Rwanda, Tanzania, Uganda, and Kenya (EAC, 2007; Tung, 2018; UNEP-UNCTAD, 2008). The EAOPS label is EAS456: 2007 Kilimo Hai (which means living agriculture in Kiswahili). The standard provides the general requirements for organic production of crops and animals, beekeeping and wild collections, handling, storage, and processing. It gives guidance on labeling and includes the International Federation of Organic Agriculture Movement (IFOAM) principles of organic agriculture, a list of substances allowed in organic plant production, a list of natural substances not allowed in organic plant production, and a list of extracts and processing aids for organic food processing (EAC, 2007).

The EAOPS borrows heavily from the European Union Organic Food and Farming Standard Council Regulation (EC) 834/2007 on organic food and production labeling, since the European Union organic framework needs enforcement of its standards by its Member States, including a checkup process supervised by competent national authorities (European Commission, 2013). The EAOPS also incorporates the best practices from the organic equivalence tools of UNEP-UNCTAD, and the Pacific Organic Standard (POS) (Tung, 2018). The EAOPS can be used for self-assessment by the producer’s declaration of conformity, in line with organic principles, certification bodies, or means of verification (project plan and log frame). When third-party certification, inspection, and certification are carried out the parties concerned must follow the international norms throughout the process (ISO Guide 65 or the IFOAM accreditation criteria) (EAC, 2007). The EAOPS lists the areas in which it can be used for international negotiations on standards as well as for agreements with other countries and regions (EAC, 2007).

1.3 Sustainability concepts and assessment

1.3.1 Definitions of sustainability

There is no universally accepted definition of sustainability. Some authors define sustainability by reference to the functioning of natural systems, which remain diverse and produce everything needed for the environment to remain in balance (Häni *et al.*, 2003; Smith *et al.*, 2019).

The Brundtland Report's 1987 definition of sustainability is widely used:

> *Sustainability, therefore, is much more than ensuring the protection of the natural resource base. To be sustainable, agriculture must meet the needs of present and future generations for its products and services, while ensuring profitability, environmental health, and social and economic equity. Sustainable agriculture would contribute to all the four pillars of food security – availability, access, utilization, and stability – in a manner that is environmentally, economically and socially responsible over time (Brundtland, 1987; FAO, 2012).*

The value of the term 'sustainability' is that it gives equal weight to all its three dimensions, i.e. environment, economy and society; not primacy to just one, i.e. the economy (Conway & Wilson, 2012; FAO, 2012).

Various authors have defined sustainability in diverse ways according to the context, relevance or process about which they write (Binder *et al.,* 2010). López-Ridaura *et al*. (2002) define sustainability by including seven general attributes of a natural resource management system, namely resilience, productivity, reliability, adaptability, stability, equity, and self-reliance. Rasul and Thapa (2004) define sustainable agriculture as a system that makes use of a farm's internal resources, incorporating the natural process into agricultural production and greater use of improved knowledge and practices. Häni *et al.* (2003) define sustainable agriculture as one that adopts productive, competitive, and efficient production practices while protecting and improving the natural environment and ecosystem as well as the socio-economic conditions of local communities.

Debates continue over the meaning and definition of sustainability to refine it further. For example the 10 elements of agro-ecology (FAO 2019) which guide policy makers, practitioners and stakeholders to plan, manage and evaluate agro ecological systems. Some academics question the feasibility of the proposed solutions to farming in the face of other societal grand challenges related to the food system, such as food security for all (Elzen *et al.*, 2011; Garnett *et al.*, 2013; Levin *et al.*, 2012). Because of the lack of consensus on this issue, sustainable agriculture can be considered a priority area for making iterative improvements, or incremental innovations, to current agri-food systems (Busch, 2012, Grin *et al.*, 2010). Specifically, sustainable agri-food systems are required to ensure that the negative environmental effects of production are limited while also providing economic benefits and socially appropriate solutions to the challenges of food security (FAO, 2014a, 2014b). However, within the space of political commitment to sustainable agriculture, more evidence is required on how farmers and organizations can transit towards practicing sustainable agriculture and, more specifically, on the motivations and driving forces needed for them to do so.

In this study, the working definition of sustainability is the integration of environmental, economic, social well-being and governance aspects, in order to create thriving, healthy, diverse and resilient societies in this generation and the next (Binder *et al.,* 2010; De Olde *et al.,* 2016; Schader *et al.*, 2014). In this sense, it improves on the narrow perspective of most agricultural science assessments, which tend to privilege only the economic dimension through a focus on yields and (narrowly defined) profits. The scope, context and tools to assess sustainability requires further conceptualization of how sustainability at the farm level is to be measured.

1.3.2 Methods for sustainability assessments of agriculture

Sustainability is measured at different levels, from the farm to the national and regional level (Binders *et al.,* 2010). A good number of sustainability assessment tools and frameworks exist to support decision making in agriculture (Pope *et al.,* 2004). Similarly, a wide range of tools has been developed to provide an in-depth picture of the sustainability of agricultural systems (Binder *et al.,* 2010; Schader *et al.,* 2014; De Olde *et al.,* 2016). The target groups are usually farmers or policy-makers who are directly or indirectly involved in discussions on the selection of indicators, aggregation and weighing methods, and time required for the implementation of sustainability tools and the outcomes of the assessment (Marchand *et al.*, 2014; Schader *et al.,* 2014). New ways of acting, designing, and assessing sustainability have emerged, from partial approaches (only environmental) to those that tackle the whole complexity (environmental, social and economic), e.g. González de Molina (2013). Many approaches and frameworks cover the three dimensions, such as poverty impact assessments (OECD, 2008), the framework for participatory impact assessment (Morris *et al.,* 2011) or participatory impact pathways analyses (Douthwaite *et al.*, 2007a, 2007b, and Alvarez *et al.*, 2004). However the number of indicators or variables that measure sustainability are limited. Schader *et al.* (2014) calculated that there were over 35 different approaches to sustainability assessment existing but that the scope and context by which users give meaning to these approaches limits the use of the results of such assessments.

A shift to indicator-based sustainability assessments has become popular in recent years (Binder *et al.*, 2010; Trisete *et al.*, 2014; Schader *et al.*, 2014; Gasporatos *et al.*, 2012). Indicators are considered the tools for the measurement of sustainability (Freyenberg *et al.*, 1997). There is a continuous discussion among different scholars on methods, approaches, and tools including indicator selection, stakeholders' participation, aggregation and normalization methods (de-Olde *et al.*, 2016; Whitehead, 2017), as well as the feasibility of various tools to measure sustainability (Sieber *et al.*, 2017; Waas *et al.*, 2014).

Table 1.3-1 presents a summary list of 23 sustainability assessment tools or approaches used to measure sustainability at different levels, including the dimensions covered, coverage, and suitability. The sustainability assessment methods/tools or approaches by Zahm *et al.* (2008); Gerrard *et al.* (2012); Coteur *et al.* (2016); Häni *et al.* (2003); Genz *et al.* (2009); Van Cauwenbergh (2007); FAO (2014) and Schader *et al.* (2016) utilized a structured system of evaluating sustainability. The sustainability assessment methods were either universal or only applicable to a specific geographical area.

Table 1.3-1: A summary list of sustainability assessment tools

Name	**Measurement level**	**Dimension**	**Coverage**	**Suitable in Europe/ Other countries**	**Reference**
AESIS (Agro-Environmental Sustainability Information System)	Farm	Environmental	Universal	Yes/No	Pacini *et al.* (2009); Pacini *et al.* (2011)
APOLA-NOVORURAL The System for Weighted Environmental Impact Assessment of Rural Activities	Farm	Environmental, Economic, Social	Universal	No/Yes	Rodrigues *et al.* (2010)
ARBRE *(Arbre de l'Exploitation Agricole Durable)*	Farm	Environmental, Economic, Social	Universal	Yes/No	Pervanchon (2005)
AVIBIO *(AVIculture BIOlogique)*	Farm, chain	Environmental, Economic, Social	Poultry	Yes/No	Pottiez *et al.*(2012)

Name	Measurement level	Dimension	Coverage	Suitable in Europe/ Other countries	Reference
COSA (Committee On Sustainability Assessment)	Farm	Environmental, Economic, Social	Coffee and Cocoa	No/Yes	COSA (2013)
Methodological approach to assess & to compare the sustainability level of agricultural plant production systems	Farm, regional	Environmental, Economic, Social	Plant, production	Yes/No	Dantsis *et al.*(2010)
DELTA (Integrated Indicator-Based Self-Assessment Tool for the Evaluation of Dairy Farms Sustainability)	Farm	Environmental, Economic, Social	Dairy	Yes/No	Bélanger *et al.* (2015)
DSI (Dairyman Sustainability Index)	Farm	Environmental, Economic, Social	Dairy	Yes/Yes	Elsaesser *et al.* (2015)
IDEA (Indicateur de Durabilité des Exploitations Agricoles)	Farm	Environmental, Economic, Social	Universal	Yes/Yes	Zahm *et al.*(2008)
ISAP (Indicator of Sustainable Agricultural Practice)	Farm	Environmental, Economic, Social	Horticulture	Yes/No	Rigby *et al.* (2001)
LCA (Life Cycle Assessment)	Product	Environmental	Universal	Yes/Yes	van der Werf *et al.*, 2020
MAUT (Multi-Attribute Utility Theory)	Farm	Environmental, Economic, Social	Dairy	Yes/No	Van Calker *et al.* (2006)
MESMIS (Framework for Assessing the Sustainability of Natural Resource Management Systems)	Farm, local	Environmental, Economic, Social	Smallholder	No/No	López-Ridaura *et al.* (2002), Speelman *et al.* (2007)
MMF (Multiscale Methodological Framework)	Farm, local, regional	Environmental, Economic, Social	Smallholder	No/No	Lopéz-Ridaura *et al.* (2005)
MOTIFS (Monitoring Tool for Integrated Farm Sustainability)	Farm	Environmental, Economic, Social	Dairy	Yes/No	Meul *et al.*(2008)
PG (Public Goods Tool)	Farm	Environmental, Economic, Social	Universal	Yes/Yes	Gerrard *et al.*(2012)
RAD *(Réseau del'Agriculture Durable)*	Farm	Environmental, Economic, Social	Dairy	Yes/No	Le Rohellec & Mouchet (2008)

Name	Measurement level	Dimension	Coverage	Suitable in Europe/ Other countries	Reference
RISE (Response-Inducing Sustainability Evaluation 2.0)	Farm	Environmental, Economic, Social	Universal	Yes/Yes	Häni *et al.* (2003)
SAT (Sustainability Assessment tool)	Farm	Environmental, Economic, Social	Fruit, arable, greenhouse	Yes/No	Coteur *et al.* (2014)
SAFA (Sustainability Assessment of Food and Agriculture Systems)	Farm, chain	Environmental, Economic, Social, Governance	Universal	Yes/Yes	FAO (2013)
SAFE (Sustainability Assessment of Farming and the Environment)	Farm, landscape, regional	Environmental, Economic, Social	Universal	Yes/No	Van Cauwenbergh *et al.* (2007)
SMART-Farm Tool (Sustainability Monitoring and Assessment RouTine)	Farm, local, regional, product	Environmental, Economic, Social, Governance	Universal	Yes/Yes	Schader *et al.*, 2016, Schader *et al.*, 2019

The sustainability assessment methods differ in their general objectives, target audience, issues addressed, and indicators, and in the way they are structured. For example, IDEA has components, objectives and indicators, PG has themes and activities, SAT has topics, themes, sub-themes and indicators, RISE uses pillars, indicators, state parameters, driving force parameters, SAFA uses principles, criteria indicators, reference values, themes and pillars, and the SMART-Farm Tool uses dimensions, themes, sub-themes and indicators (Zahm *et al.*, 2008; Gerrard *et al.*, 2012; Coteur *et al.*, 2016; Genz *et al.*, 2009; van Cauwenbergh, 2007; FAO, 2014; Schader *et al.*, 2016; van der Werf *et al.*, 2020).

The Parameters for measuring sustainability vary depending on the criteria, scope, context, or geographic location (Binder *et al.*, 2010; Schader *et al.*, 2014). Lee and Fowler (2002) draw up three main techniques of comparing organic and conventional production systems by conducting farm surveys, field studies, and case studies. They add that farm surveys are widely used in comparison to the others types and utilize methodologies such as sample groups, matched pairs, or clustered groups. Field studies utilizing field experiments have been criticized for ignoring the holistic nature of organic farming and for lacking experiential learning effects (Shadbolt *et al.*, 2009). They result in poor modeling that may not enable statistical comparisons and statements due to variations in weather and rotations (Delate *et al.*, 2002; Schader *et al.*, 2016; FAO, 2014c). Case studies are limited because of the scope, context, climatic or geographic locational differences of variables to compare the matching systems (Shennan *et al.,* 2017).

The results of a sustainability assessment, when translated into action, can guide policy-makers in their decisions to strengthen farming systems, while reflecting trade-offs between the ecological, economic and social dimensions of sustainability (Hanuš, 2004; Malcolm, 2005; Li *et al.,* 2010; Perez *et al.,* 2015). Indicators should assist in identifying policy fields where action is needed and in monitoring the impact of policy action that makes it visible to the broader public (Hanuš, 2004). Data and decision tools for assessing the various trade-offs and improving management decisions, productivity and environmental sustainability, need to be constantly improved (Foley, 2011).

The purpose of my study is to make a comparative evaluation of organic versus conventional farming systems in Kenya. The study contributes to the knowledge gap on profitability, economic resilience, and environmental sustainability of organic versus conventional farming systems. It seeks to provide evidence-based data that can back the formulation of an organic policy framework in Kenya and improve decision making at the farm level.

There is a general agreement in the sustainability discourse that policymakers have not equally prioritized the different dimensions of sustainable development (EAC, 2007; Malcolm *et al.,* 2005; Perez *et al.,* 2015). Most studies have favored environmental aspects with fewer studies on economic and social aspects, or where the latter have been studied they were treated separately (Singh *et al.,* 2012). Some sustainability assessment methods have methodological or conceptual limitations while others are limited by data availability (Bene *et al.,* 2020; Gasparatos *et al.,* 2012; Pollesch *et al.,* 2015). This study considers sustainability in a holistic manner and uses different approaches to measure it using a hierarchical framework of principles, criteria, and indicators. The results of the assessment are also easy to interpret and use. The Sustainability Monitoring and Assessment RouTine (SMART-Farm Tool) (Schader *et al.,* 2016; Ssebunya *et al.,* 2018), an indicator-based multi-criteria assessment tool, was used to assess sustainability at the farm-level. The division of indicators along the lines of the sustainability dimensions highlights the multi-dimensional nature of sustainable development and mirrors the importance of incorporating its dimensions (Hanuš, 2004; Schader *et al.,* 2016). In terms of the number of households and counties covered, this is the largest study to compare organic and conventional farming systems in Kenya. Data from 849 farms spread across three counties (Murang'a, Kirinyaga, and Machakos) was analyzed. On-farm operations' productivity and profitability are assessed, the SMART-Farm Tool is used to analyze the sustainability performance of farms, and intervention measures farmers can apply to improve sustainability gaps are identified from the results of farmer workshops

1.4 Research questions and objectives, and outline of the thesis

The purpose of this study was to assess the productivity and profitability of organic versus conventional farming systems, their sustainability performance, and farmer perceptions on sustainability gaps for improved intervention in three counties of Kenya. It aimed to contribute to the sustainability knowledge gap in aid of better decision making in the policy sector and at the farm level for farmers in Kenya. The study sought to provide evidence-based data that can back the formulation of an organic policy framework as well as improve decision making at the farmer level on sustainable farming. Three research questions guided the study.

1.4.1 Research questions and objectives

Research question 1: How productive and profitable are organic compared to conventional agricultural systems in Kenya?

Objectives

The farm is taken as a business entity where decisions are made for short- or long-term investments (Malcolm *et al.,* 2005; Ash *et al.,* 2017). Productivity and profitability are still the most important – and are by far the most commonly used – indicators in assessing the success or failure of crop production (Berhane *et al*., 2015; Greer & Hunt, 2011). Productivity is measured as the output of a system or crop output (yield of crop per ha) in a season or year (Greer & Hunt, 2011; Seufert *et al.,* 2012). The analysis of the gains or losses is referred to as profitability analysis. Profitability analysis primarily involves developing models that depict business problems. The analysis involves assessing the right profitability measures that optimize business performance (Ash *et al.*, 2017). As such, it is a move from merely a costing-oriented profitability reporting exercise to a forward-looking profitability modeling paradigm. The use of statistical and advanced analytical techniques allows the better prediction of profitability outcomes and thereby helps optimizing resource inputs; another method is the application of profitability analysis to all other enterprise management processes such as planning, consolidation and control, and strategy management (Ash *et al.,* 2017; Li *et al.,* 2010).

1. *To evaluate the productivity of organic and conventional farming systems in Kirinyaga, Machakos, and Murang'a counties of Kenya*
2. *To evaluate the profitability of organic and conventional farming systems in Kirinyaga, Machakos, and Murang'a counties of Kenya*

Research question 2: How sustainable are organic compared to conventional farming systems in Kenya?

Objectives

Sustainability in this study is a process of evaluating how a system performs given certain variables. The sustainability assessment chosen for this study utilizes a set of parameters to measure how farm systems perform in terms of environmental integrity, economic resilience, social well-being and governance aspects based on the FAO-SAFA Guidelines (FAO 2013a). To evaluate the sustainability of organic compared to conventional agricultural systems in Kenya at the farm-level, this study utilizes a farm survey technique where organic and conventional farms are grouped at the same point in time. The results of the farm survey are fed into the SMART-Farm Tool to perform the sustainability assessment.

1. *To evaluate the sustainability performance of organic compared to conventional agricultural farming systems in Kenya*
2. *To determine the differences in the performance between organic and conventional farming systems in the three counties of Murang'a, Kirinyaga and Machakos*

Research question 3: What measures can farmers undertake to improve sustainability in the study sites?

Objective

Sustainability assessment results are meaningful to the implementer of the results, in this case farmers, only when feedback is provided for them to opt for different alternatives to better their current situation. Decisions on how to improve in areas in which a farm is under-performing are guided by exactly how best the farm manager or owner comprehends the implications of the outcomes and what they mean. The full-, partial- or non-adoption of a measure is pegged on a farmer's know-how or willingness to seek information or the services that they require. The sustainability gaps in the four sustainability dimensions (environmental integrity, economic resilience, social well-being and governance) are first identified. The challenges, improvement measures, reasons for low adoption, and requirements to increase the likelihood of adoption are examined during workshops with farmers.

2 *To establish the sustainability gaps and the measures that farmers are likely to adopt to address those gaps*
3 *To determine the potential challenges, strategies, and responsibilities for the implementation of the defined intervention measures in Murang'a, Kirinyaga and Machakos counties*

1.4.2 Structure of the dissertation

Guided by the research questions this dissertation is organized into five chapters to address the research questions. This introduction (Chapter 1) describes the background and presents the literature review, research questions, and study area. The productivity and profitability of organic versus conventional agricultural systems in Kenya are addressed in Chapter 2. Chapter 3 addresses the second research question on the sustainability performance of organic versus conventional farming systems in Kenya. Chapter 4 addresses the strategies and intervention measures farmers can take-up to improve sustainability on their farms. Chapter 5 summarizes the main findings of the thesis and presents some conclusions and recommendations.

1.5 Methodology

1.5.1 Description of the study area

The primary data was collected from October 2014 to April 2017 using a structured questionnaire for the productivity and profitability study, while the sustainability assessment study was carried out between January and March 2017. The field research was carried out in three Kenyan counties, Murang'a, Kirinyaga and Machakos (Figure 1.5-1). The three counties differ in terms of agro-ecological, climatic, and farming characteristics (Jaetzold & Schmidt, 2011a, 2011b, 2011c; KNBS 2015a, 2015b, 2015c). Murang'a and Kirinyaga fall in a humid agro-ecological zone while Machakos is located in an arid and semi-arid zone (Table 1.5-1). The study sites had different organic farming systems in place due to the predominance of certain crops, climatic and other conditions, and the presence of non-governmental organizations (NGOs) and their role in enhancing the skills of farmers. At the time of the study, the Organic Agriculture Centre of Kenya (OACK) in Murang'a had trained farmers as organic but they remained non-certified. In Kirinyaga the Limbua Group (formerly Macadamia Fans) had worked with farmers to create organic farms certified by Ecocert group (an organic certification body based in Europe). In Machakos, farmers had been trained under the

Sustainable Agriculture Community Development Programme (SACDEP). SACDEP had ended in 2009 and the farmers could not maintain their organic certification however they had continued to farm organically.

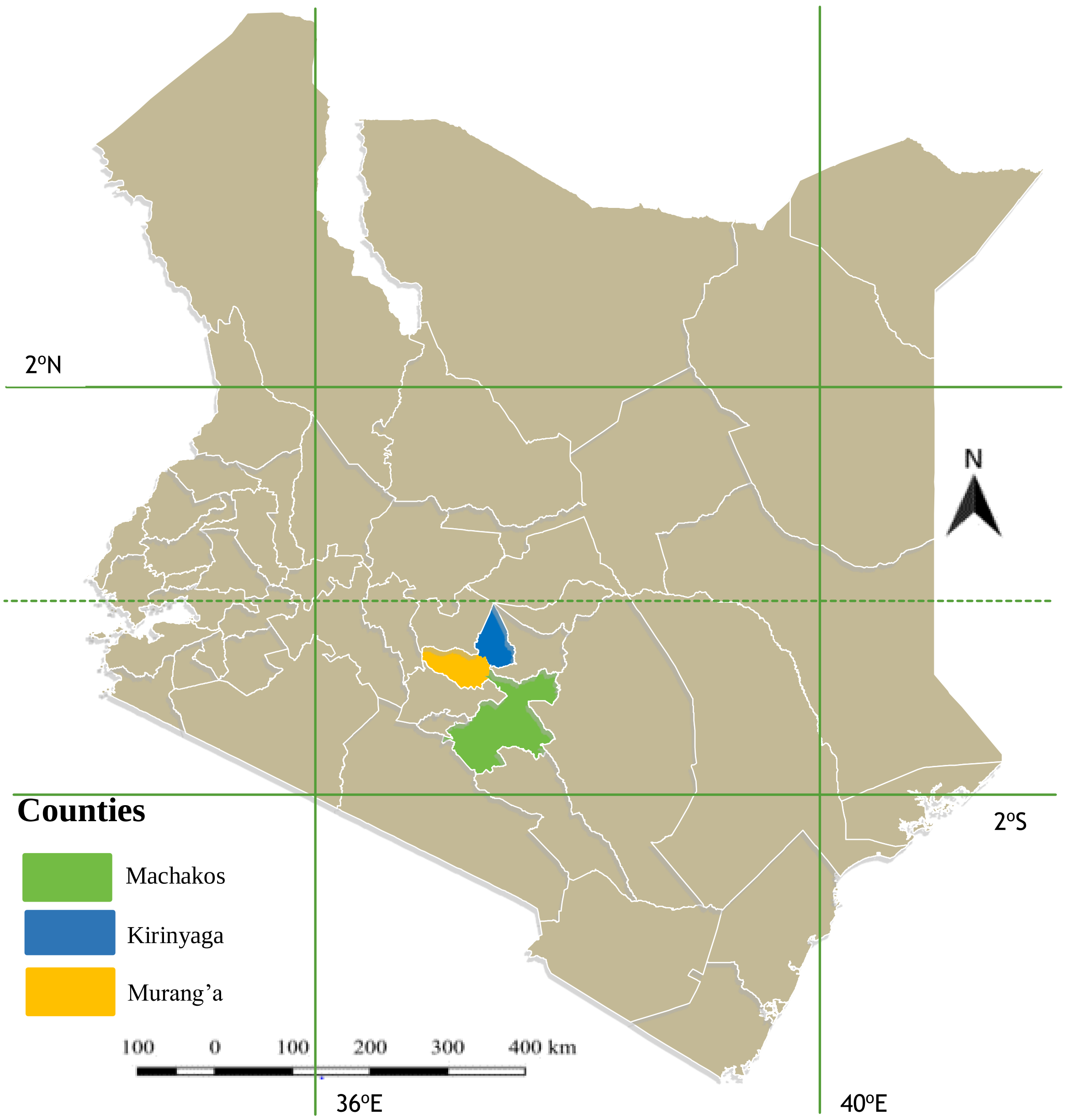


Figure 0-1: Map of Kenya showing study counties

Table 0-1: Characteristics of the study sites

Characteristics	Machakos	Murang'a	Kirinyaga
Sub-County	Yatta	Kigumo	Kirinyaga East
Agro-ecological zone	Arid and semi-arid zone	Humid	Humid
Main crops grown	Maize, cassava, beans, cowpea, pigeon pea, green gram, chili pepper, mango, citrus, lemon, banana	Maize, arrow roots, Irish potato, beans, cabbage, kale, banana, avocado, tea, coffee	Maize, beans, banana, coffee, tea, French beans, avocado, macadamia nut, kale, tomato
Organization initiating the organic project	SACDEP (Sustainable Agriculture Community Development Programme) Kenya	OACK (Organic Agriculture Centre of Kenya)	Limbua Group (formerly Macadamia Fans)
When was the project or organic initiative initiated?	Early 2007	In 2006 awareness and farmers' sensitization meetings held; from 2008 to the present day farmer recruitment and training	Early 2010 awareness raising, followed by farmer training
How farmers taking part in the initiative were selected	Applied for partnership with the organization	Interested in being trained in organic farming after an awareness and sensitization campaign	Applied for partnership with the organization
Reasons farmers joined the initiative	Belief that organic production is the most ideal, sustainable, and healthy way of farming Learned that organic products fetch premium prices	To learn new ideas and skills that could improve their farming methods	Offer of fairer prices, extension services, and capacity building For a healthy farming option
Current status 2019 (any differences between villages?)	The SACDEP initiative fizzled out late in2009 due to lack of organized market. Some farmers originally trained by SACDEP continued with organic production, training new ones.	Some villages have well-developed infrastructure i.e. good roads, electricity, water and market linkages. while other areas are remote	Ecocert group organic certification from 2016 covered all farms (the certificate ensures an environmentally friendly products, which the standard lays down)
Certification of organic system	Non-certified (formerly certified)	Non-certified	Certified
Number of farms exposed to the intervention	500	10,000 approx.	3,000
Number of organic farms at the time of the study	266	2,500 approx.	2,000 (certified)

1.5.2 County descriptions

Murang'a

Murang'a County lies between latitudes 0°34′ and 1°7′ South and longitudes 36°36′ and 37°27′ East. Occupying a total area of 2,558.8 km^2 (MCDIP, 2017b; KNBS, 2015), the county lies between 914 meters above sea level (MASL) in the east and 3,353 MASL along the slopes of the Aberdare Mountains in the west. The county is divided into six agro-ecological zones. Agro-ecological zone one (AEZ 1) consists of the highlands where forestry, tea, and the tourism industry form the most important economic activities (MCDIP, 2017b; KNBS, 2015. AEZs 2 and 3 are the lowlands east of the Aberdare Mountains, generally suitable for both coffee and dairy farming (MCDIP, 2017b; KNBS, 2015). The flatter area of the Makuyu division of Maragwa constituency is characterized by arid and semi-arid conditions (MCDIP, 2017b; KNBS, 2015). This area forms AEZs 4, 5, and 6. In these zones, coffee and pineapple plantations thrive through irrigation (MCDIP, 2017b; KNBS, 2015). The total area under food crops farming is 180,225 ha, and 42,980 ha is under cash crop farming (MCDIP, 2017b; KNBS; 2015). Food crop farming is practiced in all parts of the county, but cash crop farming is practiced in the upper and some lower zones of the county (MCDIP, 2017b; KNBS, 2015). The main livestock bred in the county include cattle, pigs, goats, sheep, rabbits, and chickens. The county has five indigenous gazetted forests covering a total area of 254.4 km^2. It has 108,352 ha under farm forestry while 11,156 ha are under organic farming (MCDIP, 2017b; KNBS, 2015).

Kirinyaga

Kirinyaga County is located between latitudes 0°1' and 0°40' South and longitudes 37° and 38° East. The county covers an area of 1,478.1 km^2 and lies between 1,158 and 5,380 MASL in the south and at the peak of Mt. Kenya, respectively (KCIDP, 2017; KNBS, 2015). The county can be divided into three ecological zones; the lowland, midland and highland areas. It has a tropical climate and an equatorial rainfall pattern with two rainy seasons. The long rains are characterized by average precipitation of 2,147 mm per month which occur between March to May. The short rains with an average precipitation of 1,212 mm per month occur in October and November (KCIDP, 2017; KNBS, 2015). The most important crops are rice, coffee, bananas, tomatoes, beans, mangoes, maize and other horticultural crops (KCIDP, 2017; KNBS, 2015). The total arable land in the county is 116,980 ha, which represents 79% of the total land area. The main types of forests are indigenous natural forests that cover an area of 35,876 ha, plantations (1,540 ha), bamboo forests (7,500 ha), bushland/grassland forests (6,956 ha) and tea zone forests that cover 290 ha (KCIDP, 2017; KNBS, 2015). Certification for organic farming under macadamia nut was first carried out by IMO (Institute for Market Ecology) and later by Ecocert (which expanded the certification to avocado too). Groups of tea and coffee producers were certified by the Rainforest Alliance.

Machakos

Machakos County lies between latitudes 0º45´ and 1º31´ South and longitudes 36º45´ and 37º45´ East. The county covers an area of 6208.2 km², with most of it being semi-arid (MCIDP, 2017; KNBS, 2015). The county receives bimodal rainfall with short rains from October to December and long rains from March to May. The average annual rainfall is between 500 to 1300mm and is unevenly distributed and unreliable (MCIDP, 2017; KNBS, 2015). The temperature varies between 18 and 29˚C throughout the year. The coldest month is July and the warmest months are October and March before the onset of the rains. Dry periods are experienced from February to March and August to September (MCIDP, 2017; KNBS, 2015). Agriculture is the predominant economic activity in terms of employment, food security, and income earnings. The main cash crops include sorghum, French beans, coffee and pineapple while the main food crops normally grown on small scale are maize, common bean, pigeon pea and cassava (MCIDP, 2017; KNBS, 2015). The total arable land in the county is 372,020 ha, of which 248,333 ha is under crop production. The total area under food crops is 161,695 ha, and under cash crops 86,638 ha. The average farm size under small-scale farming is 0.76 ha while large farms occupy about 10 ha (MCIDP, 2017; KNBS, 2015). According to the 2009 Kenya population and housing census, the number of livestock in the county was cattle 230,891, sheep 126,608, goats 629,974, indigenous poultry 862,592, pigs 4,026, donkeys 21,336 and beehives 46,370.

1.5.3 Farm Selection for the study

Kenya has 47 counties and many NGOs working on organic farming. This study selected three counties, each with different NGOs working with correspondingly different approaches to organic farming. The study is more representative because a) it compares organic and conventional farming, and b) it includes a county level analysis. The Kenya Organic Agriculture Network (KOAN) has over 200,000 farmers, exporters, and works with partner organizations throughout Kenya. Murang'a, Kirinyaga, and Machakos counties were selected because they have the highest number of organic farms in the country. The initial meetings was with KOAN since known for its work with Organic NGOs and organic farmers are registered with them as organic producers. Other meetings were held with the Organic Agriculture Centre of Kenya (OACK) in Murang'a, Limbua Group (formerly Macadamia Fans) in Kirinyaga, and SACDEP in Machakos, clarified where organic farming is concentrated in each of the counties. The largest number of organic farms are found in the sub-counties Kigumo (Murang'a County), Kirinyaga East (Kirinyaga County), and Yatta (Machakos County). A list of organic farmers was compiled by the NGO partners, while the Ministry of Agriculture, Livestock and Fisheries (MoAL&F) compiled a list of conventional farmers for each of the three sub-counties. The two lists were subjected to simple random sampling. From a total number of over 3500 farmers, 900 organic and conventional farmers were selected: 390 organic farmers and 510 conventional farmers (Table 1.5-2). There were few farms that met practiced organic farming thus included all those willing organic farmers. The voluntary farm were practicing organic at least 3years prior to the start of the study.

Table 0-2: Sample frame of farmers and final selection

County	Sourced by partners		After applying Simple random sampling		Further analysis using a selection criterion	
	Organic	Conventional	Organic	Conventional	Organic	Conventional
Kirinyaga	378	952	220	409	150	150
Machakos	111	492	90	410	90	210
Murang'a	200	263	200	248	150	150
Total	689	1707	510	1067	390	510

It is harder to identify organic farmers than conventional farmers because they are fewer in number. The identified organic farmers were subjected to an extra criterion; the farms in Murang'a must be growing cabbages, in Kirinyaga macadamia nuts, and in Machakos mangoes. These were the most common crops in each respective county according to secondary information (KNBS, 2015). In addition, a farm size selection criterion was included to ensure we had only small-scale farmers. In Murang'a, the farms had to have 0.25 to 3 acres of land under cabbage crop, while in Kirinyaga the farms had to have between 5-50 macadamia trees. In Machakos the farms had to have between 5-100 mango trees.

2. Chapter : Productivity and profitability in organic and conventional farming systems in Kenya

2.1 Introduction

Sub-Saharan Africa (SSA) is faced with the challenge of feeding its rapidly growing population of over 1 billion people (Baquedano *et al.*, 2020; FAO, 2020). SSA has the largest number and highest share of its population that is food insecure in the world (Baquedano *et al.*, 2020; FAO, 2020). Among the SSA regions, East Africa has the most food-insecure people (Baquedano *et al.*, 2020). The situation is made even worse by a growing trend in the prevalence of hunger, worsened by conflict, climate extremes, and economic slowdowns, and at times a combination of these challenges (FAO, 2020). Thus drastic transformations in the agricultural sector are needed to catalyze the sector's growth by targeted research and effective policies to ensure that the region can sustainably provide adequate nutritious food, feed, fiber, and fuel for its population (Mueller *et al.*, 2012; Müller *et al.*, 2018; Reganold & Wachter, 2016).

Agriculture is a major driver of the Kenyan economy and is the dominant source of employment (Wankuru *et al.*, 2019). The agriculture sector contributes on average 21.9% of gross domestic product (GDP), with at least 56% of the total labour force employed in agriculture in 2017 (Wankuru *et al.*, 2019). Kenya's agriculture sector is faced with constraints that affect production, inputs, post-harvest processing, and access to markets (KNBS, 2020). Production constraints include an unpredictable climate, pests and diseases, low soil fertility and land fragmentation. Input challenges include a narrow technology horizon, use of low yielding varieties, limited extension services, input price volatility, and poor mechanization in the post-harvest stage (limited and poor pre- and post-harvest handling technologies including inappropriate storage leading to losses, insufficient aggregation centres, and limited mechanization across the value chain) (KNBS, 2020; GOK, 2019). Further constraints include a limited range of products, and an unorganized marketing system (poor market access, policy regulatory shifts, and crop price volatility) (GOK, 2019).

The intensive use of natural resources by conventional farming methods lead to high pollution of soils, water, and air, chemical residuals in food, increased depletion of natural resources (like oil, gas, and coal), and an increased social cost of production (Crowder & Reganold, 2015; Godfray *et al.*, 2010; Rockstrom *et al.*, 2009). Alternative farming methods such as organic farming that are more environmentally friendly and health cognizant are on the rise (Berhane *et al.*, 2015; Crowder & Reganold, 2015; Tanrivermiş, 2006). Organic farming has the potential benefits of ecological protection, preservation of non-renewable resources, improved food quality, decrease in output surplus products, and reorganization of market demand (Berhane *et al.*, 2015; Brzezina *et al.*, 2016;

Tanrivermiş, 2006). The demand for organic foods in the world is evident and rising (Crowder & Reganold, 2015; Meemken & Qaim, 2018; Seufert & Ramankutty, 2017). Studies that provide science-based evidence of the productivity and profitability of organic farming systems help guide the agricultural sector in a more sustainable direction; however such studies are few in number (Ahmad & Heng, 2012; Gomiero *et al.,* 2011).

Organic farming offers several direct benefits to producers, such as reduced external input costs, improved agricultural techniques, and improved quality of the environment and food (Tanrivermiş, 2006). However, there are very few studies that provide science-based evidence of the productivity and profitability of organic farming systems (Crowder & Reganold, 2015; Seufert & Ramankutty, 2017; Smith *et al.,* 2019), especially in non-industrialized countries which represent only a small fraction of the overall scientific literature on the topic (De Ponti *et al.*, 2012; Ponisio *et al.*, 2014). The meta-analyses by Seufert and Ramankutty (2017) and Te Pas and Rees (2014) on yields and profits; and Crowder and Reganold (2015) and Meemken and Qaim (2018) on profitability, were done using datasets from Europe, the USA, and Asia and contribute to a huge dataset. However data from Africa is limited to a few studies.

Studying farmer practices gives the realities or the true picture of the operations and challenges experienced in each farming system (Reganold & Wachter, 2016; Shennan *et al.*, 2017). In Africa the few studies done can be grouped into field experiments (Adamtey *et al.*, 2016; Cavigelli *et al.*, 2013), on-farm studies (Ndungu *et al*., 2013), case studies (Chiputwa *et al.*, 2014), adoption studies (Ahmad & Heng, 2012) or farmer experiences' studies. These studies are done either with a combination of a single crop or multiple crops, looking at either organic and conventional crops or organic on its own; but few compare organic and conventional farming systems. Farmer experiences are the least studied area. In Africa, field experiments have been carried out that focus on productivity and profitability, on either one crop or several crops in different localities (Adamtey *et al.,* 2016). Fewer are the on-farm studies that evaluate crop performance, i.e. productivity and profitability (De Bon *et al.,* 2018). These studies are insufficient in number to draw the attention of African governments to support the organic sector (De Bon *et al.,* 2018). In other words, a lot of research is needed to support farmers' efforts.

In this chapter, an assessment of the effect of type of farming system (organic versus conventional) on yield and profitability for various crops in three counties of Kenya is reported.

2.2 Literature review

2.2.1 Comparative assessments of productivity (yield) in organic and conventional farms

In past studies that compare organic and conventional systems, yields are shown to be either lower, similar, or higher in one system. A comprehensive meta-analysis of 66 studies by Seufert and Ramankutty (2017) found that the average yield of organic production is 25% lower than that of conventional systems. The organic yields in cereals and vegetables were significantly lower than the conventional crops (-3 and -11% respectively) (Seufert and Ramankutty, 2017). A study of maize grain yields over a 22 year period found that yields were higher from conventional (5,903 kg/ha) than organic systems (4,483 kg/ha) in the first five years (Pimentel *et al.*, 2005) though after the transitional period the corn grain yields were similar between systems (6451 kg/ha during normal rainfall). Another study from Gopinath *et al.* (2008), shows that wheat produced using mineral fertilizer developed more grains per ear than those receiving organic fertility amendments, but the yield gap between conventional and organic fields narrowed in the next season (Gopinath *et al.*, 2008). Cavigelli *et al.* (2013) in the USA found that conventional maize and soybean yielded 29% and 19% more, respectively, than organically produced maize and soybean; however wheat yields were similar averaging 4.09 t/ha (Cavigelli *et al.*, 2013). De Ponti *et al.* (2012) conducted a meta-analysis of 135 publications finding that organic yields were lower than conventional yields by 20%. The data reveal that there was no significant substantial change in organic yields in the period 2004-2010 compared with the period before 2004 (De Ponti *et al.*, 2012). The yields of organic crops and per/ha organic livestock production is found to be lower than for conventional management by Hopkins and Morris (2002). Other studies in smallholder farms have similarly found that yields from conventional farming are higher than organic. Krause and Machek (2018) found up to 12% lower yields in organic farms as compared to conventional in Czech Republic. A study by Sharma (2020) in India found conventional farms had higher yields by 11% than organic in medicinal and aromatic plants. A study by Lu *et al.* (2020) in Taiwan found organic rice yield was 4,500 compared to conventional yields of 5,000 kg dried rice per ha.

A study by Gurbir *et al.,* 2021, on the long term farming system comparisons in the tropics 2007-2019 in Kenya, India and Bolivia found that in Kenya the organic and conventional high input for maize had almost similar yields. In India soybeans has similar yields for organic and conventional high input. The study reports that organic yields can match conventional ones depending on crop and agronomic management practices (Gurbir *et al*., 2021). Suja *et al*. (2017) showed that there was a similar yield performance of taro under organic and conventional systems (10.61 and 11.12 ton/ha respectively) in small-scale farms in India. The yield attributes measured were corms number, average weight of corms, maturity index (mother or young corms). The number of mother corms were the same between organic and conventional (Suja *et al*., 2017). Eyhorn *et al*. (2018) revealed that organic farms in small-scale farms in India could get similar yields to conventional in cereals and pulses with considerably lower use of external inputs.

Field experiments have shown mixed results on lentil production: over the period 2012 to 2016, Eyhorn *et al*. (2018) found the yields higher in the first year for conventional (by 14%) while in 2016 organic yields were higher by just 2%. A study by Ostapenko *et al.* (2020) on the evaluation of organic products in Ukrainian small-holder farms showed that organic crop enterprises had higher yields compared to conventional farms except for wheat which was not significantly different (organic 41.3kg/ha vs. conventional 41.5kg/ha). The organic yield levels for maize were 133.6% higher (80.3 kg/ha compared to 60.1 kg/ha); and for sunflower 112.3% higher (27.1 kg/ha compared to 24.1 kg/ha) (Ostapenko *et al.* 2020). Krause and Machek (2018) reported higher yields in organic strawberries compared to conventional smallholder farms in the Czech Republic.

The results from the above studies show that my study may get results that support either organic or conventional small-scale farming systems. Other studies have compared organic and conventional systems in terms of yields, costs, price, and profitability (Hopkins & Morris, 2002). In non-industrialized countries, organic farming generally leads to higher profits due to higher yields, reduced costs, and the price premiums of organic products (Nemes, 2009). Te Pas and Rees (2014) analyzed the differences between organic and conventional farms in countries in the tropics and subtropics. They used data from 88 papers with 458 data pairs to make comparisons in yield, gross margins, and soil organic carbon. The results revealed that under organic management, yields were on average about 26% higher and with a gross margins of 51% higher than under conventional management (Te Pas & Rees, 2014). The highest yields in organic systems in industrialized countries were on coarse soils in arid regions. The main reason for differences between organic and conventional systems for the gross margins, was the certification process (Te Pas & Rees, 2014). Higher yields alone are not the absolute solution to the problem of food security, as there are multiple social, political, and economic contributing factors to the benefits obtained by farmers (Ponisio *et al*., 2014; Vasilikiotis, 2000). For example, a market is necessary before farmers can receive price premiums for organic produce.

This section has revealed that while some studies show that higher yields from organic farming are higher (Auerbach *et al*., 2013; Te Pas & Rees, 2014; UNEP-UNCTAD, 2008) others report lower yields compared to conventional farming (Connor, 2013; Kirchmann *et al*., 2016; Ponisio *et al*., 2014; Seufert & Ramankutty, 2017). This confirms that the yield gap between organic and conventional farming is highly dependent on the location as well as the crop (Adamtey *et al.,* 2016; De Ponti *et al.*, 2012; Seufert & Ramankutty, 2017), besides other factors such as mechanization or climate.

2.2.2 Comparative evaluations of profitability in organic and conventional farms

Profitability studies that compare organic and conventional systems show similar patterns to studies of yields: either lower, similar or higher profitability for either farming system. A study by Crowder and Reganold (2015) examined the financial performance of organic and conventional agriculture through a meta-analysis of a dataset of 55 crops across five continents. The results show that when organic premiums are not applied, the benefit/cost ratios (range of -8 to -7%) and net present values (-27 to -23%) of organic agriculture are significantly lower than conventional. Another study found that conventional farming systems had higher gross margins (21%) in the first year of a two-year rotation but organic gross margins were greater after the second cycle (Forster *et al*., 2013). Froehlich *et al*. (2018) show that organic producers' profits were 7-10% lower than conventional producers' in Brazil. The low profitability was due to regional particularities, the crops cultivated, farm types, farm characteristics, regional-specific policies, and the presence of price premiums (Froehlich *et al*., 2018). Meemken and Qaim (2018) found that without the organic certification contribution to higher profitability in smaller organic farms, conventional farms gave higher profits. They conclude that organic farming is only profitable when farmers receive support such as subsidies or from development projects (Meemken & Qaim, 2018).

Profitability is similar for conventional and organic farms in the European Union (EU), although there is considerable variability within samples, between sectors, and between the opportunities and challenges for organic farming and small-scale farmers across EU countries (Greer & Hunt, 2011; Jouzi *et al*., 2017; Nieberg *et al*., 2003). In a study by Mohamad *et al*. (2014) conducted in Italy the initial and future investments of organic and conventional olive operations were found to be similar. The net present value for organic systems was 6% greater than conventional (€ 16,041 per ha vs. € 15,118 per ha respectively). The internal rate of return was higher in organic (3.51%) than conventional (3.37%) (Mohamad *et al*., 2014).

A comparative study on the economic profitability of organic and conventional farming in India reveals that although crop productivity in organic farming decreased by 9.2%, due to a 20 to 40% price premium and an 11.7% reduction in the production cost, net profits of farmers still increased by 22% (Ramesh *et al*., 2010). Where farmers benefit from premium prices in the organic system, this leads to significantly more profitable organic systems (by 22-35%) with a higher benefit/cost ratio (of 20-24%) as compared to conventional farming systems (Crowder & Reganold, 2015). The authors conclude that organic can continue to expand even if premiums decline as organic production has multiple sustainability benefits (ibid.). Sgroi *et al*. (2015) compared lemon farms in Italy and found that the gross production value of organic farms (€ 6138 per ha) is almost ten times higher than in conventional farms (€ 649 per ha) (Sgroi *et al*., 2015). Bett and Ayieko (2016) found that in Kenya, the net present value of low input organic farms (KES 22,561 per ha or € 275 per ha) was greater than conventional systems (KES 21,878 per ha or € 267 per ha). Another study in Cavigelli *et al*. (2013) showed that the net returns for conventional systems (US$ 78 per acre) were lower than for organic systems (US$ 286 per acre). The economic risk, with similar rotation lengths of three years, was greater for conventional systems than for organic (Cavigelli *et al*., 2013).

Several other studies show that organic products are more profitable due to premium prices (Fess & Benedito, 2018; Smith *et al*., 2019a). In India, organic Basmati rice is shown to be 105% more profitable than conventionally managed Basmati; and organic had higher gross margins for Basmati rice, coarse paddy, wheat, and lentils (Eyhorn *et al*., 2018). A study by Şurcă (2018) in Romania shows that organic rice had a gross margin of lei -443 per ha (€ -90.81 per ha) than conventional lei -1487 per ha (€ -304.83 per ha). Other studies reveal that organic had greater profitability than conventional farming (Hampl, 2020). Organic enterprises in the Ukraine had an average profit of € 218 per ha compared to conventional farms getting an average of € 149 per ha (Ostapenko *et al*., 2020). Other comparative studies of organic tea in China and Sri Lanka (Qiao *et al*., 2016), rice in the Philippines (Mendoza, 2004; Pantoja *et al*., 2016), honey in Ethiopia (Girma & Gardebroek, 2015), cotton in India (Fayet & Vermeulen, 2014) and pineapple in Ghana (Kleemann, 2016), suggest that organic farming can be profitable and is a feasible option for smallholders living in difficult environmental situations.

My study seeks to add to the literature on organic farming with a focus on Kenya, as few comparative studies have been carried out in Africa, sub-Saharan Africa and at the country level on the profitability of organic and conventional agriculture. A two-year dataset was generated by a study of 849 farms, which includes data on at least ten selected commonly grown crops in three counties of Kenya. The methodology of this study is presented in the next section.

2.3 Methodology

2.3.1 Study area and data

The study was conducted in three counties in Kenya (Murang'a, Kirinyaga, and Machakos). Detailed characteristics of the study sites are given in Chapter 1. Of the targeted 900 farms, a total of 864 farms were interviewed consistently for the two-year period (Table 2.3-1). Data analysis was carried out for 849 of the farms, as 15 farms were dropped out because of inconsistencies in their data during data cleaning (similar data, same farm, incomplete data, e.g. missing yields or some seasons, etc.).

Table 2.3-1: Sampling frame of organic and conventional farmers in the study areas

County	Listed by partners		Interviewed		Grouped for analysis*	
	Organic	**Conventional**	**Organic**	**Conventional**	**Organic**	**Conventional**
Kirinyaga	378	952	94	188	83	189
Machakos	111	492	55	241	40	255
Murang'a	200	263	114	172	81	201
Total	689	1707	263	601	204	645

*Note: *Grouped for analysis (intervention and non-user groups)*

Primary data was collected from October 2014 to February 2017 using a structured questionnaire (excel questionnaire template with 19 worksheets for filling data). The questionnaire captured data for organic and conventional farmers on yields, production costs, prices, markets, farm infrastructure and equipment, and social-economic characteristics. Data were collected for both crops (annual and perennial crops) and livestock (however the analysis focuses on crops). The crop data were collected for five seasons (three short rainy seasons and two long rainy seasons). Four seasons' data was used for the evaluation (two complete years of data including two long and two short rainy seasons), as the first season was considered a pre-test. Data was collected twice every month from each farm by trained enumerators, and the information was entered into a laptop using a Microsoft excel file for each farm. To enhance the reliability and validity of the data, pre-testing was done every season as more worksheets were added to the excel file for each farm. The collected data was stored in a database. The data was revised and updated each season. Data cleaning, validity checks, outlier corrections, data verification, and explorative analyses were undertaken to ensure high-quality data (Figure 2.3-1). Data cleaning, verification revealed that some farmers who were classified as organic during the interview process were not actually practicing organic farming according to the IFOAM, 2004, EAC 2007, 2014 and 2019 documents. (Kirinyaga the 11 farmers during the study period had been penalized and part of their organic farms put under conversion because of use of misuse of plant protection products above the required limits per year). In Murang'a there existed social capital system of checks where farmers apart from having regular training the farmers visited each other and sanctions placed on the farmers not complying with the organic requirements.

During the interview process, the enumerators found use of prohibited products in some organic farms and marked then as conventional farms after consultations with the team leader and NGO working in the area to train the organic farmers. in addition considerations of farmers practicing parallel or spilt farming taken into account according to the KEBs standards of EAC 2019 KS EAS 456:2019 and KS ARS/AES 01:2014.

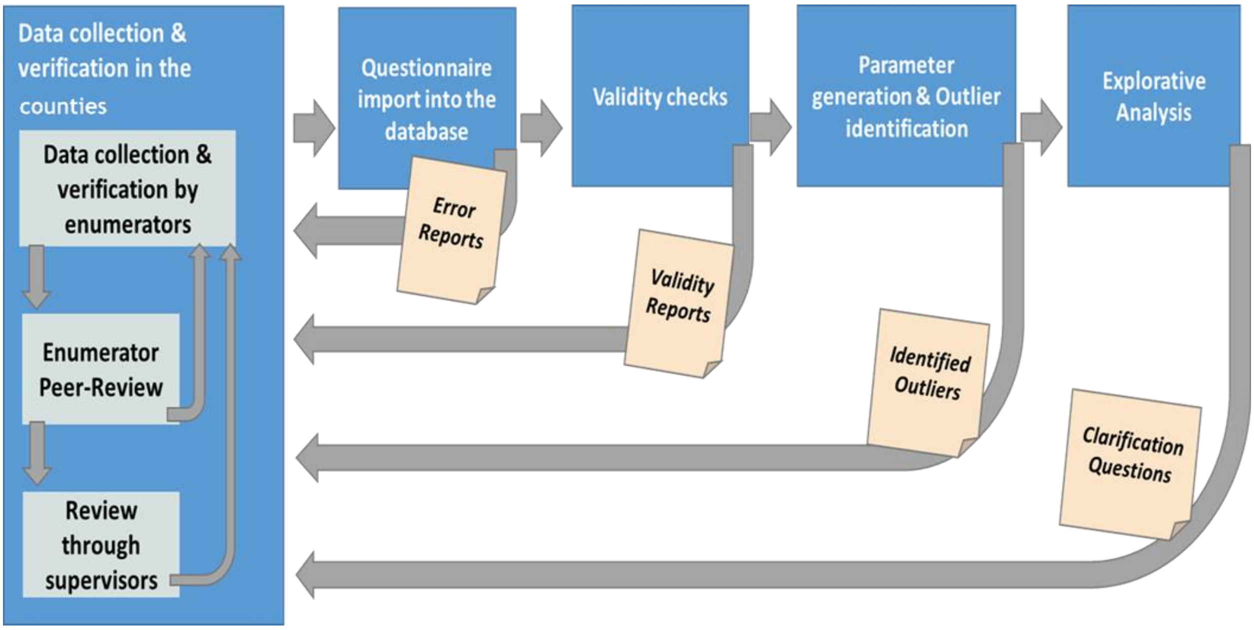


Figure 2.3-1*: Schematic of data collection and verification/correction process (Source: FiBL)*

2.3.2 Analytical approach

Computing gross margins

The gross margins (GM) were calculated by taking the total revenue (outputs quantity multiplied by the price per unit), less the total costs (inputs costs (inputs times' price of inputs) plus land costs, plus labour costs (labour hours times amount equivalent per hour)):

GM = Total Revenue – Total Costs (Equation 1)

Data for calculating the gross margins per crop were cross-referenced for each crop with data on inputs and outputs from secondary sources (land, inputs, and equipment costs), such as county statistics data (Ash *et al.,* 2017). Farm-gate prices were used to value revenues and costs where the actual prices were not known (Ash *et al.,* 2017; Berhane *et al.*, 2015). This analysis was performed using crop production data for the three counties over two years (long and short rainy seasons). The data was sorted for the farms growing the crops and twenty two different crops identified and further analysis on the 10 most widely grown crops in each county were selected for analysis and comparison between organic and conventional farms Gross margins were calculated as the output of a particular enterprise less its variable costs. The unit for transactions costs, production costs, and income was Kenya shillings (KES). The yield in weight as kilograms (kg) was the unit of measurement. Locally used measurements of yields were converted to kilograms. For example, silky oak tree is grown for its firewood, and farmers report the yields in bags or baskets ("debe", "gorogoro"). The kg equivalent measures were taken and all measurements were converted into kg. Finally the weight of the tree branches pruned or logs were converted to kg/ha (Muchiri *et al.*, 2002).

Determinants of yield and profitability: Ordinary Least Squares (OLS) approach

A production system is considered economically profitable if the returns from the use of production factors – land, labour, and capital – are higher than investments (Offermann & Nieberg, 2000). The economic analysis is made by isolating the determining variables such as yield, costs, product price, and target market and determines profitability (Nemes, 2009; Pimentel *et al.*, 2010).

Factors affecting yields and profitability of organic and conventional farming systems were evaluated using the Ordinary Least Squares (OLS) multiple linear regression model (Hutcheson, 2011; Williams, 2015) as calculated using the following equation:

$$\hat{\boldsymbol{\beta}} = \left(\sum_{i=1}^{N} \mathbf{x}'_i \mathbf{x}_i\right)^{-1} \left(\sum_{i=1}^{N} \mathbf{x}'_i y_i\right) \qquad \text{(Equation 2)}$$

Where $\mathbf{x}_i$ is the $1 \times k$ vector of independent variables, y_i is the dependent variable for each of the N sample observations, and the model for y_i is:

$$y_i = \mathbf{x}_i \boldsymbol{\beta}' + \epsilon_i \qquad \text{(Equation 3)}$$

If the ϵ_i are independently and identically distributed.

The Ordinary Least Squares multiple linear regression model estimated the effect of social-economic factors, farm, and market characteristics on profitability. The profitability level was computed as a ratio of the value of revenue to the value of total costs. Production cost and farm income were measured as the value of purchased inputs and farm revenue generated, respectively. The inputs considered in this study included fertilizer, seeds, seedlings, pesticides, and family and hired labour.

The dependent variable in the first case (profit index) is a bound variable with a range of 0 to 1 (Table 2.3-2) for analysis in Stata. Therefore a Tobit model can be used to estimate the level of profitability in farming system index to a set of right-hand side variables (Rubin, 2006; Tobin, 1985). However, in the second and the third case, the dependent variables (cost of production and revenues) are continuous; therefore, OLS can potentially be used to estimate the model relating to input use or farm income to a set of right-hand side variables (Greene, 2003). The Tobit or OLS model is expressed as:

$$Y_i = X'\beta + \alpha_m P_m + u_i \qquad i, m = 1, 2, 3, \ldots n \qquad \text{(Equation 4)}$$

Where Y_i, the dependent variable, measures the outcome, i.e. profits (Tobit equation) or cost of production or income (for the OLS equation). β is a vector of parameters to be estimated, X' is a matrix of the explanatory variables that include farmer-specific, farm-specific, asset endowment, and location (regional) characteristics. P_m is a dummy variable indicating the use of the farming system (1=user, 0=otherwise), and u_i is the error term.

In the above formulation, αm (which is a constant coefficient of the dummy P_m) gives the average effect (Average Treatment effect on the Treated – ATT) of farming systems (Heckman, 2000). If the explanatory variables *X* perfectly captured the impact of the farming system, then αm would be an unbiased estimator of the farming system. In other words, the formulation in Equation 3 assumes the absence of selection bias, which is unlikely to be the case. Ideally, the ATT is likely to be affected by other confounding factors not captured in *X*.

Effect of farming system on yield and profitability: Propensity Score Matching (PSM) approach

Ordinary Least Squares Regression (OLSR) is a generalized linear modeling technique (Greene, 2003). It is used for estimating all unknown parameters involved in a linear regression model, the goal of which is to minimize the sum of the squares of the difference of the observed variables and the explanatory variables (Vandenberghe & Robin, 2004; Wooldridge, 2002). Other methods have been proposed such as the Heckman two-step (HS) method, the Instrumental Variable (IV) method, Propensity Score Matching (PSM), and the difference-in-differences (DiD) method (Rubin, 2006; Vandenberghe & Robin, 2004; Wooldridge, 2002), which depend on strong unobserved variables among other limitations.

Propensity Score Matching consists of matching treatment with controls/comparison units, i.e. users (organic farming) with non-users (conventional farming) that are similar in terms of their observable characteristics. PSM estimates the Average Treatment Effect (ATE) on the treated group to find a comparable observation in the untreated group (Abadie & Imbens, 2016). It follows that the Average Treatment effect on the Treated (ATT) is of primary significance.

Let Yi1 = outcome after treatment (i.e. organic farming), and Yi0 = outcome without treatment. Then the causal effect on an individual i is given by:

$$Yi = Yi1 - Yi0 \qquad \text{(Equation 5)}$$

The estimated causal effect is thus given by:

$$E(Yi) = E(Yi1 - Yi0) = E(Yi1) - E(Yi0) \qquad \text{(Equation 6)}$$

When using cross-section data for impact evaluation, it is impossible to observe individual treatment effects since we do not know the outcomes for untreated observations when they are under treatment (Yi1) and for treated ones when they are not under treatment (Yi0). Propensity score matching, therefore, takes a treated individual and matches it with an untreated ones of similar pre-participation characteristics. Any difference in the outcome is then attributed to the treatment (i.e. organic farming).

The Propensity Score Matching technique begins with an estimation of a probit of a logit that assigns every individual a score (propensity score) that shows the probability of being included in the matching process. Mathematically, the match treated and untreated observations on the estimated probability of being treated can be expressed as:

$$Prob(x) = Prob\ [P=1|X=x] \quad \text{(Equation 7)}$$

Where P=1 is the observable treatment (user of treatment) and 0 otherwise; X is a vector of pre-participation characteristics including farmer-specific, farm-specific, asset endowment, and regional/location variables. The implicit functional form of estimated use the equation given by:

$$Yi = f(X) + e \quad \text{(Equation 8)}$$

Where e is the random error term.

The estimated scores are then used for matching the treated and untreated.

Entropy balancing using ebalance (a Stata Package)

Methods such as nearest neighbor matching or propensity score techniques have become popular in the social sciences in recent years to pre-process data before the estimation of causal effects in observational studies with binary treatments under the selection on observables assumption (Ho, Imai, King, & Stuart, 2007; Sekhon, 2009). The goal in pre-processing is to adjust the covariate distribution of the control group data by reweighting or discarding of units, such that it becomes more similar to the covariate distribution in the treatment group. This pre-processing step can reduce model dependency for the subsequent analysis of treatment effects in the pre-processed data using standard methods such as regression analysis (Abadie & Imbens, 2011).

The data analysis used a Stata package known as ebalance (Williams, 2015), which implements the entropy balancing method as described in Hainmueller (2012). The package is distributed through the Statistical Software Components (SSC) archive – often called the Boston College Archive – at http://ideas.RePEc.org/c/boc/bocode/s457326.html.1. The key function of the ebalance package is that it allows users to fit the entropy balancing weights and offers various options to specify the balance constraints. In the ebalance function, the balance constraints can be flexibly specified with the targets (numlist) option. The user can choose to adjust the first, second, or third moments of each covariate. Ebalance [treat] covar [if] [in] [, options]. Stata statistical package 16.1 was used for data analysis. The variables used in the analysis model were grouped into treatment and independent variables, as listed in Table 2.3-2.

Table 2.3-2: Variables used in the empirical model

Variable name	Variable Definition
'Treatment' variable	
Farming system	1=Organic, 0=Conventional

Independent variables	
Gender of farmer	1 if farmer is male, 0 otherwise
Organic management	1 if organic, 0 otherwise (the farm practices organic management)
Age of farmer	Age in years of farmer (years)
Farming experience	Year started farming
Income off-farm	1 if off-farm income, 0 otherwise
Bank savings account	1 if have bank account, 0 otherwise
Level of education of farmer	1 if informal (adult literacy), 2 if primary, 3 if secondary, 4 if tertiary, 0 otherwise
Member of farmer organization	1 if a member of group, 0 otherwise
Farm size	Total land area cultivated (Hectares)
Soil quality status	1 if soil quality is low, 2 if average, 3 if high, 0 otherwise
Household size	Number of household members
Crop count	Number of crops on the farm (count)
Irrigation	1 if with irrigation system, 0 otherwise
Fertilizer application	1 if used fertilizer application, 0 otherwise
Pesticide application	1 if used pesticide application, 0 otherwise
Seed/seedlings planting materials	1 if used planting materials, 0 otherwise
Output quantity	Yield of crop produced (kg/ha)
Labour hours/year	Labour hours spent per hectare per year
Total input cost/ha/activity/year	Total cost of inputs in KES per hectare per year
Total land cost/ha/activity/year	Total cost of land in KES per hectare per year
Murang'a	1 if the farmer is located in Murang'a County, 0 otherwise
Kirinyaga	1 if the farmer is located in Kirinyaga County, 0 otherwise
Machakos	1 if the farmer is located in Machakos County, 0 otherwise

Further analysis was conducted with a covariate balancing test to evaluate if, within each quartile of the propensity score distribution, the average propensity score and mean (χ) were similar. Robustness checks for PSM estimation were used to evaluate the unobserved heterogeneity and biasness in the data. The PSM approach allows for a robustness check of the results based on different matching algorithms similar in magnitude and effect direction. We used the nearest neighbor (NN), kernel matching (KM), and radius matching (RM) to get robust results. Lastly, a test of quality of matching and sensitivity analysis was performed to test the estimated average treatment effects and critical hidden bias. Despite the importance of the debates about conventional and organic systems, a good number of the reviewed studies on productivity and profitability fall short of accounting for omitted variable bias (selection bias). Any observed differences between the outcomes (profits) of both types of systems are not only from differences in the production process but also the unobserved characteristics that might systematically differ between organic and conventional (Latruffe *et al.*, 2015).

2.4 Results and discussion

2.4.1 Descriptive statistics (farm characteristics)

The differences in the socio-economic and farm characteristics of organic and conventional farms in Murang'a, Kirinyaga, and Machakos counties are presented in Table 2.4-1. The household head was most often considered 'the farmer', unless another household member did the actual work. The age of farmer, the gender of household head, number of household members, level of education of farmer, membership of farmer organization, years in farming, farm size, area of own land, number of crops on the farm, family labour hours and hired labour hours were significantly different for organic and conventional farms (Table 2.4-1). However, the gender of farmer, years of in farming, marital status of farmer, off-farm income of farmer, land rented-out, land rented-in, possession of a bank savings account, access to finance, soil quality, and proportion of female household members for the two cohorts were not significantly different.

The farms practicing organic management over the two years of the study were 71.1% in Murang'a, 88.3% in Kirinyaga, and 72.7% in Machakos of the 263 interviewed (Table 2.4-1). The average age of an organic farmer was 54 years, while for conventional it was 51 years. Organic farms required more labour hours than conventional ones (241 hrs/ha/yr of family labour and 296 hrs/ha/yr of hired labour in organic farming vs. 178 hrs/ha/yr of family labour and 220 hrs/ha/yr of hired labour in conventional). This is because crop operations require more time: weeding, mulching, compost-making, application of organic manure, and organic pesticides that need a repeated application are more time-consuming than the application of chemical pesticides and fertilizers once or twice per cropping season.

Table 2.4-1: Socio-economic and farm characteristics of organic and conventional farms (sample mean)

Characteristics	Organic (N=204)	Conventional (N=645)	Difference	t-values
Farmer socioeconomic characteristics				
Gender of farmer	1.49	1.54	0.054	1.352
Age of farmer	54.55	51.58	(2.974)**	-2.693
Gender of household head	1.81	1.81	-0.007	-0.228
Household member	2.68	3.36	0.681***	4.781
Proportion of female household members	0.52	0.52	-0.001	-0.058
Marital status	2.14	2.18	0.036	0.629
Level of education of farmer	2.59	2.39	(0.202)**	-2.735
Years of farming experience	28	27	0.87	0.901
Bank savings account	0.8	0.77	-0.039	-1.175
Member of farmer organization	0.86	0.75	(0.118)***	-3.541

Access to finance	0.95	0.97	0.024	1.632
Share of off-farm income	0.4	0.38	-	0
Farm characteristics				
Farm size (ha)	0.67	0.77	0.102	1.86
Area (ha) own land	0.66	0.77	0.103	1.886
Area (ha) rented-in land	0.01	0.01	-0.001	-0.241
Land rented-in	-	0	0.002	0.941
Land rented-out	-	-	-0.016	-0.421
Soil quality	2.19	2.18	-0.013	-0.311
Crop count	7.98	7.59	(0.386)	-1.816
Family labour (hr/yr)	241.46	177.86	(63.599)***	-4.254
Hired labour (hr/yr)	295.93	219.68	(76.255)*	-2.01
Murang'a	81	201	-120	
Kirinyaga	83	189	-106	
Machakos	40	255	-215	

*Source: Survey results from 2019 SPSS: t-test Significance level = *0.05, **0.01 & ***0.001 significant differences arising by virtue of being an organic or conventional farmer.*

Crops grown in the counties

The farms in the three counties grew a wide range of crops classified as cereals, legumes, fruits and vegetables, herbs and spices, agroforestry crops, and livestock fodder. The sampled farms grew between eight to 18 different crops. These crops included arrowroot, avocado, banana, cabbage, chili pepper, coffee, cowpea, field/common bean, green/French bean, green gram, silky oak, Irish potato, kale, lemon, macadamia, maize/corn, mango, papaya, pigeon pea, spinach, and tea. The same crops are reported as being common in the three counties (KNBS, 2015a, 2015b, 2015c).

The 10 most widely grown crops in each county were selected for analysis and comparison between organic and conventional farms (Table 2.4-2). This gives a total of 22 crops. Field/common bean and maize were commonly grown (and selected for analysis) in all three counties.

Table 2.4-2: Percentage of farms having crop by County and farming system

Crop	Total (All)		Murang'a		Kirinyaga		Machakos	
	Organic	Conv.	Organic	Conv.	Organic	Conv.	Organic	Conv.
Arrow root	16.7	8.8	42.0	28.4	0.0	0.0	0.0	0.0
Avocado	29.4	18.6	55.6	47.3	18.1	13.2	0.0	0.0
Banana	2.9	11.2	0.0	0.0	0.0	0.0	15.0	28.2
Banana/Plantain	63.7	47.1	69.1	59.7	89.2	97.4	0.0	0.0
Cabbage	36.3	26.4	91.4	84.6	0.0	0.0	0.0	0.0
Chilies and peppers	0.0	2.9	0.0	0.0	0.0	0.0	0.0	7.5
Coffee	38.7	27.9	0.0	0.0	95.2	95.2	0.0	0.0
Cowpea	17.6	32.2	0.0	0.0	0.0	0.0	90.0	81.6
Field/Common bean	66.2	70.7	75.3	73.6	47.0	57.7	87.5	78.0
Green/French bean	0.0	4.2	0.0	0.0	0.0	14.3	0.0	0.0
Green gram	8.3	20.3	0.0	0.0	0.0	0.0	42.5	51.4

Silky oak	6.4	2.6	0.0	0.0	15.7	9.0	0.0	0.0
Irish potato	29.4	18.8	74.1	60.2	0.0	0.0	0.0	0.0
Kale	34.8	29.5	75.3	71.6	12.0	24.3	0.0	0.0
Lemon	2.5	8.1	0.0	0.0	0.0	0.0	12.5	20.4
Macadamia nut	39.2	28.8	0.0	0.0	96.4	98.4	0.0	0.0
Maize/Corn	75.5	89.6	96.3	94.0	45.8	75.7	95.0	96.5
Mango	14.7	34.1	0.0	0.0	0.0	0.0	75.0	86.3
Papaya	5.4	15.8	0.0	0.0	0.0	0.0	27.5	40.0
Pigeon Pea	18.1	33.0	0.0	0.0	0.0	0.0	92.5	83.5
Spinach	12.7	9.8	32.1	31.3	0.0	0.0	0.0	0.0
Tea	44.1	32.1	96.3	86.6	14.5	17.5	0.0	0.0

Source: Survey analysis results 2019

2.4.2 Crop yields

The mean yields (kg per ha) for the following crops were better for organic crops. Overall, leguminous crops such as cowpea, field/common bean, green gram, and pigeon pea gave higher yields in organic interventions in the study area (Table 2.4-3). The organic farms' yields were on average higher than those of conventional farms by 3.4% for cowpea, 83.6% for field/common bean, 1.9% for green gram, 124.6% for coffee, and 22.7% for avocado. Organic yields were also higher by 67.3% for macadamia nut, 3.2% for maize, 23.3% for mango, 25.7% for papaya, and 24.2% for pigeon pea as compared to conventional farms. Organic on the other hand, had lower yields by 23.8% for arrowroot, 12.9% for banana, 14.9% for plantain, 14.8% for cabbage, 98.4% for silky oak, 2.6% for Irish potato, 32.2% for kale, 15.2% for lemon, 7.5% for spinach and 0.5% for tea.

The test for significance difference, the results show that the crop yields for three crops coffee, common bean and macadamia nut were statistically significant under organic farming system while silky oak were significant higher under conventional systems (Table 2.4-3).

At the county level, the disaggregated analysis show that the yields for maize in Murang'a under organic interventions were 33.3% lower than in conventional (Table 2.4-3). In Kirinyaga County, the crops that performed significantly better under organic farming were coffee (by 124.6%), common bean (by 231.9%), macadamia nut (by 67.3%), and maize/corn (by 29.9%). However, organic farming of plantain, silky oak and tea were significantly lower than in conventional ones by 46.0%, 99.2% and 37.9% respectively.

Moreover, in Machakos, there was no significant statistical difference in the yields of any crops under organic and conventional farming. This implies that the differences in yields of the pooled sample is driven by the yields in Murang'a and Kirinyaga Counties.

2.4.3 Farm profits

Comparison of the profitability of organic and conventional farms involved calculation of the total cost of producing the crops (Tables 2.4-4), the total revenues generated by the crops (Tables 2.4-5), and the total profits from the production of the crops (Tables 2.4-6).

Table 2.4-3: Mean yield (Quantity in kg per ha) for the 10 key crops overall and in each County

Yields	Overall					Murang'a					Kirinyaga					Machakos				
	Organic		Conventional		Diff in	Organic		Conventional		Diff.	Organic		Conventional		Diff.	Organic		Conventional		Diff.
Crop	Mean	N	Mean	N	%	Mean	N	Mean	N	%	Mean	N	Mean	N	%	Mean	N	Mean	N	%
Arrow root	5,931	34	7,784	57	-23.8	5,931	34	7,784	57	-23.8										
Avocado	127,780	60	104,113	120	22.7	161,849	45	122,439	95	32.2	25,572	15	34,474	25	-25.8					
Banana	7,946	6	9,126	72	-12.9											7,946	6	9,126	72	-12.9
Banana/Plantain	42,837	130	50,354	304	-14.9	64,869	56	53,566	120	21.1	26,165	74	48,424	184	**-46.0*** **					
Cabbage	88,035	74	103,323	170	-14.8	88,035	74	103,323	170	-14.8										
Coffee	11,863	79	5,282	180	**124.6*** **						11,863	79	5,282	180	**124.6*** **					
Cowpea	801	36	775	208	3.35											802	36	775	208	3.5
Field/Common bean	7,208	135	3,926	456	**83.6*** **	8,977	61	8,347	148	7.55	9,535	39	2,873	109	**231.9*** **	1,532	35	1,214	199	26.2
Green gram	972	17	954	131	1.89											972	17	954	131	1.9
Silky oak	897	13	57,311	17	**-98.4***						464	13	57,311	17	**-99.2***					
Irish Potato	7,472	60	7,669	121	-2.57	7,472	60	7,669	121	-2.57										
Kale	30,622	71	45,143	190	-32.2	30,849	61	53,155	144	-42	29,238	10	20,063	46	45.7					
Lemon	8,218	5	9,687	52	-15.2											8,218	5	9,687	52	-15.2
Macadamia nut	18,956	80	11,330	186	**67.3*** **						18,956	80	11,330	186	**67.3*** **					
Maize/Corn	4,957	154	4,804	578	3.2	5,989	78	9,037	189	**-33.7****	6,283	38	4,838	143	**29.9***	1,514	38	1,534	246	-1.3
Mango	15,415	30	12,500	220	23.3											15,415	30	12,500	220	23.3
Papaya	15,041	11	11,967	102	25.7											15,041	11	11,967	102	25.7
Pigeon Pea	1,159	37	933	213	24.2											1,159	37	933	213	24.2
Spinach	28,621	26	30,943	63	-7.5	28,621	26	30,943	63	-7.5										
Tea	16,599	90	16,678	207	-0.5	17,954	78	17,460	174	2.83	7,793	12	12,556	33	**-37.9***					

*Significance level = *0.05, **0.01 & ***0.001 the blanks mean – that these crops are not in the top ten list for the particular county or do not occur in the particular county.*

Total costs of producing crops

The costs are related to what is spent (expenses) to produce or acquire the product or crop. Compared to conventional production, the overall cost of organic production was lower by 36.1% in arrowroot, 9.0% in avocado, 12.9% in banana, 12.8% in cabbage, 10.7% in green gram, 3.7% for silky oak, 16.9% in Irish potato, 12.4% in kale, 19.0% in maize/corn, 19.4% in mango and 40.8% for spinach. However the cost of organic was higher in plantain, coffee, cowpea, common bean, lemon, macadamia, papaya, pigeon pea and tea.

The test of significant statistical differences, the cost of maize, mango and spinach were significant for organic intervention while the crops for the crops coffee, macadamia and cowpeas were significant differences for conventional farming (Table 2.4-4).

When we disaggregated the analysis by county, the results show that costs of common beans, maize and spinach in Murang'a under organic production were 24.6%, 40.8% and 44.3% respectively significantly lower than in conventional farming (Table 2.4-4). The crops that performed significantly better under organic farming in Kirinyaga County were maize (by 19.8 %) and tea (by 44.5%). However, the costs of organic farming of avocado, plantain, coffee and macadamia were significantly higher than in conventional farming – 57.5%, 28.1%, 27.2% and 100.0% respectively. Whereas, in Machakos the cost of organic farming was significantly higher for the crop cowpea (by 23.8%) but lower for the crop mango (by 19.4%).

Total revenues generated by crops

The total revenues are the quantities harvested (yield) multiplied by the selling price for land ha per year. The higher the revenues, the better the returns to the farm. Overall, the revenues from organic were found to be higher than conventional crops in avocado by 35.0%%, coffee by 150.7%, cowpea by 30.5%, common bean by 66.0%, green gram by 7.3%, macadamia nut by 97.9%, papaya by 46.7% and pigeon pea by 27.0% (Table 2.4-5). Organic interventions had lower gross margins for arrowroot (25.3%), banana (23.2%), plantain (4.0%), cabbage (16.2%), silky oak (63.4%), Irish potato (2.4%), kale (20.2%), lemon (30.1%), maize/corn (8.2%), mango (9.1%), spinach (13.4%) and tea (0.9%).

The test of significant statistical differences, the cost of the crops coffee (150.7%), common bean (66.0%), macadamia nut (97.9%), cowpea (30.5%) and pigeon pea (27.0%) showed significantly higher revenues while silky oak showed significantly lower revenues (about 63.4%) under organic interventions compared to conventional farming(Table 2.4-5).

Table 2.4-4: Total Costs (KES) per ha for the 10 Key crops overall and in each County

Total Costs	Overall					Murang'a					Kirinyaga					Machakos				
	Organic		Conventional		Diff. in	Organic		Conventional		Diff.	Organic		Conventional		Diff.	Organic		Conventional		Diff.
Crop	Mean	N	Mean	N	%	Mean	N	Mean	N	%	Mean	N	Mean	N	%	Mean	N	Mean	N	%
Arrow root	134,938	34	211,060	57	-36.1	134,938	34	211,060	57	-36.1										
Avocado	141,548	60	155,481	120	-9.0	161,878	45	182,937	95	-11.5	80,555	15	51,147	25	**57.5***					
Banana	7,946	6	9,126	72	-12.9											29,519	6	35,975	72	-18.0
Banana/Plantain	88,595	130	80,524	304	10.0	123,437	56	129,537	120	-4.7	62,228	74	48,560	184	**28.1*****					
Cabbage	338,661	74	388,417	170	-12.8	338,661	74	388,417	170	-12.8										
Coffee	108,514	79	85,279	180	**27.3*****						108,514	79	85,279	180	**27.2*****					
Cowpea	65,364	36	52,802	208	**23.7***											65,364	36	52,802	208	**23.8***
Field/Common bean	156,483	135	154,703	456	1.2	218,273	61	289,388	148	**-24.6****	133,679	39	141,682	109	-5.6	74,204	35	61,667	199	20.3
Green gram	50,331	17	56,374	131	-10.7											50,331	17	56,374	131	-10.7
Silky oak	43,480	13	45,156	17	-3.7						43,480	13	45,156	17	-3.7					
Irish Potato	326,108	60	392,516	121	-16.9	326,108	60	392,516	121	-16.9										
Kales	391,843	71	447,267	190	-12.4	392,704	61	483,656	144	-18.8	386,589	10	333,357	46	16					
Lemon	56,021	5	51,879	52	8.0											56,021	5	51,879	52	8
Macadamia nut	133,212	80	66,590	186	**100.1*****						133,212	80	66,590	186	**100.0*****					
Maize/Corn	123,615	154	152,669	578	**-19.0***	160,477	78	287,864	189	**-44.3*****	121,254	38	151,222	143	**-19.8***	50,310	38	49,641	246	1.4
Mango	32,479	30	40,279	220	**-19.4***											32,479	30	40,279	220	**-19.4***
Papaya	63,865	11	59,910	102	6.6											63,865	11	59,910	102	6.6
Pigeon Pea	46,569	37	44,561	213	4.5											46,569	37	44,561	213	4.5
Spinach	378,840	26	640,037	63	**-40.8***	378,840	26	640,037	63	**-40.8***										
Tea	260,128	90	255,848	207	1.7	290,027	78	281,908	174	2.9	65,786	12	118,439	33	**-44.5****					

*Significance level = *0.05, **0.01 & ***0.001*

Table 2.4-5: Total Revenue in KES per ha for the 10 Key crops overall and in each County

Total Revenues	Overall					Murang'a					Kirinyaga					Machakos				
Crop	Organic		Conventional		Diff. in	Organic		Conventional		Diff. in	Organic		Conventional		Diff. in	Organic		Conventional		Diff. in
	Mean	N	Mean	N	%	Mean	N	Mean	N	%	Mean	N	Mean	N	%	Mean	N	Mean	N	%
Arrow root	346,293	34	463,304	57	-25.3	346,293	34	463,304	57	-25.3										
Avocado	746,319	60	552,959	120	35	895,877	45	629,159	58	42.4	297,644	15	263,401	25	13					
Banana	127,876	6	166,437	72	-23.2				59							127,876	6	166,437	72	-23.2
Banana/Plantain	502,541	130	523,209	304	-4	863,788	56	682,533	60	26.6	229,165	74	419,302	184	**-45.3***					
Cabbage	560,819	74	668,873	170	-16.2	560,819	74	668,873	61	-16.2										
Coffee	937,651	79	374,041	180	**150.7***				62		937,651	79	374,041	180	**150.7***					
Cowpea	74,776	36	57,304	208	**30.5***				63							74,776	36	57,304	208	**30.5***
Field/Common bean	476,846	135	287,347	456	**66.0***	735,841	61	666,843	64	10.3	392,080	39	121,955	109	**221.5***	119,909	35	95,701	199	25.3
Green gram	81,297	17	75,757	131	7.3				65							81,297	17	75,757	131	7.3
Silky oak	63,130	13	172,302	17	**-63.4***				66		63,130	13	172,302	17	**-63.4***					
Irish Potato	292,861	60	300,124	121	-2.4	292,861	60	300,124	67	-2.4										
Kale	322,338	71	403,710	190	-20.2	303,131	61	432,995	68	-30	439,498	10	312,035	46	40.8					
Lemon	124,281	5	177,842	52	-30.1				69							124,281	5	177,842	52	-30.1
Macadamia nut	1,847,530	80	933,697	186	**97.9***				70		1,847,530	80	933,697	186	**97.9***					
Maize/Corn	119,217	154	129,902	578	-8.2	147,610	78	265,305	71	**-44.4***	133,023	38	101,735	143	**30.8***	47,131	38	42,246	246	11.6
Mango	152,555	30	167,829	220	-9.1				72							152,555	30	167,829	220	-9.1
Papaya	325,271	11	221,653	102	46.7				73							325,271	11	221,653	102	46.7
Pigeon Pea	81,792	37	64,398	213	**27.0***				74							81,792	37	64,398	213	**27.0***
Spinach	308,131	26	355,839	63	-13.4	308,131	26	355,839	75	-13.4										
Tea	1,086,994	90	1,096,399	207	-0.9	1,172,701	78	1,145,338	76	2.4	529,896	12	838,358	33	**-36.8***					

*Significance level = *0.05, **0.01 & ***0.001*

At the county level (Table 2.4-5), maize showed significantly lower revenues (about 44.4% lower) under organic farming compared to conventional farming in Murang'a County. Likewise, the crops that reported significantly higher revenues in Kirinyaga County under organic production were coffee, common bean, macadamia nut, and maize by 150.7%, 221.5%, 97.9% and 30.8% respectively while, the revenues of organic production silky oak, banana/plantain and tea was significantly lower by 63.4%, 45.3% and 36.8% respectively. In addition, the crops with significantly higher revenues in Machakos under organic production were cowpea (30.5%) and pigeon pea (27.0%) than conventional farms.

Total profits from crop production

The gross margin profits are calculated from the total revenue minus the total costs (Table 2.4-6). The higher the profits, the better the performance of the farm. Overall, organic farms had higher profits than conventional farms in avocado, coffee, cowpea, common bean, green gram, Irish potato, macadamia nut, maize/corn, papaya, pigeon pea and spinach. Organic farms, on the other hand, had lower gross margins for arrowroot, banana, plantain, cabbage, silky oak, kale, lemon, mango and tea.

The crops coffee (187.1%), common bean (141.5%), macadamia nut (97.7%), Irish potato 64.0% and pigeon pea (77.6%) showed significantly higher profits while on the contrary silky oak showed significantly lower revenues by 84.5% under organic interventions compared to conventional farming.

At county level, avocado and Irish potato showed significantly higher profits (64.5% and 64.0% respectively) under organic farming compared to conventional farming in Murang'a County.

Similarly, the crops that reported significantly higher profits in Kirinyaga County under organic production were coffee (187.1%), common beans (1409.9%), maize (123.8%) and macadamia nut (97.7%). On the contrary, the profitability of organic production of plantain, and silk oak, were significantly lower – by about 55.0%, and 84.5% respectively. In addition, the crops with significantly higher revenues in Machakos under organic production was pigeon pea (77.6%) than conventional farms.

Table 2.4-6: Total Profit in KES per ha for the 10 Key crops overall and in each County

Total Profits	Overall					Murang'a					Kirinyaga					Machakos				
	Organic		Conventional		Diff. in	Organic		Conventional		Diff. in	Organic		Conventional		Diff. in	Organic		Conventional		Diff. in
Crop	Mean	N	Mean	N	%	Mean	N	Mean	N	%	Mean	N	Mean	N	%	Mean	N	Mean	N	%
Arrow root	211,355	34	252,244	57	-16.2	211,355	34	252,244	57	-16.2										
Avocado	604,771	60	397,479	120	52.2	733,999	45	446,222	95	**64.5***	217,089	15	212,255	25	2.3					
Banana	98,357	6	130,462	72	-24.6											98,357	6	130,462	72	-24.6
Banana/Plantain	413,947	130	442,685	304	-6.5	740,351	56	552,996	120	33.9	166,938	74	370,743	184	**-55.0*** **					
Cabbage	222,158	74	280,457	170	-20.8	222,158	74	280,457	170	-20.8										
Coffee	829,137	79	288,762	180	**187.1*** **						829,137	79	288,762	180	**187.1*** **					
Cowpea	9,412	36	4,502	208	109.1											9,412	36	4,502	208	109.1
Field/Common bean	320,363	135	132,644	456	**141.5*** **	517,569	61	377,455	148	37.1	258,401	39	-19,727	109	**1409.9*** **	45,704	35	34,033	199	34.3
Green gram	30,967	17	19,384	131	59.8											30,967	17	19,384	131	59.8
Silky oak	19,650	13	127,146	17	**-84.5***						19,650	13	127,146	17	**-84.5***					
Irish Potato	-33,247	60	-92,392	121	**64***	-33,247	60	-92,392	121	**64.0***										
Kale	-69,505	71	-43,557	190	59.6	-89,573	61	-50,660	144	76.8	52,909	10	-21,322	46	-348.1					
Lemon	68,261	5	125,964	52	-45.8											68,261	5	125,964	52	-45.8
Macadamia nut	1,714,318	80	867,107	186	**97.7***						1,714,318	80	867,107	186	**97.7*** **					
Maize/Corn	-4,398	154	-22,767	578	80.7	-12,868	78	-22,558	189	43	11,769	38	-49,487	143	**123.8*** **	-3,180	38	-7,395	246	-57
Mango	120,076	30	127,551	220	-5.9											120,076	30	127,551	220	-5.9
Papaya	261,406	11	161,743	102	61.6											261,406	11	161,743	102	61.6
Pigeon Pea	35,224	37	19,836	213	**77.6***											35,224	37	19,836	213	**77.6***
Spinach	-70,710	26	-284,198	63	75.1	-70,710	26	-284,198	63	75.1										
Tea	826,865	90	840,551	207	-1.6	882,674	78	863,430	174	2.2	464,110	12	719,919	33	-35.5					

*Significance level = *0.05, **0.01 & ***0.001*

2.4.4 Determinants of yields: do farming systems matter?

This part of the study used OLS estimators to gauge the effects of the various factors associated with farm productivity of the selected crops. Specifically, attention is drawn to the type of farming system (organic or conventional) as well as socio-economic, farm, and market-related characteristics (Table 2.4-7). The organic farming system is the main variable being tested on yields, while the other factors that may influence yields are controlled and kept at a constant. The factors controlled for yield are: age, sex (male), education level (adult literacy, primary, secondary, tertiary), farm experience, household size, farm size, soil quality status, crop count (number of crops grown), bank account, off-farm income, membership in farmer group, irrigation, fertilizer use, labour hours, pesticide use, seed/seedling (planting) use and location (county). The coefficient values of the variables that are negative implies that these variables have a negative effect on yields and the others have a positive effect. Values with significant differences are shown at $P< 0.05$, 0.01 and 0.001. The selected crops shown in Table 2.4-7 are those that the sample size allowed for comparison across the three counties.

The controlled variables with an influence on yields are as follows. The size of the farm had a negative significant relationship with yield. This finding is similar to that found by Mishra *et al*. (2018). Thus, the smaller the farm size, the higher the yield for maize, field/common bean, banana/plantain, tea, coffee, pigeon pea, and cowpea in organic farms. Small farm size allows farmers to better manage their farms and thus increase the yields per unit area in organic farming (Pimentel *et al*., 2010). The education level of farmers was a significant factor in increasing the yields of most crops. The higher the level of education, the higher the crop yields. For example, farmers who had completed secondary and tertiary levels of education reported higher yields for field/common bean, macadamia nut, coffee, and mango. Off-farm income shows a positive significant relationship in the yield of maize, field/common bean, tea, and pigeon pea but a negative significant relationship with yields of coffee and cowpea. The higher the off-farm income, the higher the yields for maize, field/common bean, tea, and pigeon pea. Farmers with money from off-farm activities plowed it back into farming leading to higher yields (Reardon *et al*., 1996). In both organic and conventional farms, farmers who invested in irrigation systems had higher yields: there was significant positive effect for organic yields of maize, field/common bean, coffee, Irish potato, and mango. The adoption of an irrigation system by farmers meant less reliance on rain-fed agriculture because they could produce crops during the dry season (Pimentel *et al*., 2010; Virlanuta, 2011), and importantly, use irrigation to bridge dry spells in rainy seasons (Rockström *et al*., 2007).

Table 2.4-7: Determinants of yields using OLS for selected ten crops

	Maize	Field/common bean	Banana/ plantain	Tea	Macadamia nut	Coffee	Irish Potato	Pigeon Pea	Cowpea	Mango
Organic	-313.418	**2393.149****	-4774.538	687.997	**5705.506****	**5409.951****	998.129	9.337	-55.545	**4608.614***
Age	15.629	27.643	-9.352	83.593	-92.438	-3.632	-21.862	3.408	-2.984	89.491
Sex (Male)	266.822	-723.705	-2470.674	**-2422.179****	398.045	-1255.87	280.7	61.428	-42.229	-558.379
Education level										
adult literacy	519.476	1227.887	-11200.000	-1696.516	**-5138.493****	**-3314.564****	**5247.219****	114.038	-150.779	**20569.461****
primary	-239.808	972.655	-1233.851	1524.135	**3265.208****	295.074	866.747	177.963	-77.81	2530.215
secondary	-364.780	1516.166	1211.761	2502.238	**4650.396****	450.332	-252.945	128.22	-85.629	**4820.624***
tertiary	691.142	**2688.880****	-9196.194	-1243.411	4127.469	**3010.655****	3126.12	-130.129	125.833	7797.007
Farm experience	-17.796	1.802	52.545	-69.094	103.069	-38.136	-52.734	-3.715	-0.718	40.432
Household size	-100.687	-170.474	1651.985	896.105	-1182.045	-562.855	308.163	**-45.215****	11.938	127.404
Farm size	**-986.082****	**-577.243***	**-17936.200****	**-4297.698****	262.035	**-2482.124***	-1431.3	**-112.565***	**-146.196****	-900
Soil quality status	-621.255	256.168	2031.989	-27.654	2322.703	**-1295.633***	-174.181	81.47	226.175	**6100.736***
Crop Count	61.921	**-187.620***	789.144	**590.455***	95.063	160.516	-58.334	31.228	4.266	-86.7
Bank Account	453.461	-265.312	-6020.379	1162.764	1919.499	600.201	-56.419	129.218	**244.426***	**3213.072***
Off farm income	**931.015***	**1588.750***	-4825.058	**2016.289***	1146.434	**-1788.008***	-892.156	137.158	-157.997	-539.711
Membership in Farmer Group	480.999	**1153.997***	1357.554	1531.784	0	0	864.702	-19.052	-73.479	-1829.85
Irrigation	**1088.032***	**1373.769***	-300.321	-1176.381	-443.042	**1482.125****	**2314.738***	197.865	128.135	3345.852
Fertilizer use	**6.929****	**6.683****	5.710	7.575**	4.294	0.803	1.44	0.539	1.594	**75.121***
Labour hours	0.157	-0.016	-0.618	0.021	1.122	0.328	**0.529****	0.24	0.232	-0.547
Pesticide use	12.448	**297.479****	410.919	130.177	35.337	**216.196****	697.657	**15.277****	**-15.833****	31.351
Seed/seedling (Planting) use	3.156	13.689	28.540	**79.923****	11.646	-11.571	**13.739***	**7.706****	1.226	44.34
Machakos	-827.353	1176.814						0	0	0
Murang'a	1181.734	**4327.261****	11329.731	494.702			0			
Kirinyaga (Constant)	1658.714	-2106.546	**50601.306***	361.871	5779.574	**7213.755****	4716.045	6.532	**878.304***	-1137.06
N	709	571	414	297	244	241	181	249	243	247
R^2	0.335	0.356	0.110	0.346	0.251	0.434	0.232	0.382	0.191	0.171
p	0	0	0	0				0	0	0

*Significance level = *0.05, **0.01, R2 =R squared, P= probability factor*

Generally, organic pesticides are used to control pests. However diseases still had a significant factor on yields. The use of organic pest control methods appears to have played a role in preventing higher yield loss of field/common bean, coffee and pigeon pea. Pest and disease control mechanisms provide the crops with an additional boost to survive pest and disease attacks, thus increasing the overall crop yield on the farm (Ayuya *et al.*, 2015). However perhaps more important are improvements to the soil structure in organic farms: a healthy soil is a prerequisite for healthy plants, which are then better able to withstand or avoid pest or disease attacks.

Of importance are the OLS results for the farming system. The results showed that the adoption of organic farming techniques is associated with a significant increase in the productivity of field/common bean, macadamia nut, coffee, and mango: a yield increase of 2393 kg/ha in common bean, 5706 kg/ha in macadamia nut, 5410 kg/ha in coffee, and 4609 kg/ha in mango for organic farming. There was no significant differences between organic and conventional farming for the other crops (maize, plantain, tea, Irish potato, pigeon pea and cowpea). In the OLS analysis, yields are an important determinant for the farming systems

2.4.5 Determinants of profitability: does the farming system matter?

OLS indicators were used to determine the effects of farming system type on farm profitability. The socio-economic and farm characteristics, and location variables considered are shown in Table 2.4-8. When all other factors are held constant the results showed that organic farming was significantly more profitable for macadamia nut and coffee production but significantly less profitable (as compared to conventional) for maize, field/common bean, and mango production. Furthermore, improved yields were associated with increased profitability for all crops. Organic farming profits were significantly higher for macadamia nut (by KES 156,054 per ha) and coffee (by KES 43,776 per ha) than under conventional farming. On the other hand conventional farming profits were significantly higher for maize (by KES 10,611 per ha), field/common beans (by KES 34,420 per ha), and mango (by KES 33,860 per ha). The profits from other crops (plantain, tea, Irish potato, pigeon pea and cowpea) were not significant for the farming system, even if positive or negative.

The other factors were held constant or controlled for profits. These variables may have an influence on profits from a crop. The results show that sex (if male), education level, farm size, input costs, cost of land and location influence profits.

Male farmers reported significantly more profits in the production of maize, field/common bean, macadamia nut, and coffee. The other crops (banana/plantain, tea, Irish potato, pigeon pea, cowpea, and mango) did not show significant differences in profitability between male and female farmers. The education level of farmers had an effect: those with tertiary level education, in particular, had significantly higher profits for the production of maize and banana/plantains. For coffee, pigeon pea, cowpea, and mango, a higher level of education had a significant negative effect on profitability. The level of education did not affect the profitability of field/common bean, tea, macadamia nut, and Irish potato.

Farm size had a positive significance on profits for field/common bean and tea while farm size under maize had a negative significance on profits. The smaller the farm size for maize the more unprofitable it became because of the costs of inputs, labour requirement and mechanization. A study by Muzari *et al*., (2012) found similar results where the smaller the maize farm size the less profitable the crop enterprise became. Small-scale farmers plant maize for subsistence (Muzari *et al.*, 2012). The other crops (banana/plantain, macadamia nut, coffee, Irish potato, pigeon pea, cowpea, and mango) did not show significant differences in profitability in relation to farm size. Lower total input costs led to significantly more profits in the production of maize and mango but significant negative profits for coffee, Irish potato, and cowpea. Some authors show that a reduction in the cost of production leads to more profit margins (Manglik & Goyal, 2018), however this is clearly not always the case: it depends on the crop in question. The other crops (field/common bean, macadamia nut, banana/plantain, tea, and pigeon pea) did not show significant differences in profitability in organic systems.

The cost of land is included in the calculation of profits as it is a cost incurred for the production of the crop (Eyhorn *et al*., 2018; Maltchik *et al*., 2017; Mendoza, 2004). Total land costs showed a positive significance on profits of maize, field/common bean, and banana/plantain but significant negative (loss) profits for tea. Investing in land for the growing of either maize, field/common bean, or banana/plantain is clearly more profitable than for tea. The cost of inputs and labour requirements were higher in tea than in maize and common bean. For the other crops (macadamia nut, coffee, pigeon pea, Irish potato, cowpea, and mango) there were no significant differences in profitability associated with land costs. In this study, farmers rarely hired land or purchased land for crop production (the low and no values from the farm characteristics on land rented-in or land rented-out).

Table 2.4-8: Determinants of Profits using OLS for selected ten crops

	Maize	Field/common beans	Banana/ plantain	Tea	Macadamia	Coffee	Irish Potato	Pigeon pea	Cowpea	Mango
Organic	-10611.010	**-34420.6****	30558.916	2962.321	**156054.2***	**43775.822***	21189.959	501.041	-4910.470	-33860.490
Output Quantity/ha	**12.219****	**69.645****	**10.652****	**65.857****	**88.682****	**77.545****	**38.249****	**60.294****	**43.341****	**11.137****
age	-547.878	280.765	613.146	-96.112	-4106.463	198.550	-258.050	-125.671	47.669	307.33
sex (Male)	12882.816	**17139.729***	-35500.000	-18500.000	**55804.998***	17632.023	21135.422	1460.114	1904.098	5145.4
education level										
adult literacy	18445.787	-24100.000	32591.171	11193.241	78300.056	-7336.000	**-124112.400***	-933.376	-7326.330	-28300.000
primary	-17110.75	-852.772	15355.217	-4465.378	-78921.04	-13900.000	-95023.33	-2287.427	-5836.07	6847.300
secondary	-10000	3426.063	**70483.195***	-6996.284	-34700.000	-18400.000	-90863.65	-2499.576	**-10560.37***	18353
tertiary	**38170.867***	-40300.000	**79343.221***	-66200.000	41008.519	**-43640.92***	-122000.000	**-21536.21****	-13664.56	-90478.29
farm experience	**535.000***	-329.617	716.838	-463.181	4090.413	-618.500	-1055.034	-13.438	-120.191	-93.52
household size	1289.511	2815.218	-9548.101	1212.904	-12900	373.800	1899.930	**-1326.566****	437.463	2365.000
farm size	**-11359.700***	9269.951	30456.216	**31697.875***	23341.448	-5003.000	-2817.328	567.670	-127.505	2028.000
soil quality status	**22986.300***	18605.782	-25000.000	-10400.000	-64800.000	-6586.000	-4658.905	-6366.333	161.850	-21400.000
Crop Count	325.561	-2491.84	-11900.000	**4121.929***	14871.646	**7059.780***	3117.574	-265.269	709.728	1662.800
Bank Account	-11200	**-1.5845.01***	33642.222	**36489.152****	209000.000	18053.000	3163.189	2255.623	771.369	6851.700
Off farm income	1489.579	13796.982	-8478.201	-14200	35987.603	10437.000	-164.390	1194.147	1847.513	8349.900
Membership to Farmer Group	6329.459	11091.803	**145731.300***	458.980	0	0	-28475.160	1390.061	2395.674	16520
Total Input Cost/ha Activity	**0.968****	-0.643	-47.599	-3.945	1.970	**-2.042****	**-0.394****	0.035	**-0.377***	**7.064***
Total Land Cost/ha Activity	**0.482***	**4.646****	**6.710****	**-2.982****	0	0	0	0	0	0
Machakos	**38070.602****	**183610.200****						0	0	0
Murang'a	0	0	0	0			0			
Constant	-37100	**-276079.1****	**-426995.8****	16913.171	-283000	-84500	28692.047	1968.334	**-21495.6****	-70500
N	709.000	571.000	414.000	297.000	244.000	241.000	181.000	249.000	243.000	247.000
R^2	0.501	0.947	0.777	0.958	0.878	0.964	0.797	0.843	0.743	0.602
P	0	0	0	0				0	0	0

*Significance level = *0.05, **0.01, R2 =R squared, P= probability factor.*

2.4.6 Effects of the farming system on yields: Results from the PSM approach

This section estimates the effect of the farming system ('treatment variable') on the yield of selected crops. Three different matching algorithms (Nearest Neighbor (NN), Kernel Matching (KM), and Radius Matching (RM)) were used for robustness checks. As discussed in the methods section, the PSM technique allows for the estimation of the magnitude of the treatment variable on the outcome based on observable characteristics.

Findings for the 3 algorithms (NN, KM, and RM) show that, after controlling for all observable characteristics, organic farming practices significantly increased the yields of field/common bean, macadamia nut, coffee, and mango for the matching (Table 2.4-9). Specifically, organic farming increased the yield of field/common bean by about 2360-2983 kg/ha (a 49.6% to 72.1% increase). Similarly, organic farming increased the yield of macadamia nut by 4937 kg/ha to 5603 kg/ha (36.6% to 43.7% increase), of coffee by about 3235-3830 kg/ha (37.3% to 47.4% increase) and mango by 4645-5446 kg/ha (43.1% to 54.6% increase) respectively. In other crops, no significant differences between organic and conventional farming systems.

Table 2.4-9: Effect of farming system on yields of selected crops

Crop	Matching algorithm	Number of observations		Output Quantity per Ha			t-value
		Organic	Conv.	Organic	Conv.	Difference	
Maize	Nearest Neighbour	149	560	5281.77	6570.19	-1288.42	-1.53
	Kernel Matching			5281.77	5652.64	-370.87	-0.54
	Radius Matching			5281.77	5502.85	-221.08	-0.33
Field common bean	Nearest Neighbour	130	441	7123.16	4762.72	2360.44**	2.58
	Kernel Matching			7123.16	4294.11	2829.05***	3.39
	Radius Matching			7123.16	4140.11	2983.05***	3.62
Banana/ plantain	Nearest Neighbour	125	289	43933.44	52169.76	-8236.32	-1.41
	Kernel Matching			43933.44	49888.08	-5954.64	-1.17
	Radius Matching			43933.44	49834.05	-5900.61	-1.2
Tea	Nearest Neighbour	90	201	16861.21	17797.90	-936.69	-0.58
	Kernel Matching			16861.21	16612.88	248.33	0.19
	Radius Matching			16861.21	16321.21	540.00	0.42
Macadamia Nut	Nearest Neighbour	74	170	18408.39	13215.33	5193.06*	2.37
	Kernel Matching			18408.39	13471.43	4936.96*	2.40
	Radius Matching			18408.39	12805.93	5602.46**	2.85
Coffee	Nearest Neighbour	75	166	11907.97	8672.56	3235.41*	2.35
	Kernel Matching			11907.97	8077.71	3830.26**	3.28
	Radius Matching			11907.97	8114.38	3793.59***	3.38
Irish Potato	Nearest Neighbour	59	120	7407.25	6697.09	710.16	0.58
	Kernel Matching			7407.25	6245.11	1162.15	1.13
	Radius Matching			7407.25	6405.90	1001.35	1.02

Pigeon Pea	Nearest Neighbour	37	160	1125.45	1161.98	-36.53	-0.15
	Kernel Matching			1125.45	1141.42	-15.96	-0.08
	Radius Matching			1125.45	1086.30	39.16	0.21
Cowpea	Nearest Neighbour	36	155	912.44	778.05	134.38	0.79
	Kernel Matching			912.44	727.05	185.38	1.18
	Radius Matching			912.44	723.93	188.50	1.22
Mango	Nearest Neighbour	30	142	15414.76	10769.47	4645.28	1.66
	Kernel Matching			15414.76	9968.14	5446.62*	2.1
	Radius Matching			15414.76	10036.06	5378.70*	2.09

*psmatch2, Significance level = *0.05, **0.01 & ***0.001, Caliper (0.3), chi2 = 0.0001*

Some studies have shown similar results. For example, Te Pas and Rees (2014) found that organic farming systems had, on average, 26 % higher yields for bean, millet, peanut, sorghum and maize in countries in the tropics and subtropics. Crops like tomato, spinach, pepper and lettuce produced lower yields under organic conditions (Te Pas & Rees, 2014). According to (Gurbir *et al*., 2021), the long term systems comparison study in Kenya 2009-2019 reports that organic yields can match conventional ones depending on crop and agronomic management practices. Other studies have shown that organic farming has higher yields depending on the crop or region (Auerbach *et al.,* 2013; Müller *et al.,* 2018; Ostapenko *et al.,* 2020; UNEP-UNCTAD, 2008); while others have found conventional yields to be higher than organic (Krause & Machek, 2018; Lu *et al.,* 2020; Sharma, 2020; Suja *et al.,* 2017) in Czech, Taiwan, and India respectively.

To achieve higher yields in organic, farmers are encouraged to adhere to recommendations on organic management practices and not to apply them to practices in a piecemeal manner (Abdullah et al., 2020). Organic practices, needless-to-say, need to be adjusted to fit local conditions to achieve environmental sustainability (Abdullah *et al.,* 2020). Since farmers make decisions based on a variety of criteria such as market demand, cost of production and ease of management, and do not always aim to maximize yield, capacity or skills building is necessary for the uptake of good agricultural practices (Shennan *et al.,* 2017).

2.4.7 Effects of the farming system on profits: Results from the PSM approach

This section estimates the effect of farming systems ('treatment variable') on the profits of selected crops (Table 2.4-10). Like in the estimation of the effect of type of farming system on yield, this analysis also uses the three matching algorithms NN, KM, and RM. The results show that organic farming only increased the profitability of field/common bean and macadamia nut. The profits of field/common bean increased by between KES 100,398 to 139,028 (35.3% to 56.6% increase). Similarly, the profits for macadamia nut increased by between KES 531,524 to 587,323 (44.4% to 51.5% increase).

There were no significant differences, between organic and conventional farms, in the profits generated for the other crops (maize, banana/plantain, tea, coffee, Irish potato, pigeon pea, cowpea and mango). The negative differences and t-values indicate that conventional farms had better profits than organic for maize, tea, cowpea, and mango. However, the differences in profits for these crops are not statistically different.

Table 2.4-10: Effect of farming system on profits of selected crops

Crop	Matching algorithm	Number of observations		Output Quantity per Ha			t-value
		Organic	Conv.	Organic	Conv.	Difference	
Maize	Nearest Neighbour	149	560	41456.43	49490.03	-8033.60	-0.53
	Kernel Matching			41456.43	48917.69	-7461.26	-0.6
	Radius Matching			41456.43	50430.50	-8974.07	-0.75
Field/ common bean	Nearest Neighbour	130	441	384855.56	477357.03	-92501.47	-1.45
	Kernel Matching			384855.56	284457.25	100398.31*	1.78
	Radius Matching			384855.56	245827.43	139028.13*	2.48
Banana/ plantain	Nearest Neighbour	125	289	459858.39	438715.88	21142.52	0.34
	Kernel Matching			459858.39	459459.75	398.64	0.01
	Radius Matching			459858.39	471150.51	-11292.11	-0.19
Tea	Nearest Neighbour	90	201	982250.06	988797.92	-6547.87	-0.07
	Kernel Matching			982250.06	1008692.58	-26442.52	-0.33
	Radius Matching			982250.06	1005213.09	-22963.03	-0.3
Macadamia nuts	Nearest Neighbour	74	170	1728511.72	1196987.46	531524.26**	2.77
	Kernel Matching			1728511.72	1173232.64	555279.08**	3.23
	Radius Matching			1728511.72	1141187.82	587323.90***	3.55
Coffee	Nearest Neighbour	75	166	905922.71	806440.04	99482.67	0.88
	Kernel Matching			905922.71	915225.40	-9302.69	-0.09
	Radius Matching			905922.71	764618.16	141304.55	1.58
Irish Potato	Nearest Neighbour	59	120	150675.62	124015.84	26659.78	0.67
	Kernel Matching			150675.62	143333.92	7341.70	0.21
	Radius Matching			150675.62	144954.81	5720.81	0.17
Pigeon Pea	Nearest Neighbour	37	160	58459.00	46397.70	12061.30	1.15
	Kernel Matching			58459.00	47460.79	10998.21	1.18
	Radius Matching			58459.00	45806.29	12652.71	1.36
Cowpea	Nearest Neighbour	36	155	11283.05	20929.51	-9646.47	-1.44
	Kernel Matching			11283.05	15307.13	-4024.08	-0.66
	Radius Matching			11283.05	14728.64	-3445.59	-0.57
Mango	Nearest Neighbour	30	142	107592.65	161638.42	-54045.77	-1.31
	Kernel Matching			107592.65	140401.01	-32808.35	-0.95
	Radius Matching			107592.65	142623.60	-35030.94	-1.02

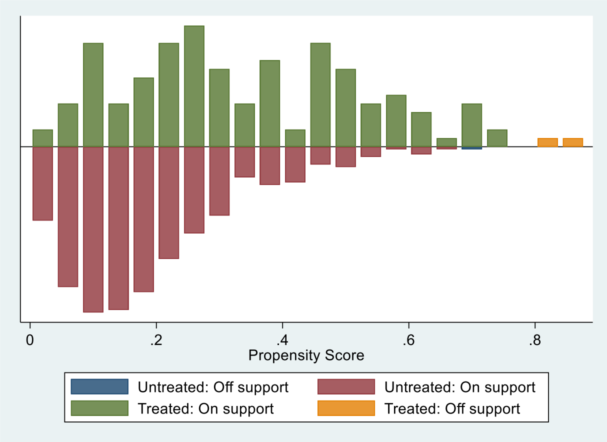
*psmatch2, Significance level = *0.05, **0.01 & ***0.001, Caliper (0.3), Chi2 = 0.0001*

Several authors reported that organic farms produce lower yields compared to conventional ones, but emphasize that the former production systems is more profitable and environmentally friendly, and deliver equally or more nutritious foods that contain less (or no) pesticide residues than the latter one (Rahman & Chima, 2016; Ramesh et al 2010; Reganold & Wachter, 2016; Te Pas & Rees, 2014). Sgroi et al. (2015) compared lemon farms in Italy and found that the gross production value of organic farms (€ 6138 per ha) is almost ten times higher than in conventional farms (€ 649 per ha) (Sgroi et al., 2015). Other studies reveal that organic had higher profitability than in conventional farming (Hampl, 2020). Organic enterprises in Ukraine had an average profit of € 218 per ha compared to conventional farms recording an average of € 149 per ha (Ostapenko et al., 2020). Other comparative studies of organic, such as tea in China and Sri Lanka (Qiao et al., 2016), rice in the Philippines (Mendoza, 2004; Pantoja et al., 2016), honey in Ethiopia (Girma & Gardebroek, 2015), cotton in India (Fayet & Vermeulen, 2014) and pineapple in Ghana (Kleemann, 2016), suggest that organic farming can be profitable and is a feasible option for smallholders living in difficult environmental situations.

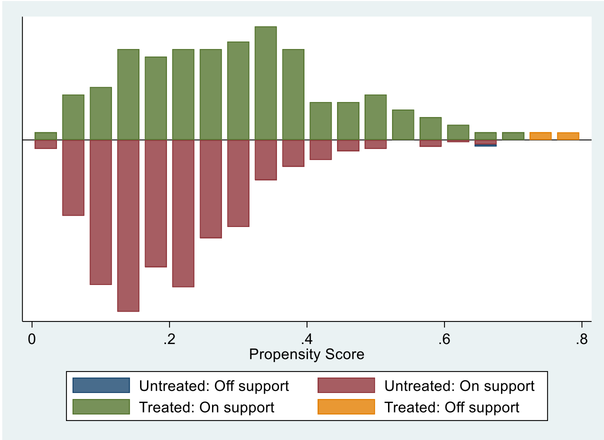
2.4.8 Robustness checks for PSM estimations

To establish whether the common support requirement is achieved, the distribution of propensity scores among the two groups was established across the three matching algorithms. This matching compares the situation before and after matching and checks if any remaining differences are likely to affect the outcome variables. Propensity Score Matching analysis on the effect on yield showed that there was significance for some of the crops like field/common bean, macadamia nut, coffee, and mango (Figure 2.4.1). On the effect on profitability, there were significance differences for field/common bean and macadamia nut. The graphical representation of the distribution of the covariates between the treated and untreated groups for the selected crops was significant (yield looked at field/common bean, macadamia nut, coffee and mango, while profits looked at field/common bean and macadamia nut).

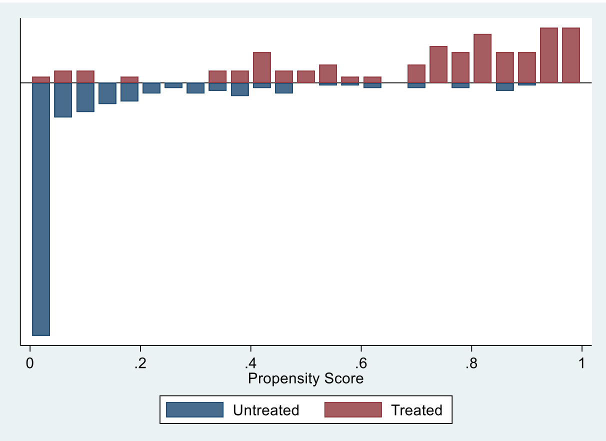
The distribution of the propensity scores is presented along with the area of common support. The results show matching occurs within the region of common support. There is a skewed distribution of the propensity scores between the organic (treated) and conventional farms (untreated) for some of the crops (common beans, macadamia nut, coffee and mango). The results compare the situation before and after matching to check if any remaining differences are likely to affect the outcome variables (Table 2.4-11). The median absolute bias, the value of R-square, and the joint significance of covariates are compared before and after matching.



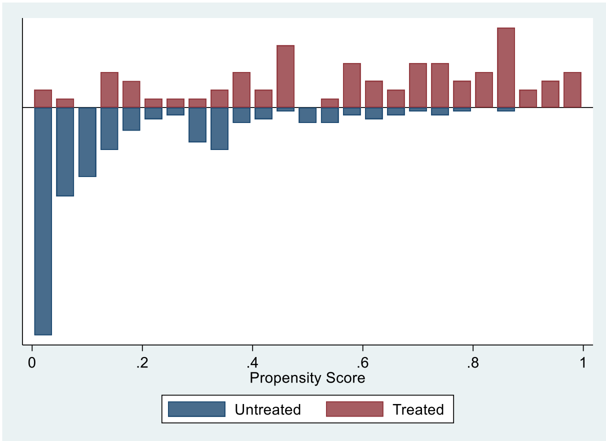
a.) Field/common bean effect on yield



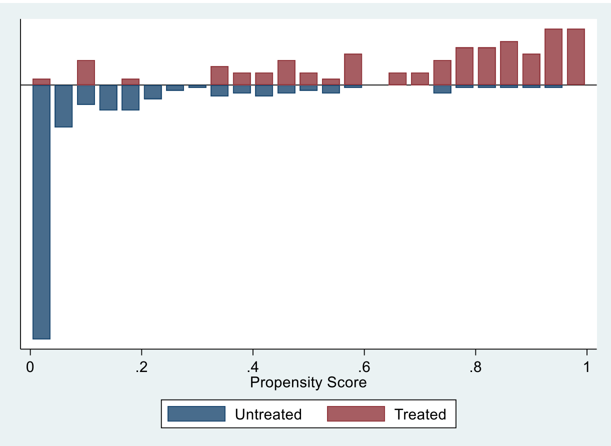
e.) Effect on profits



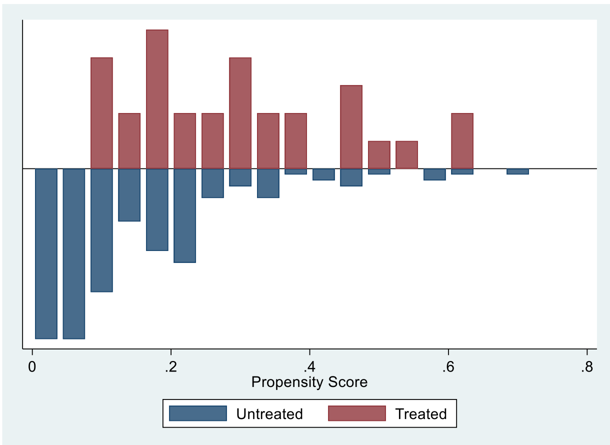
b.) Macadamia nuts effect on yield



f.) Effect on profits



c.) Coffee yields



d.) Mango yields

Source: Survey results 2020, Stata: Psgraphs bin. (25)

Figure 2.4-1: Propensity score distribution and common support for propensity score estimation

Table 2.4-11: Test for Quality of Matches and Sensitivity Analysis

Outcome variable	Matching Algorithm	Median bias before matching	Median bias after matching	% bias reduction	Pseudo R^2 unmatched	Pseudo R^2 matched	p-value of LR unmatched	value of LR matched	Critical level of Hidden bias (gamma)
Yield of Common bean	NNM	13.4	2.6	19.0	0.131	0.007	0.000	1.000	1.00-1.05
	KM		5.1	38.3		0.026		0.986	
	RM		6.9	58.1		0.047		0.739	
Yield of Macadamia nuts	NNM	27.6	12.6	116.0	0.520	0.202	0.000	0.001	1.85 – 1.90
	KM		6.8	87.8		0.128		0.094	
	RM		5.7	89.1		0.132		0.076	
Yield of Coffee	NNM	28.4	11.3	101.9	0.514	0.162	0.000	0.013	1.80 – 1.85
	KM		7.6	88.7		0.131		0.076	
	RM		6.5	90.0		0.135		0.061	
Yield of Mango	NNM	14.1	8.9	32.2	0.171	0.019	0.039	1.000	1.00-1.05
	KM		7.5	59.2		0.065		0.993	
	RM		10.1	78.3		0.112		0.901	
Profits of Common bean	NNM	13.4	3.8	21.6	0.084	0.008	0.000	1.000	1.30-1.35
	KM		8.2	40.5		0.029		0.921	
	RM		10.7	53.8		0.050		0.461	
Profits of Macadamia nut	NNM	24.8	10.0	65.2	0.376	0.073	0.000	0.455	1.80 – 1.85
	KM		7.5	61.0		0.066		0.559	
	RM		7.9	65.1		0.075		0.418	

Note: NNM= Nearest Neighbour Matching, KM= Kernel Matching and RM= Radius Matching

Table 2.4-11 indicates a reduction in median absolute bias before and after matching, for all three matchings, as a result of matching algorithms for the yields of field/common bean, macadamia nut, coffee, and mango, and for the profits of field/common bean and macadamia nut. The estimates show that the reduction in the median bias were all greater than 19% for the yields (field/common bean 19%, macadamia nut 87%, coffee 88%, and mango 32%) and greater than 21% for the profits (field/common beans 21% and macadamia nut 61%). According to Abadie and Imbens (2011), Beal and Kupzyk (2014), and Rubin (2006), a large reduction in bias improves the quality of matching.

Results of the Pseudo-R^2 before (unmatched) and after (matching),presented in the columns 6 and 7 in Table 2.4-11, show the matching lower than before matching for the yields (field/common bean, macadamia nut, coffee and mango) and profits (field/common bean and macadamia nut). The results signify that there were no systematic differences in the distribution of covariates between organic and conventional farms after the matching process for the crop yields (field/common bean, macadamia nut, coffee, and mango) and profits (field/common bean and macadamia nut).

The p-values of the likelihood ratio (LR) tests in the before and after matching scenarios are shown in columns 8 and 9 of Table 2.4-11. The results indicate that the hypothesis of the joint significance of the regressors is rejected after matching for yields in the field/common bean, macadamia nut, coffee, and mango, and profits in the field/common bean and macadamia nut. The hypothesis of the joint significance of the regressors is also rejected before matching for mango yields.

The results of the sensitivity analysis of the critical level of the hidden bias, shown by the gamma, Γ, at which a causal inference of the significant impact of the choice of the farming system may be questioned, are presented in the last column of Table 2.4-11. Gamma measures the difference in response variables between treated and untreated cases. For example, the value of 1.85-1.90 for the yield of macadamia nut implies that if farms that had the same characteristics were to differ in the yields by a factor of 85-90%, the significance of the impact of yield on the farming system would be questionable. The profits for field/common bean of a value of 1.30-1.35 and macadamia nut value of 1.80-1.85 implies that if farms with the same characteristics were to differ in the profits of field/common bean and macadamia nut by a factor of 30-35% and 80-85% respectively, the significance of the impact of profits on the farming system would be questionable. The results suggest that even a large amount of unobserved heterogeneity would not alter the inference about the estimated effect of yields and profits on the farming system for the different crops.

2.5 Conclusion

The analysis presented in this chapter was undertaken to assess the effect of the type of farming system (organic vs. conventional) on yield and profitability for various crops in Murang'a, Kirinyaga and Machakos counties of Kenya. Some of the socio-economic and farm characteristic aspects of the farmer influenced the productivity and profitability of organic and conventional farming systems. The variables (age, number of household members, education level, membership in farmer organization, farm size, land owned, crop count (the number of crops grown on the farm), and hours worked by family and hired labour) considered for productivity (yield) had positive significance for organic farming.

On the productivity of organic and conventional farming systems, the study also demonstrates that in overall, the organic system had higher significant yields for coffee, common bean, macadamia nut, and pigeon pea. The crops plantain, cabbage, and silky oak had lower significant yields for organic interventions. Organic was significantly more profitable for the crops avocado, Irish potato, spinach, pigeon pea, coffee, common bean, and macadamia nut while significant less profitable only for silky oak.

The effect on yields for four organically grown crops, compared by using the nearest neighbor, kernel matching and radius matching, showed that there was a significant increase in yields for organic field/common bean, macadamia nut, coffee and mango more than in conventional farms. Likewise, the profits of field/common bean and macadamia nut were significantly different on organic as compared to conventional farms.

The results have agreed with the study objectives that organic farming systems can achieve similar or higher productivity and profitability as conventional farming for some crops tested. Organic can thus provide an alternative farming system that can viably compete with conventional systems and should be promoted. The results show that for some crops, organic farming systems can improve the livelihoods and household incomes of farmers in the three counties. The constraints organic farmers face should be addressed to increase yields and profits. Capacity building of farmers to enhance their skills on organic principles will go a long way in increasing the yields and profitability of organic farming. The application of organic crop management practices by farmers is dependent on the knowledge farmers have acquired in their farming experience, including trainings they have participated in. On organic farms, soil health management, use of cover crops, crop rotation, composting, integrated pest and disease management, and proper weed management all aid the gaining of a higher yield. Since organic farming has significant positive impacts on yields and profitability for some crops, these should be promoted among small-scale producers as a way of improving their livelihoods. Strategies that promote good agricultural practices in the production and marketing of farm produce should be adopted to enhance existing organic farming systems. This could help other farmers see that organic is a viable alternative option, competitive to conventional farming systems.

3. Chapter : Sustainability performance of smallholder organic and conventional farms in Kenya

3.1 Introduction

The mechanization of agriculture and development and use of high-yielding crop varieties and artificial fertilizers and pesticides, was initiated as a means to increase food production (Kannan *et al.*, 2005; Pretty & Bharucha, 2014). Compared to conventional farming, alternative agricultural farming methods such as conservation agriculture, precision farming, agro-ecological farming and organic agriculture among others, aim to provide more sustainable farming practices that conserve biodiversity and ecosystem services for future generations (Hansen, 1996; Latruffe *et al.*, 2016; Pretty & Bharucha, 2014). It has been suggested that such alternative approaches can meet the increasing demand for food as the world population rises (Pretty & Bharucha, 2014; Waney *et al.*, 2014).

The concept of sustainable agricultural systems is centered on the need to develop techniques and practices that have low effects on the environment, improvements in productivity, and positive side-effects on agricultural goods and services (Kannan *et al.*, 2005; Waney *et al.*, 2014). Conventional agriculture is characterized by the extensive use of artificial fertilizers and pesticides, with detrimental effects on the environment and human health (Luttikholt, 2007; Pretty & Bharucha, 2014). By contrast, organic farming utilizes on-farm or locally available resources, less or no synthetic fertilizers and pesticides, and practices such as crop rotation and mulching with natural plant materials, while encouraging diversification of crops and animal species (Adamtey *et al.*, 2016; Shennan *et al.*, 2017. Organic farming conserves soil fertility and quality, leads to harmony with nature, builds on relationships that ensure fairness, and protects current and future generations and the environment (Luttikholt, 2007). Since organic production targets the development of a sustainable cultivation-based system, organic agriculture is a relevant tool to advance the United Nations SDGs on sustainable agriculture, sustainable consumption and production, climate change, and ecosystems (UNEP-UNCTAD, 2008).

For a system to be defined as sustainable, certain variables that make it viable need to be measured (Hayati *et al.*, 2010; Latruffe *et al.*, 2016; Pretty & Bharucha, 2014). The parameters for measuring agricultural sustainability are multi-dimensional and complex, and vary depending on the criteria used, scope of the study, and context or geographic location (Binder *et al.,* 2010; FAO, 2013; Marchand *et al.,* 2014; Schader *et al.,* 2014). Although many sustainability assessment methods and tools exist, if they are not suited to the particular system to be assessed they may fail to correctly measure the desired sustainability aspects (de Olde *et al.*, 2016; Röös *et al.*, 2019). Coteur (2018) adds that for strategic decision making, sustainability assessment tools need to be well-tuned to farmers' needs, motivations, and vision. The methods need to assess any given farm from a broader sustainability assessment approach to identify and highlight areas in need of improvement, study trade-offs, and follow developments over time (Binder *et al.*, 2010; FAO, 2013; Marchand *et al.*, 2014; Schader *et al.,* 2014).

Past research that has compared organic and conventional production systems has utilized farm surveys, field experiments, and case studies in similar geographical areas (Binta *et al.,* 2015; Gabriel *et al.,* 2013; Shennan *et al.*, 2017). Assessments take the farm level as the evaluation unit, where the production of goods and services (economic); the management of natural resources (ecological); the contribution to rural dynamics (social); and decision making (governance) takes place (Hayati *et al.*, 2010; Latruffe *et al.,* 2016; Waney *et al.,* 2014).

A limited number of studies on the sustainability of farming systems in Kenya exist. They largely lack a holistic approach and fail to capture the multidimensional impacts expected in organic farming. The existing studies on sustainability have assessed energy use (Mirko *et al.*, 2019), external input technologies (De Jager *et al.*, 2001), priorities for extension and training in agriculture (Grenz *et al.*, 2009), school gardens (Sottile *et al.*, 2016), urban sustainability (Mutisya & Yarime, 2014), typology of farms (Kamau *et al.,* 2018), adoption and sustainability of dairy technologies (Mwirigi *et al.*, 2009), biogas (Nzila *et al.,* 2012) and input-output tea management (Onduru *et al.*, 2012). In these studies, the data or sample sizes were relatively small e.g. 30 farms in Grenz *et al.*, (2009), 15 case studies in Sottile *et al.*, (2016), 200 farms in Mwirigi *et al.*, 2009, 120 farms in Onduru *et al.*, (2012) and 53 households in Spaling, *et al.* (2014).

The current study seeks to provide evidence on how farmers and farming practices under organic farming perform in Kenya in comparison with conventional farming systems. Most existing studies examine only conventional farming methods and practices. Only a few focus on organic farming and, in particular, farmer experiences in ecological farming (as against organic experimental research). This study uses a novel approach to measure sustainability: it considers the holistic nature of the sustainability concept, constructed through a hierarchical framework of principles, criteria, and indicators. The indicator-based multi-criteria assessment tool used in this study is known as the Sustainability Monitoring and Assessment RouTine Farm Tool (SMART-Farm Tool) (Schader *et al.*, 2016; Ssebunya *et al.*, 2018). The SMART-Farm Tool's indicators are spread across four sustainability dimensions emphasizing the multi-dimensional nature of sustainable development (Hanuš, 2004; Schader *et al.*, 2016). Each of the four dimensions has its own set of indicators, sub-themes and themes.

Within the space of political commitment to sustainable agriculture, more evidence is required on how farmers and organizations transit towards practicing sustainable agriculture and, more specifically, what their motivations and driving forces are. This study seeks to add to the existing organic agriculture debate as well as to policy framework measures in Kenya that support organic farming as a suitable alternative for sustainable farming, food and nutrition security, and income generation of small-scale households. In this chapter, an assessment of the sustainability performance of organic and conventional farming systems in three Kenyan counties (Kirinyaga, Machakos, and Murang'a) is reported. The research questions is:

How sustainable are organic compared to conventional farming systems in Kenya?

Whereas the objectives are:

- To evaluate the sustainability performance and differences of organic compared to conventional agricultural farming systems in three counties of Murang'a, Kirinyaga and Machakos in Kenya (at the sub-theme and indicator level).

3.2 Methodology

Study areas

This study was carried out between January and March 2017 in three counties, each with different agro-ecological, climatic, and farming characteristics (see Chapter 1). The crops grown in the case study counties include cereals, fruits, vegetables and stimulant crops. In Murang'a, the crops include arrowroot, avocado, plantain, cabbage, common beans, Irish potato, kale, maize, spinach and tea. In Kirinyaga, the crops were avocado, plantain, coffee, common beans, French beans, silky oak, kale, macadamia, maize and tea. In Machakos, the crops include banana, chili pepper, cowpea, common beans, green gram, lemon, maize, mango, papaya, and pigeon pea. The organic farming systems in each of the counties have differing degrees of certification. At the time of the study in Murang'a, the Organic Agriculture Centre of Kenya (OACK) had trained farmers in organic ecological farming but they were yet to be certified. In Kirinyaga the Limbua group (formerly Macadamia Fans) had certified organic farms using an organic certification body based in Europe known as the Ecocert group (Walaga, 2004). In Machakos, farmers had been trained under the Sustainable Agriculture Community Development Programme (SACDEP). SACDEP ended in 2009, and the farmers were unable to renew their organic certification after it lapsed in early 2010.

Sample selection

The sample size was determined based on an equation given by *Yamane (1967)*, quoted in Israel (1992, p. 3) as, *"Equation 1.*

$$n = \frac{N}{1+N(e)^2} \qquad \text{(Equation 1)}$$

Where:

n is the suggested sample size,

N is the total number of farms, and

e is the level of precision, set at 3% to 5% for the study*"*.

The farms included in this study in chapter 1 are the same farms were selected for sustainability assessment (Table 3.2-1). The targeted number of farms were 900 with each county having 300 farms. To reach the targeted number of farms, the margins were increased by between 10 to 30 %, to take into account sampling factors such as farmers dropping out or declining the interview (Israel, 1992).

Table 3.2-1: Farms sampled in the survey instrument used for data collection

County	**Targeted and selected farms**		**Farms from where data were collected**		**Farms whose data were analyzed**	
	Organic	**Conventional**	**Organic**	**Conventional**	**Organic**	**Conventional**
Kirinyaga	150	150	94	188	84	192

Machakos	90	210	55	241	40	256
Murang'a	150	150	114	172	81	201
Total	390	510	263	601	205	649

Data were eventually collected from 864 farmers but only 854 farmers (205 organic, 649 conventional) were included in the subsequent statistical analysis, since not all the farmers completed the survey and some dropped out during the interview process since they had other commitments or due to natural demise. The 205 organic farms were those under the intervention.

SAFA guidelines and the SMART-Farm Tool

The Sustainability Assessment of Food and Agriculture Systems (SAFA) guidelines developed by the Food and Agriculture Organization of the United Nations (FAO) provide a universal framework for sustainability assessments. These guidelines aim to harmonize sustainability assessment methods and increase the transparency and comparability of their results (FAO, 2013a). This study uses the SMART-Farm Tool developed by the Research Institute of Organic Agriculture (FiBL). This indicator-based multi-criteria assessment tool was created following the SAFA guidelines (Schader *et al.*, 2016; Ssebunya *et al.*, 2018).

The SMART-Farm Tool, coded under the reference SMART-Farm Tool; RRID: SCR_018197, has four dimensions (governance, environmental integrity, economic resilience, and social well-being), 21 themes, and 58 sub-themes. The tool takes a holistic approach by incorporating a wide range of indicators and capturing the multidimensional impacts of sustainability in its four dimensions. Constructed through a hierarchical framework of principles, criteria, and indicators, it utilizes a set of indicators and impact weights to determine the degrees of goal achievement for different sustainability dimensions and sub-themes (Schader *et al.*, 2016; Ssebunya *et al.*, 2018). It has about 327 indicators, with 1769 linkages between these indicators and the 58 SAFA sub-themes (Annex 1 highlights the sub-themes used in the analysis of this study). From the 327 indicators for 58 SAFA sub-themes, a set of relevant indicators was selected for each farm interview by using a specific relevance check function in the SMART-Farm Tool. This function selects indicators based on three factors: geographic region, farm type (organic or conventional), and specific farm components (crops, livestock, labour type, pesticides, or fertilizer use), as described by Schader *et al.* (2016) and

Ssebunya *et al.* (2018). The relevance check function is standardized to improve efficiency during the interview as it reduces the number of indicators to only those that apply to each farm, and reduces the subjectivity of the interviewer by selecting the relevant indicators. The results are normalized on a scale of 0-100% indicating the worst (unacceptable) to the best performance according to the SAFA guidelines (FAO, 2013a; Schader *et al.*, 2016). The pre-determined impact weights (rated at -1 to +1) of relevant indicators for respective sub-themes, inbuilt in the SMART-Farm Tool, enables determination of the degree of goal achievement of the farm tied to specific sub-themes (Schader *et al.*, 2016).

The degree of goal achievement (*DGAix*) of a farm *x* concerning a sub-theme *i* is defined as (equation 2) the ratio of the sum of impacts of all indicators (n = 1) that are relevant for a sub-theme *i* (IM_{ni}) multiplied by the actual performance of a farm *x* concerning an indicator *n* (IS_{nx}) and the sum of the impacts multiplied by the maximal performance possible on these indicators (IS_{maxn}). (FAO, 2013a; Schader *et al.*, 2016). The impacts thus serve as "weights" for the different indicators used to assess the degree of goal achievement for a sub-theme (FAO, 2013a; Schader *et al.*, 2016)

Expressed as:

$$DGA_{ix} = \frac{\sum_{n=1}^{N} (IM_{ni} X IS_{ns})}{\sum_{n=1}^{N} (IM_{ni} X IS_{maxn})} \quad \text{(Equation 2)}$$

Where:

x = farm

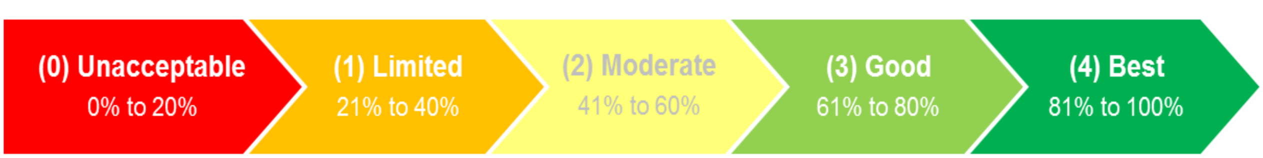
i = sub-theme

IM_{ni} = all indicators relevant to the sub-theme i

IS_{nx} = actual performance of a farm x with reference to an indicator n

IS_{maxn} = maximal performance with reference to n indicators

The level of goal achievement scale ranged from 0% to 100%.



Thus, the SMART-Farm Tool can be conceptualized as a Multi-Criteria Analysis (MCA) (Dodgson, 2001) for each sub-theme (Figure 3.2-1) of the SAFA guidelines (FAO, 2013b, 2013a; Schader *et al.*, 2016).

Differences in the performance of organic and conventional farming systems in the three counties for each sub-theme were tested using a non-parametric Mann-Whitney U test (Equation 3), which allows for two groups or conditions to be compared without assuming a normal distribution:

$$U = R_1 - \frac{n_1(n_1+1)}{2} \qquad \text{(Equation 3)}$$

Where:

n is the number of items in the sample, and

R_1 is the sum of the ranks in the sample.

The Statistical Package for Social Science (SPSS) version 22 was used to analyze the data for the Mann-Whitney U test (IBM SPSS, 2014).

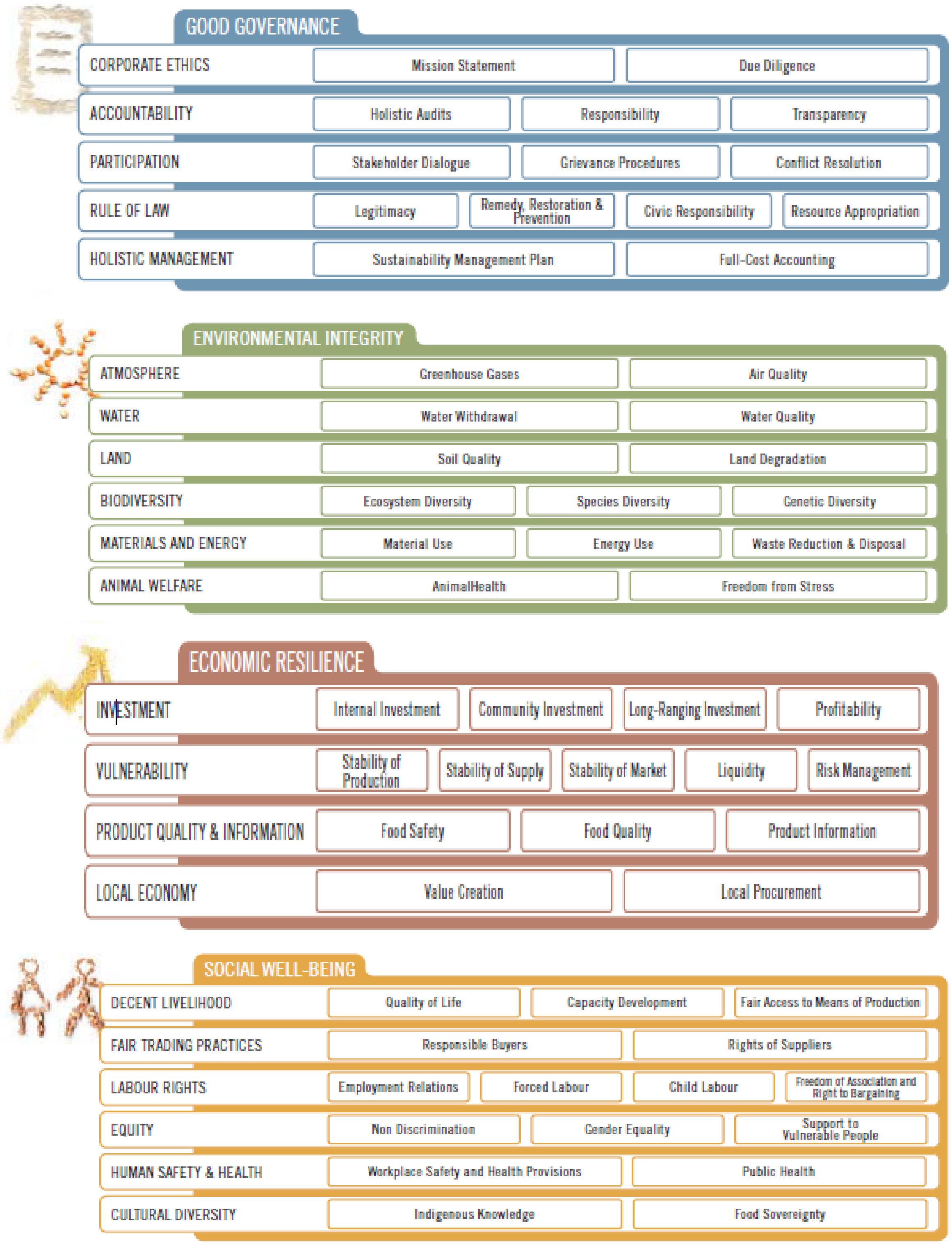


Figure 3.2-1: Summary of the dimension, themes, sub-themes and indicators of the Sustainability Assessment of Food and Agriculture Systems guidelines. Source FAO, (2013)

Survey design

To be defined as such, organic farmers should follow organic principles and organic management practices (Luttikholt, 2007; Weidmann et al., 2004). The organic farms included in this survey are those that practiced organic by default and those that were organic certified. A list of such farms was provided by NGOs working on organic agriculture in the study area. Follow-up questions about being organic were included in the questionnaire. Questions seeking the following information were built into the farmer questionnaire: Is the farmer an organic farmer (yes/no)? What is the reason for farming organically? Since when has the farmer been organic/when did the farmer convert to organic? If the farmer has stopped farming organically, what was the main reason? Is the whole farm certified organic or just a part of it? In which year was the entire farm, or a part of the farm, certified organic? If a part of the farm only, which fields were certified organic? Which was the certification body? Is there any internal control system? Other questions concerning inputs used (fertilizer, insecticides, fungicides and herbicides) and management practices assisted in grouping the farmers into the organic and conventional groups. Even if the farmer was initially considered organic, the results of the (farm operations) analysis might have led to the farmer being reclassified as conventional, and vice versa. The questionnaire incorporated both quantitative and qualitative measures about the each farm and its operations. An extensive literature review had informed the survey design on the geography, crops, yields, prices, typical farm activities, agricultural inputs, and climatic conditions of the sampled counties, providing background information used as a reference and as bench-marking points in the questionnaire.

Data collection

Prior to the onset of the farm survey, 15 auditors and six facilitators were trained for two weeks. The questionnaire was piloted before the onset of the surveys. The survey was a process involving farm tours, interviews (between auditor and farmer), and observations. All interviews started with a brief introduction, a tour of the farm, and concluded after a face to face interview with the farm manager covering all relevant evaluation topics. Clarification was sought from farmers for answers to questions that were not clear, for example by scanning through records of farm receipts or viewing input containers (for active insecticide, fungicide and herbicide ingredients).

After the farmer interviews, the surveys were reviewed by the auditors to ensure that each question had been appropriately answered. A peer-review process was established to ensure consistency in terms of the rating approaches used by different auditors. The peer-review involved the exchange of the day's surveys between auditors in the same county. If irregular responses were detected, further consultation with the farmer was sought. A facilitator and auditor discussion also took place to identify further corrective action to be taken before the final farm questionnaire was uploaded to the SMART-Farm Tool (version 4.1) database.

Subsequent plausibility checks were conducted by a third person focusing on indicators that raised issues of inconsistency or relevance checks in the database (Annex 1). Data errors were verified with the respective auditors or corrected using available literature to maintain consistency in the ratings. Where possible, the data was cross-referenced with existing secondary information as part of the consistency check.

Data analysis

The surveys, as SMART-Farm Tool survey files, were analyzed with the SMART-Farm Tool software to compute the degree of goal achievement per indicator, sub-theme, and theme.

Additional statistical analysis, including descriptive analysis (frequencies, percentages, means, and medians), were conducted to check which goal achievement scores, across organic and conventional farms and across counties, were the highest. Each sub-theme has several relevant indicators and impact weights, which give the performance ratings at the sub-theme level (Annex 2). The sum of the impact weights and the scores for the sub-theme category gave the level of achievement at the sub-theme level. It is worth noting that for each sub-theme there is a group of indicators that in combination allow for assessment of the degree of goal achievement. Each of the indicators has a rating associated with it to be used in the analysis. A non-parametric test was carried out to check if there were any significant differences between the sub-theme and indicators in organic and conventional farms. The Mann-Whitney U test, using IBM SPSS version 22, was used for a quick check on which of the means and mean rank scores were higher for organic and conventional farms (IBM SPSS, 2014).

Further analysis to test for significant differences was carried out using Stata version 16. A mixed-effect regression model was used and the farm type (organic or conventional) was considered as the random factor for each variable in the "varlist mission statement to food sovereignty" for the sub-theme and indicators (58 sub-themes and 1,300 sub-theme indicator combinations). The standard error for the goal achievement scores were also included to show where there were significant differences between organic and conventional farms. The $P<0.05$ shows the significance level of the sub-theme/indicator scores for the distribution. A Fisher's protected Least Significant Difference (LSD) test was used for the pairwise comparison analysis, as recommended by Milliken and Johnson (2009). The methodology was recommended for planned comparisons, assuming the corresponding joint test is significant (Milliken & Johnson, 2009). Apart from comparing the overall performance of organic and conventional farms at the sub-theme level, the comparison is also done at the county (case study) level. This checks the performance of organic and conventional farms at the county level and if they are significantly different.

Deeper analysis of 12 sub-themes

A further, deeper analysis, was required for a selected number of sub-themes to understand the scores and the reasons behind the scores for the two systems as the results are interpreted. At times, the result of the scores can be the same or almost the same for both organic and conventional farming. It is therefore necessary to understand at a more detailed level the indicators for a better interpretation of the data. Since it is not possible to look at the whole data-set of the sustainability assessment (over 1300 sub-theme indicator combinations), a selected number that were relevant, manageable, consistent and sufficient to include all sustainability goals were chosen for the further indicator analysis. 12 sub-themes (Table 3.2-2) were selected using the following four criteria:

Criteria 1: A synopsis of statistical analysis was done to check which of the sub-themes have significant differences between the two groups (organic versus conventional). Of the total 58 sub-themes (Annex 1), 13 had no significant difference and 46 were significant (across all four sustainability dimensions: environmental integrity 10, economic resilience 12, social well-being 10, and governance 14).

Criteria 2: Relevance to the case study (county) settings (based on the SAFA sub-theme objectives, some had little or no relevance and were thus dropped). For example, in the "responsible buyers" sub-theme, the buyers set the price and there are no real negotiations on the set prices; therefore this sub-theme was deemed irrelevant and dropped.

Criteria 3: Not redundant but excluded because other analysis methods would be needed to assess the sub-theme. For example, in the "emissions of greenhouse gases" sub-theme, a quantitative measure would be necessary to assess the degree of goal achievement. Needless-to-say, this was beyond the scope of this study.

Criteria 4: Availability of secondary information, for Kenya, on the opportunities, challenges and constraints that affect the topic of the sub-theme. For example, some interesting aspects on production, marketing and value addition along various value chains were considered, as was the *Economic Review of Agriculture in Kenya 2015(MoALF 2015)* and the recent *Agricultural Sector Transformation and Growth Strategy 2019-2029* (GoK, 2019). The information was used to interpret the results at the sub-theme and indicator levels. For example, which plant/pest protection control measures are allowed or not allowed in organic farming and if allowed, what quantity per area per time period (EAOPS 2007).

Finally, we compared the sub-theme means for organic and conventional farming systems across the three counties to arrive at a number of sub-themes for further detailed analysis. The 12 sub-themes selected were: water withdrawal, ecosystem diversity, and soil quality (dimension: environmental integrity); stability of supplies, stability of the market, and food safety (economic resilience); capacity development, indigenous knowledge, and public health (social well-being); and holistic audits, civic responsibility, and sustainability management plan (governance) (Table 3.2-2). Annex 3 for the full list of sustainability subthemes and their objectives. Further comparison of the indicators and sub-themes was undertaken to reduce the number of indicators to those relevant to the 12 sub-themes. To do so, a high impact weight of 0.7 was applied to the data to get absolute weights of between 0 and 1 to generate the sub-theme indicators for analysis and comparison. For the indicators selected, a Fisher's protected Least Significant Difference (LSD) test was used to check if the means were significantly different at the farming system and the case study levels.

A mixed effect regression model is used for the final analysis. The mixed model takes the farm as a random factor for each of the variables in the valist (mission statement to food sovereignty) for the subthemes and valist (Air quality _00186_RenewableEnergyProductionOnFarm_Calculated to Work place safety and health provision _00790_EmplyeesProtectiveGear) for the indicators. The mixed, contrast and margins for the interactions are generated between organic and conventional farms for significance differences test for the 854 farms.

Table 3.2-2: Selected Sub-themes and their objectives for the deeper analysis

SAFA dimension	Sub-theme	Sub-theme objectives
Environmental integrity	Water withdrawal	Withdrawal of ground and surface water and/or use does not impair the functioning of natural water cycles and ecosystems and human, plant and animal communities.
	Ecosystem diversity	The diversity, functional integrity and connectivity of natural, semi-natural and agri-food ecosystems are conserved and improved.
	Soil quality	Soil characteristics provide the best conditions for plant growth and soil health, while chemical and biological soil contamination is prevented.
Economic resilience	Stability of supplies	Stable business relationships are maintained with a sufficient number of input suppliers and alternative procurement channels are accessible.
	Stability of market	Stable business relationships are maintained with a sufficient number of buyers, income structure is diversified and alternative marketing channels are accessible.
	Food safety	Food hazards are systematically controlled and any contamination of food with potentially harmful substances is avoided.
Social well-being	Capacity development	Through training and education, all primary producers and personnel have opportunities to acquire the skills and knowledge necessary to undertake current and future tasks required by the enterprise, as well as the resources to provide for further training and education for themselves and members of their families.
	Public health	The enterprise ensures that operations and business activities do not limit the healthy and safe lifestyles of the local community and that they contribute to community health resources and services.
	Indigenous knowledge	Indigenous knowledge and intellectual property rights related to traditional and cultural knowledge are protected and recognized.
Governance	Holistic audits	All areas of sustainability in the SAFA dimensions that pertain to the enterprise are monitored internally in an appropriate manner, and wherever possible are reviewed according to recognized sustainability reporting systems.
	Civic responsibility	Within its sphere of influence, the enterprise supports the improvement of the legal and regulatory framework on all dimensions of sustainability. It does not seek to avoid the impact of human rights, or sustainability standards, or regulation through the corporate veil, relocation, or any other means.
	Sustainability management plan	A sustainability plan for the enterprise is developed which provides a holistic view of sustainability and considers synergies and trade-offs between all the four dimensions, i.e. the environmental, economic, social, and governance dimensions.

Source: based on FAO, 2013a

The indicators selection is based on the 12 sub-themes. About 1300 indicators from the 58 sub-themes are in the dataset. Each indicator has an impact value of -1 to +1. A high impact weights of 0.7 was applied to the data to get absolute weights of between 0 and 1. When apply the impact weight of 0.7 there was a slight reduction in the number of indicators to 1219. Further comparing the indicators and sub-themes was done to reduce the indicators to those relevant to the 12 sub-themes. Non-parametric tests carried out to test and the means and mean ranking scores with significance reported for each case study.

3.3 Results

This section presents, under the headings of the four sustainability dimensions, the results of the differences in the degree of achievement scores at a) the sub-theme level for organic and conventional farming systems, b) the county level, and c) the indicator level for selected sub-themes.

3.3.1 Environmental integrity

Overall performance of organic vs. conventional at sub-theme level

This dimension includes six themes (atmosphere, water, land, biodiversity, materials and energy, and animal welfare), and 14 sub-themes. Compared to conventional organic farms had a higher degree of achievement scores in 10 of the 14 sub-themes, namely greenhouse gases, air quality, water quality, soil quality, ecosystem diversity, species diversity, genetic diversity, material use, energy use, and waste reduction and disposal. Organic and conventional farms had very little difference in the degree of achievement scores in the sub-themes, namely water withdrawal, land degradation, animal health, and (animal) freedom from stress than conventional farms. The median and mean values for organic and conventional farms are reported in Figure 3.3-1 and Annexes 4

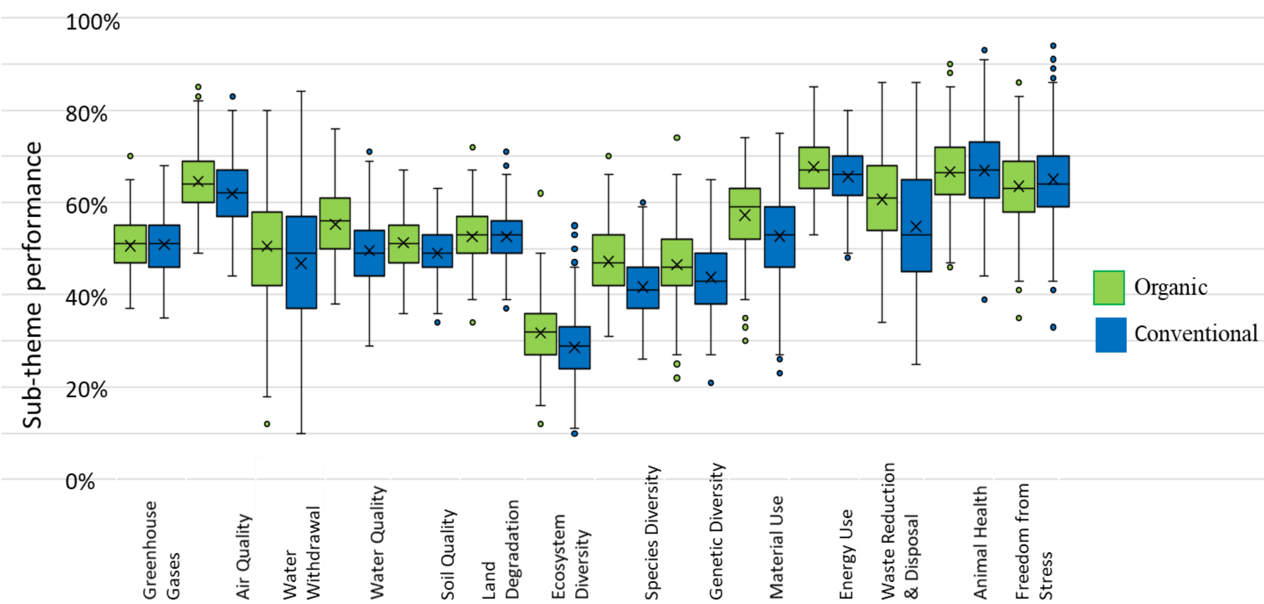


Figure 3.3-1: Environmental integrity sub-theme median values for organic vs. conventional (x: mean, -: median)

The mean values of the two farming systems at the sub-theme level were further analyzed to identify if they had significant differences. The results reveal that compared with conventional, the mean values for organic farms were higher and also significantly different at $P < 0.05$ for the sub-themes greenhouse gases (52 vs. 51%), air quality (65 vs. 62%), water quality (54 vs. 50%), and soil quality (51 vs. 49%). The other sub-themes with a higher score in organic farms were ecosystem diversity (32 vs. 29%), species diversity (47 vs. 42%) and genetic diversity (47 vs. 44%), material use (56 vs. 53%) and energy use (68 vs. 66%), and waste reduction and disposal (58 vs. 55%) (Table 3.3-1). Thus, the performance for organic farms was better than that of conventional farms under 10 sub-themes.

In the four of the sub-themes, namely water withdrawal, land degradation, animal health and (animal) freedom from stress, there were no significant differences between organic and conventional farms. This means that statistically organic and conventional have roughly the same overall impact on water withdrawal, land degradation, animal health, and (animal) freedom from stress.

Performance at county level: organic vs. conventional

When comparing the farming system and the county, since in each county there were both organic and conventional farms, there were mixed results (Table 3.3-1). This assessment checks if there are any differences between the farming system and county level (case study level), and which farming system and county is more sustainable on a scale of 0-100%.

The subthemes with statistical significance for organic interventions were genetic diversity, material use, waste water reduction and disposal in Kirinyaga County while in organic Murang'a were greenhouse gases, water quality, ecosystem diversity, species diversity and genetic diversity. There were no farms under organic interventions with statistical significance in Machakos. Conventional farms on the other hand, had statistical significance for the subthemes air quality, ecosystem diversity, species diversity and genetic diversity in Kirinyaga County while Murang'a had the subthemes greenhouse gases, air quality, and water quality. The farms under conventional farming with statistical significance in Machakos were species diversity and freedom from stress. In the environmental integrity the farming systems that managed or contained the sustainability measure in the subthemes were more sustainable than the other.

Table 3.3-1:Sub-theme and the degree of achievement scores (%) comparing differences between system, county, system and county with standard error margin

	System			County				System and County						
								P	Kirinyaga		Murang'a		Machakos	
Sub-theme	P	Organic	Conventional	P	Kirinyaga	Murang'a	Machakos		Organic	Conventional	Organic	Conventional	Organic	Conventional
Greenhouse Gases	<0.05	51.6(±0.4) a	50.6(±0.2)b	<0.05	49.7(±0.3)a	46.2(±0.3)b	56.2(±0.3)c	<0.05	50.3(±0.6)	49.6(±0.4)	48.3(±0.5)a	45.6(±0.3)b	56.0(±0.8)	56.2(±0.3)
Air Quality	<0.05	65.1(±0.5) a	61.6(±0.2)b	<0.05	60.0(±0.4)a	61.3(±0.4)b	66.0(±0.4)c	<0.05	63.1(±0.8)	58.9(±0.5)a	64.7(±0.7)	60.1(±0.4)b	67.3(±1.2)	65.6(±0.4)
Water Withdrawal	ns	49.0(±1.0)	47.1(±0.6)	<0.05	47.8(±0.8)a	52.4(±0.7)b	42.8(±1.0)c	<0.05	53.7(±1.1)	46.0(±0.9)	51.1(±1.3)	52.8(±1.3)	42.7(±2.3)	42.9(±1.0)
Water Quality	<0.05	54.2(±0.6) a	49.7(±0.3)b	<0.05	48.9(±0.4)a	55.5(±0.4)b	48.0(±0.4)	<0.05	54.2(±0.7)	47.2(±0.5)	59.4(±0.8)a	54.3(±0.4)b	49.2(±1.2)	47.7(±0.4)
Soil Quality	<0.05	51.0(±0.4) a	49.0(±0.2)b	<0.05	49.1(±0.3)	50.3(±0.3)b	49.0(±0.3)	<0.05	52.1(±0.6)	48.2(±0.4)	51.1(±0.7)	50.2(±0.4)	50.0(±0.8)	48.8(±0.3)
Land Degradation	ns	52.6(±0.5)	52.6(±0.2)	<0.05	53.4(±0.3)	51.4(±0.3)b	53.1(±0.3)	<0.05	54.0(±0.7)	53.1(±0.4)	51.1(±0.7)	51.5(±0.3)	52.8(±1.0)	53.1(±0.4)
Ecosystem Diversity	<0.05	31.8(±0.5) a	28.6(±0.2)b	<0.05	25.3(±0.4)a	32.0(±0.3)b	30.6(±0.4)c	<0.05	28.6(±0.7)	24.3(±0.5)a	34.9(±0.6)b	31.1(±0.4)	31.8(±1.2)	30.1(±0.4)
Species Diversity	<0.05	46.8(±0.5) a	41.8(±0.2)b	<0.05	39.9(±0.4)a	47.0(±0.4)b	42.1(±0.4)c	<0.05	44.7(±0.7)	38.3(±0.5)a	51.1(±0.7)b	45.7(±0.5)	44.5(±1.2)	41.2(±0.3)c
Genetic Diversity	<0.05	46.7(±0.5) a	43.7(±0.3)b	<0.05	40.2(±0.4)a	46.4(±0.4)b	46.3(±0.5)	<0.05	42.3(±0.8)a	39.6(±0.4)b	50.6(±0.7)c	45.1(±0.5)	47.0(±1.2)	46.1(±0.5)
Material Use	<0.05	55.7(±0.6) a	52.9(±0.3)b	<0.05	53.8(±0.5)a	57.0(±0.4)b	50.3(±0.6)c	<0.05	60.8(±0.6)a	51.5(±0.6)	57.2(±0.8)	56.9(±0.5)	49.6(±1.4)	50.5(±0.7)
Energy Use	<0.05	68.0(±0.4) a	65.5(±0.2)b	<0.05	66.2(±0.4)a	63.7(±0.3)b	68.3(±0.4)c	<0.05	68.7(±0.7)	65.3(±0.5)	65.9(±0.6)	63.0(±0.4)a	69.5(±0.9)	67.9(±0.4)
Waste Reduction & Disposal	<0.05	58,3(±0.6) a	55.2(±0.4)b	<0.05	52.0(±0.5)a	66.9(±0.6)b	49.1(±0.6)c	<0.05	59.2(±0.6)a	49.8(±0.6)	68.2(±1.0)	66.5(±0.7)	48.2(±1.4)	49.5(±0.7)
Animal Health	ns	66.0(±0.7)	66.7(±0.4)	<0.05	63.5(±0.4)a	67.5(±0.6)	68.6(±0.6)	ns	67.1(±0.8)	62.4(±0.5)	67.5(±1.0)	68.9(±0.6)	63.7(±1.4)	68.7(±0.6)
Freedom from Stress	ns	63.6(±0.6)	64.6(±0.4)	<0.05	61.2(±0.4)a	63.6(±0.6)b	67.9(±0.6)c	<0.05	64.2(±0.8)	60.2(±0.5)	62.3(±1.1)	64.1(±0.7)	64.2(±1.3)	69.1(±0.6)a

Note: margins showing letters in the group are significantly different at the 5% level

Performance at the sub-theme level (1): Water withdrawal

The sub-theme water withdrawal is important in farming activities as it addresses water conservation targets and practices, and how farmers utilize ground and surface water in their farming activities. The objective aims to ensure that farms do not contribute to the water supply problems of ecosystems or human water users at any of the sites where they operate (FAO 2013, p. 117). The seven indicators that were relevant for this study were information on water availability, waste water disposal, irrigation water consumption, yield decrease due to lack of water, irrigation-precipitation measurement, water storage capacity and reusable packaging materials.

Comparing organic and conventional farms, the mean values for organic farms had statistical significant differences (P< 0.05) for the two indicators: irrigation: water consumption per ha (at 64%), and irrigation precipitation measurement (at 53%) (Table 3.3-2), meaning that organic farms were more sustainable for these two indicators. There was no significant difference for the other five indicators. The measures imply that the farms had taken steps to reduce water withdrawal in the farms by irrigating their crops. Also measure how much irrigation water is required in the farm.

According to the SAFA Guidelines (FAO 2013), the lowest point on the scale of 0-100% is the unacceptable range of 0-20%, which depicts that a farm has a very poor performance and needs intervention measures to sustain it. On the other hand, 21-40% is classified as limited, 41-60% as modest, 61-80% as good, while a farm that scores about 80% is the most sustainable.

Table 3.3-2: Indicators and the degree of achievement scores (%) comparing the differences between farming systems with standard error margin

Indicator	P	Organic	Conventional
00376_1_InformationWaterAvailability	ns	30.64(±1.9)	29.59(±1.1)
00377_05_WastewaterDisposal	ns	6.33(±1.3)	9.23(±0.8)
00389_IrrigationWaterConsumption_Calculated	<0.05	64.14(±2.8)a	54.83(±1.6)b
00400_YieldDecreaseLackOfWater	ns	16.66(±1.4)	17.72(±0.8)
00404_IrrigationPrecipitationMeasurement	<0.05	52.64(±2.2)a	46.23(±1.3)b
00405_WaterStorageCapacity	ns	13.09(±1.6)	14.07(±0.9)
00739_ReusablePackagingMaterials	ns	14.53(±0.5)	14.31(±0.3)

Note: margins showing a letter in the group label are significantly different at the 5% level.

Performance at the sub-theme level (2): Ecosystem diversity

The sub-theme objective is the conservation and improvement of diversity, functional integrity and connectivity of natural, semi-natural and agrifood ecosystems (FAO 2013, p. 127). Of 21 indicators, in the current study, seven indicators' means with positive significant differences (P-value< 0.05) for organic farms (meaning they were more sustainable than conventional farms) include: no use of synthetic chemical insecticides (34%), no use of active ingredients toxic to bees (18%), no use of active ingredients toxic to aquatic organisms (18%), average quantities of mineral N fertilizers (4%), average quantities of mineral P fertilizers (3%), management of riparian stripes (29%), and use of growth regulators (3%) (Table 3.3-3). Even though organic farms looked to be more sustainable than conventional farms the degree of goal achievement score for the indicators "no use of synthetic chemical insecticides", "no use of active ingredients toxic to bees" and "no use of active ingredients toxic to aquatic organisms", were expected to be much higher for organic farms in line with the organic norms, meaning that a good number of farms used the inputs.

Some farms that were labeled as organic actually used some forms of synthetic chemicals in at least one of the growing seasons, on at least one of their plots or fields. According to the East African Organic Products Standards EAS456:2007 under schedule annex B (p. 19), certain active ingredients of synthetic origin may be used if listed, e.g. copper salt allowed up to a maximum of 8 kg/ha/yr (on a rolling average range base) (EAOPS, 2007).

Table 3.3-3: Indicators and the degree of achievement scores (%) comparing differences between farming systems with standard error margin

Indicator	P	Organic	Conventional
00202_AgroForestrySystems_Calculated	ns	5.67(±1.2)	5.27(±0.6)
00204_WoodlandsDeforestation	ns	6.32(±0.1)	6.44(±0.1)
00208_WoodlandsShareAgriculturalLand_Calculated	ns	8.53(±1.1)	6.5(±0.6)
00215_ArableLandShareTemporaryGrassland_Calculated	ns	6.99(±0.7)	5.91(±0.4)
00222_PermanentGrasslandsShareOfAgriculturalArea_Calculated	ns	2.7(±0.7)	3.7(±0.3)
00233_NoUseSynthChemFungicides	ns	31.58(±0.7)	31.22(±0.4)
00234_NoUseSynthChemInsecticides	<0.05	33.89(±0.7)a	28.16(±0.4)b
00253_PermanentGrasslandsExtensivelyManaged	ns	16.92(±2.4)	13.94(±0.9)
00257_1_PesticidesToxicityBees	<0.05	18.38(±1.2)a	12.52(±0.6)b
00257_2_PesticidesToxicityAquaticOrganisms	<0.05	17.75(±1.2)a	10.01(±0.6)b
00257_ArableLandAveragePlotSize_Calculated	ns	38.83(±0.7)	39.4(±0.4)
00323_MineralNFertilizers	<0.05	3.82(±0.1)a	3.03(±0.1)b

00324_MineralPFertilizers	<0.05	3.29(±0.1)a	2.72(±0.0)b
00371_AccessToPasture	ns	6.24(±0.5)	6.42(±0.2)
00605_ManagementRiparianStripes	<0.05	28.95(±1.9)a	18.62(±1.1)
00620_PermanentGrasslandMowingFrequency	ns	14.69(±1.8)	13.07(±0.8)
00711_EcolComensationValuableLandscapeElements	ns	2.46(±0.7)	1.1(±0.3)
00740_GrowthRegulation	<0.05	3.11(±0.1)a	2.6(±0.1)b
00743_SealedAreas_Calculated	ns	3.45(±0.0)	3.39(±0.0)
00758_NumberPerennialcrops	ns	1.57(±0.5)	2.5(±0.2)
00764_ShareLegumesOnPerennialCropArea	ns	5.08(±1.0)	3.8(±0.4)

Note: margins showing a letter in the group label are significantly different at the 5% level.

Performance at the sub-theme level (3): Soil quality

This objective covers the protection and enhancement of the physical, chemical and biological properties of soil used by an enterprise (FAO, 2013, p. 122). Twenty four (24) indicators were deemed relevant and were utilized in the analysis of the current study. The four indicators' means with statistical significant differences (P-value< 0.05) for organic farms included: antibiotics presence in livestock manure/fertilizer (25%), arable land gradients greater than 15% (42%), average quantities of mineral N fertilizers (42%), average quantities of mineral P fertilizers (43%); meaning that organic farms were more sustainable for these indicators (Table 3.3-4). On the other hand, the six indicators' means with statistical significant differences (P-value< 0.05) for conventional farms include: share of arable land that is direct seeded (4%), no use of synthetic chemical fungicides (45%), soil improvement (65%), sealed areas calculated (33%), humus formation humus balance (59%), and presence of some perennial crops (2%) meaning that conventional farms were slightly more sustainable for these indicators than organic farms, even though conventional has higher significant scores, the highest percentage point differences between the two systems is just 5%.

Also, according to a 2020 UNDP report, the use of fertilizer per ha in Kenya is very low. It is reported that the use of fertilizer nutrient nitrogen (N) per area of cropland (/indicators/196006) was on average 9.5 kg per hectare and the use of fertilizer nutrient phosphorus (expressed as P2O5) per area of cropland (/indicators/196106) averaged 2.3 kg per hectare (UNDP, 2020). The high cost of synthetic chemicals is a factor contributing to low input use by both organic and conventional farmers (Chianu *et al.,* 2012).

Table 3.3-4: Indicators and the degree of achievement scores (%) comparing the differences between farming systems with standard error margin

Indicator	P	Organic	Conventional
00202_AgroForestrySystems_Calculated	ns	3.62(±0.8)	3.35(±0.4)
00206_ShareLegumesArableLand	ns	30.28(±1.4)	30.57(±0.9)
00207_ArableLandShareDirectSeeding	P<0.05	1.92(±0.8)a	3.98(±0.5)b
00215_ArableLandShareTemporaryGrassland_Calculated	ns	7.93(±1.0)	7.1(±0.6)
00222_PermanentGrasslandsShareOfAgriculturalArea_Calculated	ns	2.88(±0.7)	3.93(±0.3)
00233_NoUseSynthChemFungicides	P<0.05	40.1(±1.6)a	45.36(±0.9)b
00234_NoUseSynthChemInsecticides	ns	45.12(±1.6)	42.18(±0.9)
00286_SoilDegradationCounterMeasures	ns	50.61(±2.6)	50.75(±1.5)
00295_AntibioticsLivestockFertilizer	P<0.05	25.28(±1.6)a	19.25(±0.9)b
00298_SoilImprovement	P<0.05	59.33(±2.0)a	64.91(±1.0)b
00300_ArableLandGradientsGreater15Percent	P<0.05	41.81(±1.4)a	47.27(±0.7)b
00323_MineralNFertilizers	P<0.05	42.43(±1.2)a	34.19(±0.8)b
00324_MineralPFertilizers	P<0.05	43.04(±1.1)a	38.24(±0.7)b
00327_WasteDisposalPesticidesVeterinaryMedicines	ns	11.66(±1.5)	11.07(±0.9)
00377_1_PesticidesNumberActiveSubstances	ns	27.1(±1.0)	25.65(±0.5)
00474_2_PesticidesPersistenceSoil	ns	38.34(±1.9)	41.04(±1.2)
00708_PreciseFertilisation	ns	13.03(±1.3)	11.61(±0.7)
00710_HarmfulSubstancesPFertilizer	ns	32.66(±2.0)	31.31(±1.0)
00740_GrowthRegulation	ns	34.59(±1.3)	31.96(±0.8)
00743_SealedAreas_Calculated	P<0.05	30.38(±0.8)a	33.37(±0.4)b
00748_HumusFormationHumusBalance	P<0.05	55.93(±0)a	59.33(±0.0)b
00758_NumberPerennialcrops	P<0.05	1.43(±0.5)a	2.48(±0.2)b
00764_ShareLegumesOnPerennialCropArea	ns	6.5(±1.3)	4.64(±0.5)
00202_AgroForestrySystems_Calculated	ns	4.1(±0.9)	3.81(±0.4)

Note: margins showing a letter in the group label are significantly different at the 5% level.

3.3.2 Economic Resilience

Performance of organic vs. conventional at sub-theme level

The economic resilience dimension has five themes (investment, vulnerability, product quality and information, and local economy) and 14 sub-themes (see Table 3.3-5). Organic farms had a higher degree of achievement scores in 10 sub-themes: internal investment, community investment, long-ranging investment, stability of supply, stability of market, liquidity, risk management, food safety, food quality, and product information (Figure 3.3-2 and annex 4 and annex 9).

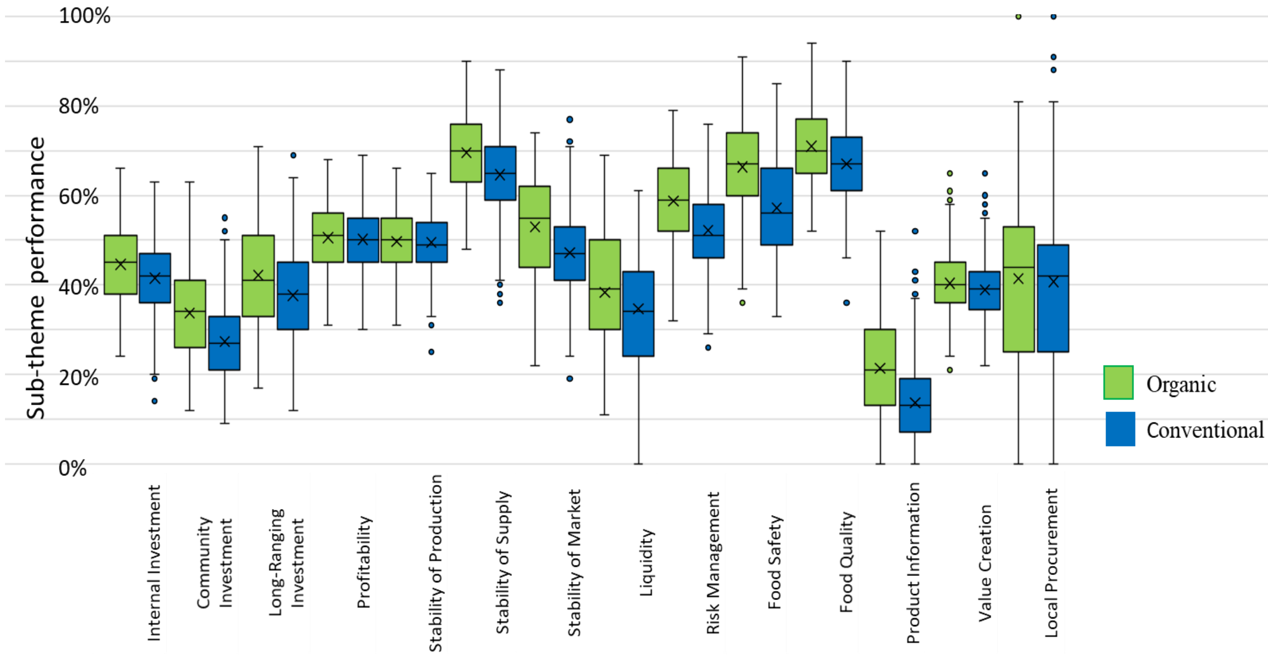


Figure 3.3-2: Economic resilience sub-theme median values for organic vs. conventional (x: mean, -: median)

The 10 sub-themes that were significantly different (P< 0.05) and higher in organic systems than conventional ones include: internal investment (43 vs. 42%), community investment (31 vs. 28%), long-ranging investment (41 vs. 38%), stability of supply (70 vs. 65%), stability of market (51 vs. 48%), liquidity (37 vs. 35%), risk management (57 vs. 53%), food safety (64 vs. 58%), food quality (71 vs. 67%) and product information (19 vs. 14%) (Table 3.3-5). The performance of organic farms was better than that of conventional farms under those sub-themes. The other four sub-themes were not significantly different between organic and conventional farms (profitability, stability of production, value creation, and local procurement), meaning that organic and conventional farms have roughly the same overall impacts for these sub-themes.

Performance at county level: organic vs. conventional

Comparing the sustainability of the two systems of farming in each county, using the scale of 0-100%, there were mixed results at the sub-theme level (Table 3.3-5). The sub-themes that were significantly different (P<0.05) varied per system type and county. Organic farms in Kirinyaga were significantly different for internal investment (at 48%), long-ranging investment (at 41%), profitability (at 54%), the stability of markets (at 57%), and product information (at 27%), i.e. these were higher than for any other county-farming system.

Table 3.3-5: Sub-theme and the degree of achievement scores (%) comparing differences between system, county, system and county with standard error margin

Economic Resilience

	System			County				System and County						
								P	Kirinyaga		Murang’a		Machakos	
Sub-theme	**P**	**Organic**	**Conventional**	**P**	**Kirinyaga**	**Murang’a**	**Machakos**		**Organic**	**Conventional**	**Organic**	**Conventional**	**Organic**	**Conventional**
Internal Investment	<0.05	43.4(±)0.6a	41.8(±0.3)b	<0.05	43.3(±0.5)	44.2(±0.4)	39.1(±0.5)a	<0.05	48.4(±0.8)a	41.7(±0.6)	43.3(±0.9)	44.5(±0.4)	39.0(±1.2)	39.2(±0.5)
Community Investment	<0.05	31.4(±0.6)a	27.6(±0.3)b	<0.05	27.9(±0.5)a	34.0(±0.4)b	23.9(±0.4)c	<0.05	35.4(±1.0)	25.5(±0.6)	37.7(±0.9)	32.8(±0.5)a	21.7(±1.0)b	24.6(±0.5)
Long-Ranging Investment	<0.05	41.0(±0.8)a	37.9(±0.3)b	<0.05	33.8(±0.6)	46.9(±0.6)a	35.2(±0.6)	<0.05	40.6(±1.1)a	31.7(±0.6)b	47.3(±1.4)	46.8(±0.6)	35.3(±1.6)	35.1(±0.5)
Profitability	ns	49.5(±0.5)	50.3(±0.3)	<0.05	52.0(±0.4)	51.5(±0.4)	47.0(±0.4)a	<0.05	53.9(±0.7)a	51.4(±0.5)	50.2(±0.8)	51.9(±0.4)	44.7(±1.1)b	47.8(±0.4)c
Stability of Production	ns	48.7(±0.5)	49.6(±0.3)	<0.05	50.1(±0.3)	50.6(±0.4)	47.5(±0.4)a	<0.05	51.6(±0.6)	49.6(±0.4)	50.1(±0.8)	50.8(±0.4)	44.8(±1.0)a	48.3(±0.4)
Stability of Supply	<0.05	69.6(±0.6)a	64.5(±0.4)b	<0.05	64.6(±0.6)	64.4(±0.4)	68.0(±0.6)a	<0.05	70.0(±1.1)	62.8(±0.7)	68.8(±0.9)	63.1(±0.5)	70.0(±1.3)	67.3(±0.6)
Stability of Market	<0.05	50.9(±0.7)a	47.5(±0.3)b	<0.05	53.3(±0.5)a	48.5(±0.6)b	43.5(±0.5)c	<0.05	57.3(±1.1)a	52.0(±0.6)	53.7(±1.1)	46.9(±0.7)b	42.3(±1.5)	43.9(±0.5)
Liquidity	<0.05	37.2(±1.0)a	34.6(±0.5)b	<0.05	31.8(±0.8)	40.5(±0.7)a	33.4(±0.8)	<0.05	38.5(±1.5)	29.7(±0.9)	41.6(±1.4)	40.1(±0.9)	31.8(±2.2)	33.9(±0.8)
Risk Management	<0.05	57.0(±0.6)a	52.5(±0.3)b	<0.05	51.6(±0.4)a	61.3(±0.5)b	48.0(±0.5)c	<0.05	57.1(±0.7)a	49.8(±0.5)	65.2(±0,7)b	60.1(±0.6)b	48.9(±1.5)	47.7(±0.5)
Food Safety	<0.05	64.3(±0.8)a	57.6(±0.3)b	<0.05	57.9(±0.5)a	67.6(±0.5)b	52.5(±0.6)c	<0.05	65.7(±0.9)	55.4(±0.6)	72.5(±0.8)a	66.1(±0.6)	55.1(±2.1)	51.6(±0.5)
Food Quality	<0.05	71.2(±0.6)a	66.7(±0.3)b	<0.05	67.6(±0.4)a	63.8(±0.4)b	71.8(±0.6)c	<0.05	75.4(±0.7)	65.2(±0.5)	65.3(±0.6)	53.4(±0.5)a	73.1(±1.5)	71.3(±0.5)
Product Information	<0.05	19.1(±0.7)a	13.7(±0.4)b	<0.05	17.6(±0.7)	16.3(±0.5)	11.4(±0.4)a	<0.05	26.9(±1.3)a	14.7(±0.9)	21.5(±1.0)b	14.5(±0.6)	9.7(±1.2)	11.9(±0.4)
Value Creation	ns	39.4(±0.5)	39.2(±0.2)	<0.05	40.3(±0.4)a	42.5(±0.4)b	35.2(±0.3)c	<0.05	40.3(±0.8)	40.3(±0.5)	42.8(±0.9)	42.4(±0.4)	35.2(±0.9)	35.2(±0.3)
Local Procurement	ns	41.2(±1.0)	40.7(±0.4)	<0.05	32.4(±0.7)a	49.5(±0.7)b	40.4(±0.7)c	<0.05	34.5(±1.4)	31.7(±0.7)	49.6(±2.0)	49.4(±0.7)	39.3(±1.9)	40.7(±0.8)

Note: margins sharing a letter in the group label are not significantly different at the 5% level

Organic farms in Murang'a were significantly different and higher than the other county-systems in risk management (at 65%) and food safety (at 73%). Conventional farms in Murang'a, on the other hand, were significantly different (i.e. more sustainable) for the sub-themes community investment, stability of market, risk management, and food quality. The sub-themes stability of supply, liquidity, value creation, and local procurement were not significantly different for any of the counties or farming systems.

Performance at the sub-theme level (4): Food safety

The sub-theme objective is that food hazards are systematically controlled and any contamination of food with potentially harmful substances is avoided (FAO, 2013, p. 166). Twenty (27) indicators were utilized (Table 3.3-6). Twelve (12) indicators had means with significant difference (P< 0.05) for organic farms, namely: no use of synthetic chemical seed dressings (at just 14%), transparency of production (at 14%), no use of synthetic chemical insecticides (at 37%), no antibiotics from livestock in organic fertilizers (24%), average quantities of mineral N fertilizers applied in the farm/ha/yr (23%), fewer different pesticides used (38%), no use of pesticides with chronic toxicity (49%), no use of pesticides with acute toxicity (38%), no use of pesticides with acute toxicity inhalation (37%), no use of pesticides that are persistent in water (33%), knowledge about active substances in pesticides (36%), and no use of growth regulators (44%). This means that organic farms were more sustainable than conventional farms for the 12 mentioned indicators. On the other hand, conventional farms were significantly (P-value< 0.05) more sustainable for the three indicators: no contaminated products (84%), number of quality drinking points (26%), and wastewater disposal (8%) (Table 3.3-6).

Table 3.3-6: Indicators and the degree of achievement scores (%) comparing the differences between farming systems with standard error margin

Indicator	P	Organic	Conventional
00034_2_UseageChemSynthSeedDressings	P<0.05	13.95(±1.4)a	6.14(±0.6)b
00167_ No contaminated Products	P<0.05	83.13(±0.5)a	84.36(±0.1)b
00169_ContaminationCasesMeasures	ns	57.52(±3.0)	52.25(±1.6)
00175_TrasparencyProduction	P<0.05	14.09(±1.3)a	3.59(±0.5)b
00233_NoUseSynthChemFungicides	ns	33.47(±0.7)	33.08(±0.4)
00234_NoUseSynthChemInsecticides	P<0.05	37.33(±0.8)a	31.02(±0.5)b
00295_AntibioticsLivestockFertilizer	P<0.05	24.48(±1.6)a	18.78(±0.9)b
00323_MineralNFertilizers	P<0.05	22.79(±0.6)a	18.08(±0.4)b
00353_LivestockHealthProphylacticTreatments	ns	42.34(±1.6)	40.99(±0.9)

00369_NumberQualityDrinkingPoints	P<0.05	23.07(±1.4)a	26.33(±0.8)b
00376_2_InformationWaterQuality	ns	9.32(±1.5)	7.23(±0.7)
00377_05_WastewaterDisposal	P<0.05	5.54(±1.2)a	8.22(±0.7)b
00377_1_PesticidesNumberActiveSubstances	P<0.05	38.48(±0.8)a	32.45(±0.4)b
00377_5_PesticidesChronicToxicity	P<0.05	49.37(±2.1)a	30.47(±1.3)b
00377_7_PesticidesAcuteToxicity	P<0.05	38.22(±1.8)a	26.33(±0.9)b
00377_75_PesticidesAcuteToxicityInhalation	P<0.05	37.45(±1.8)a	24.51(±0.9)b
00470_CertifiationUsagePlantProtectionAnimalTreatment Products	ns	20.53(±2.0)	23.36(±1.1)
00474_1_PesticidesPersistenceWater	P<0.05	33.23(±2.0)a	19.82(±1.1)b
00474_2_PesticidesPersistenceSoil	ns	43.38(±1.4)	40.94(±1.0)
00474_3_PesticidesKnowledge	P<0.05	36.29(±1.8)a	28.88(±1.1)b
00608_UseageAntibioticDryingAgents	ns	37.15(±1.8)	35.07(±0.9)
00609_MilkWaitingPeriodAntibiotics	ns	18.04(±1.0)	17.55(±0.5)
00708_PreciseFertilisation	ns	9.94(±1.0)	9.09(±0.5)
00710_HarmfulSubstancesPFertilizer	ns	28.99(±1.8)	28.72(±0.9)
00720_SilageStorage	ns	16.68(±2.0)	14.91(±1.1)
00721_FeedConcentrateStorage	ns	37.62(±2.3)	39.53(±1.2)
00740_GrowthRegulation	P<0.05	43.94(±1.1)a	36.74(±0.8)b

Note: margins showing a letter in the group label are significantly different at the 5% level.

Performance at the sub-theme level (5): Stability of market

The objective of the sub-theme is to ensure that stable business relationships are maintained with a sufficient number of buyers, income structure is diversified and alternative marketing channels are accessible (FAO, 2013, p. 160). Organic farms were not more sustainable than conventional ones for any of the 11 indicators used. For conventional farms, the indicator means with significant differences (P-value< 0.05), meaning they were more sustainable than organic farms, were direct sales (at 26%), no returned products (at 60%) and length of customer relationships (at 52%) (Table 3.3-7). The other eight indicators were not significantly different between the farming systems, meaning there were no differences between organic and conventional farms.

Table 3.3-7: Indicators and the degree of achievement scores (%) comparing the differences between farming systems with standard error margin

Indicator	P	Organic	Conventional
0083_SalesDiversification	ns	38.67(±1.6)	36.88(±0.8)
00084_AvailabilityAlternativeMarkets	ns	47.93(±3.0)	41.41(±1.6)
00141_DirectSales	P<0.05	17.36(±1.7)a	25.95(±0.9)b
00146_No ProductReturns	P<0.05	54.42(±1.9)a	60.17(±1.0)b
00149_LengthCustomerRelationshios	P<0.05	43.41(±2.1)a	51.89(±1.3)b

00202_AgroForestrySystems_Calculated	ns	1.75(±0.4)	1.62(±0.2)
00208_WoodlandsShareAgriculturalLand_Calculated	ns	2.94(±0.4)	2.45(±0.2)
00223_RareEndangeredCrops	ns	1.74(±0.3)	1.37(±0.1)
00707_CustomerRelationship	ns	28.32(±2.7)	29.53(±1.5)
00751_DependencyMainCustomer	ns	40.72(±2.2)	41.14(±1.0)
00768_CollectiveMarketing	ns	9.02(±0.5)	9.75(±0.5)

Note: margins showing a letter in the group label are significantly different at the 5% level.

Performance at the sub-theme level (6): Stability of supplies

The objective of the sub-theme is to ensure stable business relationships are maintained with a sufficient number of input suppliers and accessible alternative procurement channels (FAO, 2013, p. 158). Of 12 indicators, selected, organic farms were more sustainable than conventional in three: hybrid cultivars (12%), average quantities mineral N fertilizers (32%), and average quantities mineral P fertilizers (34%) (Table 3.3-8). For another three indicators, conventional farms were found to be more sustainable, i.e. with significant difference (P< 0.05), namely: farm inputs secure supply (75%), no use of synthetic chemical insecticides (32%), and "if bought organic fertilizer" (50%). The other six indicators were not significantly different between the farming systems meaning that there were no difference between organic and conventional.

Explanation: Under hybrid cultivars it should be noted that organic farmers used conventionally-bred seeds as there were limited alternatives (farmers lack skills to select own high yielding propagation materials including seeds, and, because there are no enterprises specializing in this and supplying organic farms with seeds and seedlings). The hybrid cultivars are coated in fungicide as pre-treated. For organic farmers growing tea and coffee, use of mineral N and P fertilizers was allowed as per the Free-trade agreements with the tea and coffee factories that the farmers supply the produce to, since the factories were the same as those conventional farmers took the produce to. The tea and coffee factories provided the inputs to the farmers at a subsidized cost.

Table 3.3-8: Indicators and the degree of achievement scores (%) comparing the differences between farming systems with standard error margin

Indicator	P	Organic	Conventional
00088_FarmInputsSecureSupply	P<0.05	68.67(±2.2)a	75.25(±1.2)b
00093_CooperationSuppliersQuality	ns	30.71(±1.8)	29.32(±1.2)
00199_BoughtConcentratedFeed	ns	4.91(±1.3)	7.18(±0.7)
00233_NoUseSynthChemFungicides	P<0.05	28.1(±1.2)a	31.86(±0.6)b
00234_NoUseSynthChemInsecticides	ns	31.67(±1.2)	29.59(±0.6)
00247_HybridCultivars	P<0.05	11.9(±1.4)a	7.66(±0.6)b

00323_MineralNFertilizers	P<0.05	32.22(±0.9)a	26.2(±0.6)b
00324_MineralPFertilizers	P<0.05	33.76(±0.9)a	30.13(±0.6)b
00626_BoughtInRoughage	ns	47.15(±2.1)	50.13(±1.2)
00708_PreciseFertilisation	ns	6.18(±0.6)	5.5(±0.3)
00712_BoughtOrgFert	P<0.05	38.37(±2.0)a	50.34(±0.9)b
00740_GrowthRegulation	ns	30.99(±1.2)	28.64(±0.7)

Note: margins showing a letter in the group label are significantly different at the 5% level.

3.3.3 Social well-being

Performance of organic vs. conventional at sub-theme level

The social well-being dimension has six themes (decent livelihood, fair trading practices, labour rights, equity, human safety and health, cultural diversity. These six themes contain 16 sub-themes, listed in Figure 3.3-3 and annex 4 and annex 9. The Figure shows that the median and mean values for the degree of goal achievement were higher in organic farms than conventional farms for the five sub-themes: responsible buyers, rights of suppliers, workplace safety and health provisions, public health, and indigenous knowledge. Conventional farms only had a higher degree of goal achievement for the sub-theme employment relations.

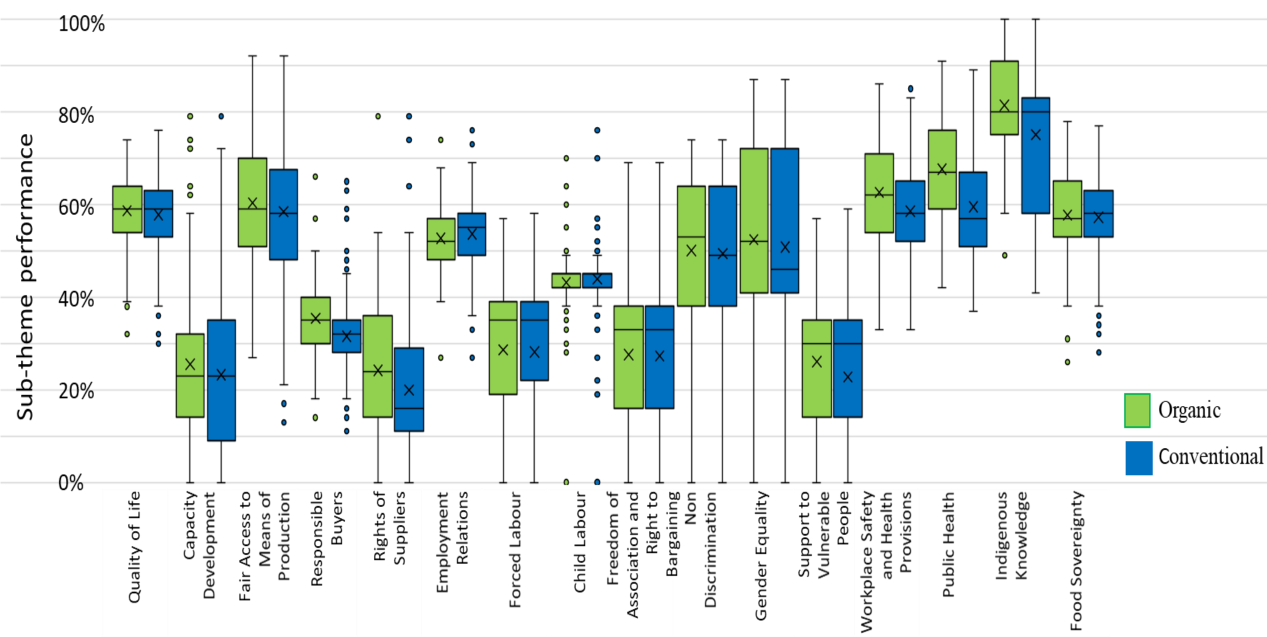


Figure 3.3-3: Social well-being sub-theme median values for organic vs. conventional (x: mean, -: median)

The five sub-themes that were significantly different (P< 0.05) and higher (meaning the performance was better) in organic systems as compared to conventional were namely responsible buyers (34 vs.

32%), rights of suppliers (22 vs. 21%), workplace safety and health provisions (61 vs. 59%), public health (66 vs. 60%), and indigenous knowledge (80 vs. 75%) (Table 3.3-9 and Annex 4). Conventional farming had a significantly higher degree of goal achievement only for the sub-theme employment relations (54 vs. 53%).

Performance at county level: organic vs. conventional

When comparing the system of farming and the county there were mixed results for the sub-themes (Table 3.3-9). The five sub-themes capacity development, fair access to means of production, employment relations, child labour, and freedom of association and right to bargaining, were not significantly different. Quality of life was only significantly lower for organic farms in Murang'a. Responsible buyers and rights of suppliers were significantly different only for organic farms in Kirinyaga. Non-discrimination was significantly different for organic farming in Kirinyaga (62%), and for conventional farming in both Kirinyaga (57%) and Machakos (48%). Public health was significantly different for organic farming in both Kirinyaga (64%) and Murang'a (76%), and for conventional farming in Murang'a (70%).

Organic farms in Kirinyaga had higher significant differences in the degree of goal achievement, meaning they were more sustainable, for five sub-themes: responsible buyers, rights of suppliers, non-discrimination, gender equality, support to vulnerable people. Organic Murang'a had higher significant differences in the degree of goal achievement (were more sustainable) for the two sub-themes workplace safety and health provisions, and public health.

Table 3.3-9: Sub-theme and the degree of achievement scores (%) comparing differences between system, county, system and county with standard error margin

	System			County				System and County						
								P	Kirinyaga		Murang'a		Machakos	
Sub-theme	P	Organic	Conventional	P	Kirinyaga	Murang'a	Machakos		Organic	Conventional	Organic	Conventiona l	Organic	Convention al
Quality of Life	ns	57.8(±0.6)	57.9(±0.3)	ns	58.1(±0.4)	57.9(±0.5)	56.6.(±0.5)	<0.05	60.4(±0.6)	58.7(±0.4)	59.2(±0.8)	57.5(±0.6)	54.0(±1.3)a	57.5(±0.5)
Capacity Development	ns	23.5(±1.2)	23.5(±0.7)	ns	25.3(±0.9)	27.6(±1.0)	18.0(±1.1)	ns	27.3(±1.5)	24.7(±1.1)	28.7(±2.0)	27.2(±1.2)	15.0(±2.4)	19.0(±1.2)
Fair Access to Means of Production	ns	59.6(±0.9)	58.5(±0.5)	p<0.05	57.0(±0.6)	58.2(±0.6)	61.1(±0.8)c	ns	63.6(±1.3)	54.9(±0.7)	58.6(±1.6)	61.9(±0.8)	57.1(±1.8)	58.5(±0.9)
Responsible Buyers	<0.05	34.2(±0.5)a	31.7(±0.3)b	p<0.05	34.3(±0.5)a	32.7(±0.4)b	30.2(±0.4)c	<0.05	39.8(±0.9)a	32.5(±0.6)	33.7(±0.7)	32.4(±0.5)	29.6(±0.9)	30.4(±0.4)
Rights of Suppliers	<0.05	21.9(±0.6)a	20.5(±0.4)b	p<0.05	26.6(±0.7)a	24.2(±0.5)b	12.3(±0.4)c	<0.05	29.5(±1.2)a	25.6(±0.8)	24.5(±0.8)	24.2(±0.6)	12.4(±0.8)	12.3(±0.4)
Employment Relations	<0.05	52.5(±0.5)a	53.7(±0.3)b	p<0.05	54.4(±0.4)	52.6(±0.4)	53.3(±0.5)	ns	53.2(±0.7)	54.7(±0.4)	52.5(±0.7)	52.6(±0.5)	51.6(±1.3)	54.7(±0.4)
Forced labour	ns	27.7(±1.2)	28.2(±0.6)	p<0.05	35.8(±0.7)a	21.1(±1.0)b	27.8(±1.0)c	<0.05	36.8(±1.1)	35.4(±0.9)	22.3(±2.0)	20.7(±1.2)	24.4(±2.7)	28.9(±0.9)
Child labour	ns	43.1(±0.5)	43.9(±0.2)	ns	43.6(±0.4)	43.7(±0.2)	43.9(±0.4)	ns	42.8(±0.7)	43.9(±0.5)	42.9(±1.3)	43.7(±0.3)	43.7(±0.4)	44.2(±0.3)
Freedom of Association and Right to Bargaining	ns	26.5(±1.2)	27.5(±0.6)	p<0.05	36.7(±0.7)a	19.8(±1.0)b	25.8(±1.0)c	ns	35.8(±1.1)	36.9(±0.8)	21.7(±1.9)	19.2(±1.2)	22.5(±2.8)	26.8(±1.0)
Non Discrimination	ns	48.1(±1.4)	49.6(±0.6)	p<0.05	58.2(±0.7)a	43.8(±1.3)	46.2(±1.0)	<0.05	61.6(±1.2)a	57.2(±0.8)b	42.7(±2.4)	44.2(±1.5)	40.9(±3.2)	47.9(±0.9)c
Gender Equality	ns	49.8(±1.7)	51.2(±0.8)	p<0.05	61.9(±0.9)a	45.4(±1.4)	45.8(±1.3)	<0.05	67.0(±1.4)a	60.3(±1.1)b	40.4(±3.8)	46.1(±1.7)	43.1(±2.6)	47.6(±1.3)
Support to Vulnerable People	<0.05	23.7(±1.0)	23.1(±0.6)	p<0.05	32.2(±0.8)a	20.1(±1.0)	18.1(±0.8)	<0.05	35.7(±1.3)a	31.1(±0.9)b	21.4(±1.9)	19.7(±1.2)	14.4(±2.0)c	19.1(±0.8)
Workplace Safety and Health Provisions	<0.05	61.3(±0.8)a	58.8(±0.3)b	p<0.05	59.0(±0.5)a	64.9(±0.6)b	54.5(±0.6)c	<0.05	58.7(±0.9)	59.1(±0.6)	70.4(±0.9)c	63.2(±0.7)b	55.0(±2.0)	54.4(±0.5)
Public Health	<0.05	66.1(±0.7)a	59.8(±0.3)b	p<0.05	56.3(±0.5)	71.3(±0.5)b	56.0(±0.6)	<0.05	63.9(±0.8)a	53.9(±0.6)	76.1(±0.8)b	70.2(±0.6)c	58.5(±1.8)	55.2(±0.5)
Indigenous Knowledge	<0.05	80.7(±0.9)a	74.7(±0.6)b	p<0.05	68.2(±0.8)a	79.2(±1.0)	80.6(±0.7)	ns	84.1(±1.4)	63.2(±1.0)b	80.1(±1.5)	78.9(±1.2)	78.2(±1.8)	81.3(±0.8)
Food Sovereignty	ns	57.6(±0.7)	57.3(±0.3)	p<0.05	57.5(±0.5)	57.3(±0.5)	57.4(±0.5)	<0.05	57.4(±1.0)	57.5(±0.6)	58.8(±1.0)	56.8(±0.6)	56.6(±1.3)	57.7(±0.5)

Note: margins sharing a letter in the group label are not significantly different at the 5% level

Performance at the sub-theme level (7): Capacity development

The sub-theme's objective is to ensure that the opportunities are available for farmers to acquire the skills and knowledge necessary to undertake current and future tasks required on their farm, as well as the resources to provide for further training and education for themselves and members of their families (FAO, 2013, p. 180). The sub-theme has two indicators. For training of farm staff, the indicator's means and mean ranks (Table 3.3-10) are significantly different (P< 0.05) and higher, i.e. more sustainable, for organic farms (at 45%) than for conventional farms. The second sub-theme indicator, access to advisory services, was not significantly different for either of the two farming systems.

Table 3.3-10: Indicators and the degree of achievement scores (%) comparing the differences between farming systems with standard error margin

Indicator	P	Organic	Conventional
00072_FarmStaffTraining	P<0.05	45.11(±2.6)a	32.64(±1.4)b
00703_AccessAdvisoryServices	ns	23.41(±2.0)	25.61(±1.2)

Note: margins showing a letter in the group label are significantly different at the 5% level.

Performance at the sub-theme level (8): Indigenous knowledge

The sub-theme objective is that the intellectual property rights related to traditional and cultural knowledge are protected and recognized (FAO, 2013, p. 205). Both of the indicators' means are significantly different (P< 0.05) and higher for organic farms, namely prevention of resource conflicts (at 53% vs. 43%) and costs of social involvement outside the farm (25% vs. 18%) (Table 3.3-11), meaning that organic farms were found to be more sustainable than conventional farms for the sub-theme indigenous knowledge.

Table 3.3-11: Indicators and the degree of achievement scores (%) comparing the differences between farming systems with standard error margin

Indicator	P	Organic	Conventional
00067_PreventionResourceConflicts	P<0.05	52.98(±2.8)a	42.61(±1.3)b
00075_CostsSocialInvolvementOutsideFarm	P<0.05	25.18(±1.7)a	18.1(±0.9)b

Note: margins showing a letter in the group label are significantly different at the 5% level.

Performance at the sub-theme level (9): Public health

The sub-theme objective is to ensure that the workplace is safe, has met all appropriate regulations, and caters to the satisfaction of human needs in the provision of sanitary facilities, a safe and ergonomic work environment, clean water, healthy food, and clean accommodation (if offered) (FAO, 2013, p. 200). The sub-theme has 36 indicators. The 12 indicators' means with a higher, significant difference (P< 0.05) for organic farms (meaning they were more sustainable than conventional farms) were: use of synthetic chemicals in seed dressings (14%), number of measures taken in cases of contamination (39%), no use of synthetic chemical insecticides (41%), no use of active ingredients toxic to aquatic organisms (20%), absence of antibiotics from livestock in fertilizers (21%), proportion of curative treatments for livestock health (28%), no use of pesticides with chronic toxicity (42%), no use of pesticides with acute toxicity (27%), no use of pesticides with acute toxicity on inhalation (26%), no use of pesticides that are persistent in water (30%), food security measures for local communities (14%), and no use of growth regulators (39%) (Table 3.3-12).

There was a positive significant difference (P< 0.05) for just four indicators for conventional farms, namely crop resistance (21%), recycling plastic (9%), mutilation anesthetics analgesics (7%), and wastewater disposal (12%). The remaining 20 indicators were not significantly different for either of the farming systems.

Table 3.3-12: Indicators and the degree of achievement scores (%) comparing the differences between farming systems with standard error margin

Indicator	P	Organic	Conventional
00034_2_UseageChemSynthSeedDressings	P<0.05	14.3(±1.9)a	6.52(±0.8)b
00167_No ContaminatedProducts	ns	53.1(±2.7)	54.67(±1.5)
00169_ContaminationCasesMeasures	P<0.05	38.84(±2.3)a	31.65(±1.4)b
00200_SlurryStoresCovered	ns	17.3(±2.2)	16.46(±1.1)
00208_WoodlandsShareAgriculturalLand_Calculated	ns	3.05(±0.5)	2.46(±0.2)
00233_NoUseSynthChemFungicides	ns	34.05(±2.3)	37.46(±1.2)
00234_NoUseSynthChemInsecticides	P<0.05	40.65(±2.4)a	35.34(±1.2)b
00257_1_PesticidesToxicityBees	ns	21.4(±2.3)	17.84(±1.2)
00257_2_PesticidesToxicityAquaticOrganisms	P<0.05	19.8(±2.3)a	14.7(±1.1)b
00295_AntibioticsLivestockFertilizer	P<0.05	20.48(±1.3)a	15.05(±0.9)b
00320_CropResistance	P<0.05	16.83(±)1.8a	21.31(±1.0)b
00327_WasteDisposalPesticidesVeterinaryMedicines	ns	13.9(±1.8)	12.54(±1.0)
00331_WasteDisposalCadaver	ns	36.44(±2.0)	33.48(±1.4)
00334_3_RecyclingPlastic	P<0.05	6.33(±0.0)a	8.81(±0.0)b
00334_RecyclingWasteOil	ns	29.86(±1.7)	32.09(±1.1)

Indicator	P	Organic	Conventional
00352_LivestockHealthCurativeTreatments	P<0.05	28.19(±1.6)a	22.19(±1.0)b
00353_LivestockHealthProphylacticTreatments	ns	23.73(±1.6)	22.83(±0.9)
00357_MutilationAnaestheticsAnalgesics	P<0.05	4.97(±0.7)a	7.45(±0.5)b
00376_2_InformationWaterQuality	ns	11.06(±1.9)	7.71(±0.9)
00377_05_WastewaterDisposal	P<0.05	7.72(±1.8)a	12.19(±1.1)b
00377_1_PesticidesNumberActiveSubstances	ns	31.07(±1.8)	28.05(±0.9)
00377_5_PesticidesChronicToxicity	P<0.05	41.8(±2.4)a	27.93(±1.5)b
00377_7_PesticidesAcuteToxicity	P<0.05	27.16(±2.2)a	21.95(±1.1)b
00377_75_PesticidesAcuteToxicityInhalation	P<0.05	25.66(±2.2)a	19.96(±1.1)b
00380_NutrientsPollutantsSourcesOnFarm	ns	19.22(±2.2)	16.24(±1.2)
00474_1_PesticidesPersistenceWater	P<0.05	30.33(±2.8)a	20.67(±1.4)b
00474_2_PesticidesPersistenceSoil	ns	32.74(±3.2)	35.39(±1.6)
00474_3_PesticidesKnowledge	ns	26.44(±1.9)	22.46(±1.1)
00502_PublicHealthMeasures	ns	1.34(±0.6)	2.27(±0.4)
00506_FoodSecurityMeasuresLocCommunities	P<0.05	13.78(±1.4)a	9.97(±0.8)b
00606_LandslidesMudslides	ns	31.45(±1.7)	32.27(±0.9)
00609_MilkWaitingPeriodAntibiotics	ns	14.78(±1.1)	14.38(±0.7)
00710_HarmfulSubstancesPFertilizer	ns	25.68(±2.0)	23.23(±1.1)
00740_GrowthRegulation	P<0.05	39.38(±2.1)a	32.43(±1.2)b
00788_OpenBurning	ns	34.22(±2.1)	32.64(±1.2)
00790_EmplyeesProtectiveGear	ns	21.37(±1.8)	21.46(±1.2)

Note: margins showing a letter in the group label are significantly different at the 5% level.

3.3.4 Governance

Performance of organic vs. conventional at sub-theme level

In the governance dimension there are five dimensions: corporate ethics, accountability, participation, rule of law, and holistic management. Of 14 sub-themes, the median and mean values in organic farms had a higher degree of goal achievement, i.e., the performance was more sustainable, for 13 sub-themes, namely mission statement, due diligence, holistic audits, responsibility, transparency, stakeholder dialogue, grievance procedures, conflict resolution, legitimacy, ‘remedy, restoration and prevention’, civic responsibility, resource appropriation and sustainability management plan (Figure 3.3-4, annex 4 and annex9). The final sub-theme, full-cost accounting, had the same degree of goal achievement scores for organic and conventional farms.

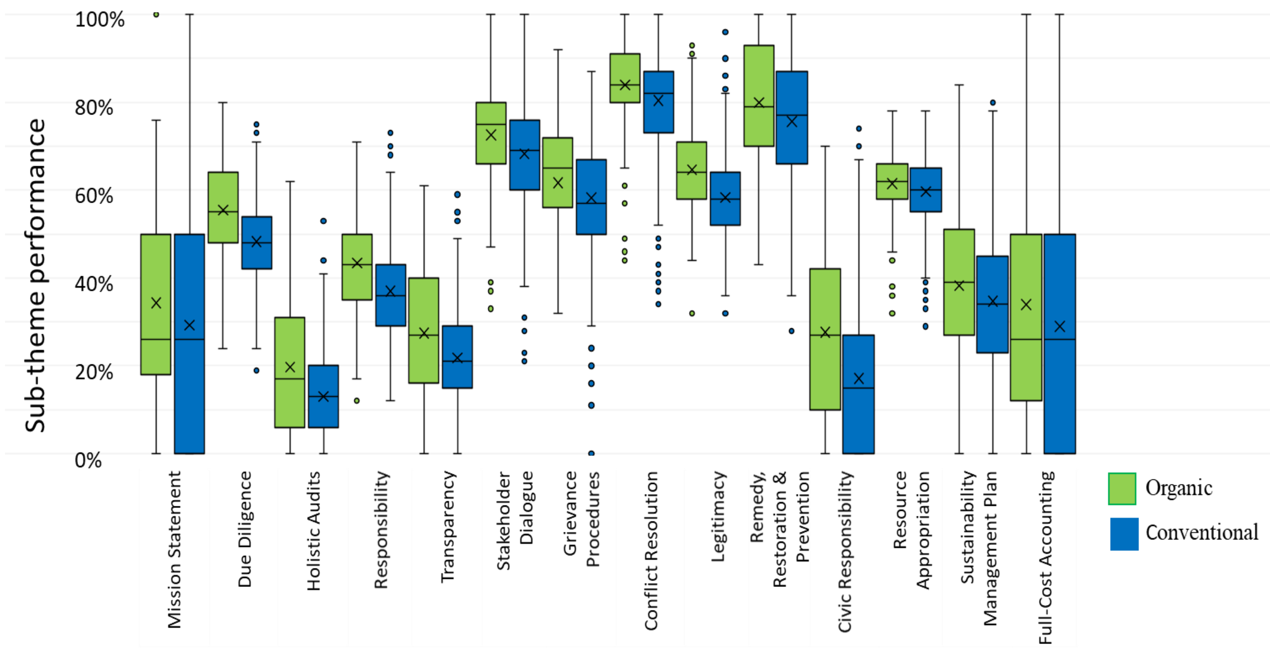


Figure 3.3-4: Governance sub-theme median values for organic vs. conventional (x: mean, -: median)

Organic farms had a higher significant difference ($P< 0.05$) than conventional for 11 sub-themes: due diligence (54 vs. 49 %), holistic audits (17 vs. 13%), responsibility (in accountability) (41 vs. 37%), transparency (25 vs. 22%), stakeholder dialogue (72 vs. 68%). The other sub-themes with significantly higher scores for organic systems were grievance procedures (62 vs 58%), conflict resolution (84 vs 80%), legitimacy (63 vs 59%), remedy, restoration & prevention (79 vs 76%), civic responsibility (25 vs 18%) and resource appropriation (61 vs 60%) (Table 3.3-13 and Annex 5). The performance for organic farms was significantly better than in conventional farms under those sub-themes. The sub-themes mission statement, sustainability management plan, and full-cost accounting, although slightly higher for organic, were not significantly different for the two farming systems, i.e. organic and conventional have the same overall impacts for these sub-themes.

Performance at county level: organic vs. conventional

When comparing the two systems of farming and the counties there were mixed results for the sub-themes (Table 3.3-13, annex 6). This assessment checks if there are any differences between the farming system and county (case study), and which farming system and county is more sustainable on a scale of 0-100%. The three sub-themes stakeholder dialogue, conflict resolution and resource appropriation were not significantly different for any of the combinations of farming system and county.

The sub-theme holistic audits was significantly different for organic farms in Kirinyaga and Machakos, and conventional farms in Kirinyaga. The sub-theme responsibility (in accountability) was significantly different in organic Machakos (lower), conventional Kirinyaga, Murang'a and Machakos (higher). The sub-theme legitimacy was significantly different to organic Kirinyaga and Machakos and conventional Murang'a. Organic Kirinyaga had a higher degree of goal achievement that was significantly different for the sub-themes mission statement, holistic audits, transparency, 'remedy, restoration and prevention', and full-cost accounting, meaning that organic farms in Kirinyaga are more sustainable than all five other combinations in these five sub-themes. Organic farms in Murang'a had a higher degree of goal achievement that was significantly different for the sub-theme legitimacy, meaning it is more sustainable for this sub-theme.

Table 3.3-13: Sub-theme and the degree of achievement scores (%) comparing differences between system, county, system and county with standard error margin

	System			County				System and County						
								P	Kirinyaga		Murang'a		Machakos	
Sub-theme	P	Organic	Conventional	P	Kirinyaga	Murang'a	Machakos		Organic	Conventional	Organic	Conventional	Organic	Conventional
Mission Statement	ns	30.5(±1.6)	30.0(±1)	<0.05	35.4(±1.3)	35.8(±1.7)	19.7(±1.3)a	<0.05	44.3(±2)a	32.6(±1.6)	33.4(±3.2)	36.6(±2)	15.0(±2.9)	21.2(±1.4)
Due Diligence	<0.05	53.7(± 0.8)a	48.6(± 0.4)b	<0.05	50.2(±0.6)a	54.8(±0.6)b	44.7(±0.6)c	<0.05	57.9(±1.2)	47.8(±0.6)	57.8(±1.1)	53.8(±0.6)a	45.9(±1.8)	44.3(±0.5)
Holistic Audits	<0.05	17.1(±0.8)a	13.2(±0.4)b	<0.05	20.1(±0.7)a	12.9(±0.5)b	9.9(±0.6)c	<0.05	33.1(±1.5)a	16.0(±0.7)b	12.1(±1.1)	13.1(±0.6)	7.0(±1.4)c	10.8(±0.6)
Responsibility	<0.05	41.3(±0.7)a	37.2(±0.4)b	<0.05	39.5(±0.6)a	41.3(±0.6)b	34.0(±0.5)c	<0.05	47.4(±1.3)	37.0(±0.7)a	45.1(±1.1)	40.0(±0.7)b	31.9(±1.3)c	34.7(±0.5)d
Transparency	<0.05	25.3(±0.9)a	21.9(±0.4)b	<0.05	27.4(±0.7)a	21.8(±0.7)b	19.2(±0.7)c	<0.05	35.0(±1.4)a	25.1(±0.8)	25.1(±1.2)	20.7(±0.9)	16.5(±1.9)	20.1(±0.7)
Stakeholder Dialogue	<0.05	72.0(±1.0)a	68.3(±0.4)b	ns	68.5(±0.6)	69.1(±0.7)	69.7(±0.8)	<0.05	72.0(±1.2)	67.4(±0.7)	74.6(±1.1)	67.4(±0.8)	69.4(±2.3)	69.8(±0.8)
Grievance Procedures	<0.05	61.6(±0.8)a	58.0(±0.5)b	<0.05	56.8(±0.5)	58.2(±0.8)	61.4(±0.8)a	<0.05	53.5(±1.0)	54.7(±0.6)a	59.6(±1.3)	57.8(±1.0)	61.7(±1.9)	61.4(±0.8)
Conflict Resolution	<0.05	83.5(±0.9)a	80.4(±0.4)b	ns	80.7(±0.5)	81.0(±0.5)	81.7(±0.9)	<0.05	84.5(±1.0)	79.4(±0.6)	81.4(±0.8)	80.0(±0.7)	81.9(±2.3)	81.6(±0.9)
Legitimacy	<0.05	62.7(±0.6)a	58.5(±0.4)b	<0.05	55.8(±0.4)	67.9(±0.7)b	55.0(±0.4)	<0.05	63.2(±0.7)a	53.5(±0.5)	71.2(±1.2)b	66.8(±0.9)c	54.1(±1.0)	55.2(±0.4)
Remedy, Restoration & Prevention	<0.05	78.9(±1.0)a	75.5(±0.5)b	<0.05	74.9(±0.7)a	76.9(±0.8)	77.1(±0.8)	<0.05	85.9(±1.1)a	71.4(±0.8)	75.9(±1.4)	77.3(±0.9)	75.5(±2.2)	77.6(±0.8)
Civic Responsibility	<0.05	24.5(±1.2)a	17.5(±0.6)b	<0.05	19.7(±1.0)a	25.6(±1.1)b	12.6(±0.8)c	<0.05	29.1(±2.0)	16.7(±1.1)a	34.6(±2.3)	22.7(±1.2)b	10.6(±2.1)	13.2(±0.8)
Resource Appropriation	<0.05	61.1(±0.6)a	59.5(±0.3)b	<0.05	58.6(±0.4)a	60.5(±0.4)	60.6(±0.5)	<0.05	62.9(±0.9)	57.2(±0.5)	60.8(±0.7)	60.4(±0.4)	59.8(±1.5)	60.9(±0.5)
Sustainability Management Plan	ns	35.6(±1.2)	35.0(±0.6)	<0.05	33.6(±0.8)a	42.9(±0.9)b	29.1(±1.0)c	<0.05	42.3(±1.6)	30.9(±0.9)	41.4(±1.9)	43.4(±1.1)	24.0(±2.7)a	30.7(±1.0)
Full-Cost Accounting	ns	30.3(±1.6)	29.6(±1.0)	<0.05	35.2(±1.3)	35.4(±1.7)	19.4(±1.2)a	<0.05	44.0(±2.1)a	32.5(±1.6)	32.8(±3.2)	36.3(±2.0)	15.2(±2.9)	20.7(±1.4)

Note: margins sharing a letter in the group label are not significantly different at the 5% level

Performance at the sub-theme level (10): Holistic audits

The objective of the sub-theme is to ensure that all areas of sustainability in the SAFA dimensions that pertain to the enterprise are monitored internally in an appropriate manner, and wherever possible are reviewed according to recognized sustainability reporting systems (FAO, 2013, p. 86). The means of the two indicators were not significantly different ($P < 0.05$) for either of the farming systems: the indicators humus formation for humus balance and oral information sustainability improvements were similar when the margin of error was considered (Table 3.3-14 annex 5). In other words, organic and conventional farming systems have roughly the same overall impacts for the two indicators.

Table 3.3-14: Indicators and the degree of achievement scores (%) comparing the differences between farming systems with standard error margin

Indicator	P	Organic	Conventional
00748_HumusFormationHumusBalance	ns	33.09(±2.2)	31.55(±1.1)
00750_OralInformationSustainabilityImprovements	ns	19.34(±1.0)	18.05(±0.6)

Performance at the sub-theme level (11): Civic responsibility

The objective of the sub-theme is to ensure that within its sphere of influence, the enterprise supports the improvement of the legal and regulatory framework in all dimensions of sustainability and does not seek to avoid its responsibility to fulfill its duties of human rights, or sustainability standards, or regulation through the corporate veil, relocation, or any other means (FAO, 2013, p. 100). Of five indicators, the means and mean ranks with significant positive difference ($P < 0.05$) for organic farms include: involvement in improving laws and regulations (17%), costs for environmental involvement outside the farm (12%), costs for social involvement outside the farm (34%) and food security measures for local communities (24%) (Table 3.3-15). The performance for organic farms was better than conventional farms under those indicators. The indicator ethical cooperation with financial institutions was not significantly different for either of the farming systems, meaning organic and conventional have roughly the same overall impacts for this indicator.

Table 3.3-15: Indicators and the degree of achievement scores (%) comparing the differences between farming systems with standard error margin

Indicator	P	Organic	Conventional
00057_InvolvementImprovingLawsRegulations	P<0.05	16.84(±2.0)a	9.44(±1.0)b
00070_CooperationEthicalFinancialInstitutions	ns	16.15(±1.7)	18.59(±0.9)
00074_CostsEnvironmentalInvolvementOutsideFarm	P<0.05	11.59(±1.4)a	6.37(±0.7)b
00075_CostsSocialInvolvementOutsideFarm	P<0.05	34.07(±2.3)a	24.14(±1.2)b
00506_FoodSecurityMeasuresLocCommunities	P<0.05	24.33(±1.9)a	17.54(±1.1)b

Note: margins showing a letter in the group label are significantly different at the 5% level.

Performance at the sub-theme level (12): Sustainability management plan

The objective of the sub-theme is to ensure that a sustainability plan for the enterprise is developed which provides a holistic view of sustainability and considers synergies and trade-offs between dimensions, including each of the environmental, economic, social and governance dimensions (FAO, 2013, p. 105). Of the six indicators, just one indicator's mean score had a significant difference ($P < 0.05$) for organic farms: market challenges (31%), meaning the performance of organic farms was better than for conventional farms under the market challenges indicator (Table 3.3-16). Conventional farms had a better performance score in "guaranteed farm succession for staff" indicator (38%), with a 10%-point difference to organic farms (at 28%). The other indicators were not significantly different for either of the farming systems, meaning organic and conventional farms have roughly the same overall impacts for the other indicators.

Table 3.3-16: Indicators and the degree of achievement scores (%) comparing the differences between farming systems with standard error margin

Indicator	P	Organic	Conventional
00008_VerbalCommitmentSustainability	ns	17.58(±1.4)	17.6(±0.8)
00100_MarketChallenges	P<0.05	30.85(±1.8)a	26.11(±1.0)b
00124_GuaranteedStaffReplacemetFarmSuccession	P<0.05	28.19(±1.7)a	37.93(±0.8)b
00134_KnowledgeClimateChangeProblems	ns	36.33(±1.5)	36.68(±0.8)
00136_ClimateChangeAdaptationMeasures	ns	31.72(±2.5)	33.28(±1.3)
00750_OralInformationSustainabilityImprovements	ns	20.39(±1.1)	18.91(±0.7)

Note: margins showing a letter in the group label are significantly different at the 5% level.

3.4 Discussion

Performance of organic and conventional farming systems at the sub-theme level

When comparing the sustainability scores of organic and conventional farms at the sub-theme level, the results indicate that organic farms perform better than conventional farms (Annex 5, 6, 7). Within the “Environmental Integrity” dimension, the organic interventions had a significantly higher degree of goal achievement scores for 10 of the 14 sub-themes (the sub-themes that were not significantly different are water withdrawal, land degradation, animal freedom from stress, and animal health). These results suggest that certain organic farm practices (soil quality, crop rotation, animal and plant diversity, water quality, and material and energy use) are more sustainable than conventional ones. The positive impacts in the environmental integrity dimension are due to changes in the farm management practices, i.e. improvements in soils fertility, mulching and crop rotation (Kamau *et al.*, 2018; Schader *et al.,* 2016). Organic farming standards include the application of good farming practices, use of manure, mulching, and inter-cropping that emphasize improvement in the environment, namely soil health and fertility, and preventive pest and disease management (Kannan *et al.*, 2005).

Within the “Economic Resilience” dimension, 10 of the 14 sub-themes had a significantly higher degree of goal achievement scores in organic interventions as compared to conventional ones. The other four sub-themes – profitability, stability of production, value creation, and local procurement – were not significantly different. The degree of achievement scores for the sub-themes in the “Social Well-being” dimension revealed that 5 of the 16 sub-themes – responsible buyers, rights of suppliers, workplace safety and health provisions, public health, and indigenous knowledge – had a significantly higher degree of goal achievement scores in organic than conventional farms. The subtheme employment relations scored significantly higher for conventional systems than organic interventions, whereas the other sub-themes were not significantly different. In the “Governance” dimension, 11 of the 14 sub-themes had a significantly higher degree of goal achievement scores in organic farms than in conventional ones. The remaining three sub-themes – mission statement, sustainability management plan, and full cost accounting – were not significantly different.

The results for the environmental integrity, economic resilience, and governance sub-themes suggest that organic farms' performance was better than conventional farms, indicating that some organic practices improve sustainability, e.g. food safety, public health, indigenous knowledge, and civic responsibility had a 6-8% point difference over conventional farms. Though small in their overall coverage, organic initiatives have substantial impacts in the communities or niche areas. Other studies have also shown that organic farms perform better in environmental integrity and economic resilience than conventional ones (Coteur *et al.*, 2016; Marchand *et al.*, 2014; Smith *et al.*, 2019; Ssebunya *et al.*, 2018).

Performance of organic and conventional farming systems at the county level

In the environmental integrity dimension, the performance at the county level (Annex 6) showed mixed results when comparing the farming systems. Of the organic systems with sub-themes that were significantly different at the county level, meaning more sustainable than conventional farms, Murang'a had five sub-themes (greenhouse gases, water quality, ecosystems, species diversity, and genetic diversity) and Kirinyaga had three sub-themes (genetic diversity, material use, and waste reduction and disposal). In Machakos, none were significantly different. Of the conventional systems with sub-themes that were significantly different at the county level, Kirinyaga had four sub-themes (air quality, ecosystems, species diversity and genetic diversity), Murang'a had three (greenhouse gases, air quality and water quality) and Machakos had two (species diversity and animal freedom from stress). This means that the conventional farming systems were more sustainable than organic ones for these sub-themes in those counties.

In the economic resilience dimension, the performance at the county level were in favor of organic farms. Of the organic farms where sub-themes were significantly different at the county level, Kirinyaga had six sub-themes (internal investment, long-range investment, profitability, the stability of the market, risk management, and product information), Murang'a had three sub-themes (risk management, food safety, and product information) and Machakos had three sub-themes (community investment, profitability, and stability of market). For these sub-themes in those counties, organic farming was more sustainable than conventional farming. Conventional systems where sub-themes were significantly different, meaning more sustainable, included: Kirinyaga with one sub-theme (long-range investments), Murang'a with four sub-themes (community investment, the stability of the market, risk management, and food quality), and Machakos with one sub-theme (profitability).

The results of the performance at the county level were mixed in the social well-being dimension. Organic interventions were more sustainable than conventional farming, i.e. sub-themes were significantly different, in Kirinyaga for six sub-themes (responsible buyers, rights of suppliers, non-discrimination, gender equity, support to vulnerable people and public health), in Murang'a for two sub-themes (workplace safety and health provisions, and public health), and in Machakos for two sub-themes (quality of life and support to vulnerable people). Conventional systems were more sustainable than organic farms for the following sub-themes: four in Kirinyaga (non-discrimination, gender equity, support to vulnerable people, and indigenous knowledge), and one in Machakos (non-discrimination).

In the governance dimension, the results for the performance at the county level were also mixed. Organic farms were more sustainable than conventional farms for the following counties and sub-themes: in Kirinyaga six sub-themes (mission statement, holistic audits, transparency, legitimacy, 'remedy, restoration and prevention', and full cost accounting), Murang'a one sub-theme (legitimacy), and Machakos three sub-themes (holistic audits, responsibility, and sustainability management plan). Conventional systems were more sustainable than organic farms for four sub-themes in Kirinyaga (holistic audits, responsibility, grievance procedures, and civic responsibility), four in Murang'a (due diligence, responsibility, legitimacy, and civic responsibility) and one in Machakos (responsibility).

Performance of organic farming: Selected sub-themes at the indicator level

The 12 sub-themes selected for further analysis at the indicator level were water withdrawal, ecosystem diversity, and soil quality (environmental integrity), stability of supplies, stability of the market, food safety (economic resilience), capacity development, indigenous knowledge, and public health (social well-being), and holistic audits, civic responsibility and sustainability management plan (governance). Of the 209 indicators related to the 12 sub-themes analyzed, a total of 88 indicators were significant: 64 of these were higher and significantly different for organic farming, while 24 were lower and significant different for organic farms.

Farming practices that have an impact on the sustainability of the farming systems

In the results from the performance of organic and conventional farming systems at the sub-theme level, at the county level and for selected sub-themes at the indicator level, a number of farming practices are shown to clearly have an impact on the sustainability of each farming system.

The use of compost in farming activities: On the use of compost (Figure 3.4-2), the farmers were asked whether they apply compost to their fields. In the sustainability assessment, the use of compost has impacts on the sub-themes soil quality, land degradation, air quality, energy use, greenhouse gasses, species diversity, water quality and waste reduction and disposal. The results in Figure 3.4-1 show that a relatively low share of farms prepared and applied compost in all the field sites. The possible reasons could be that compost is a labour intensive practice, or that the farmers lack knowledge in compost making. This is important to understand, because according to Te Pas & Rees (2014), in organic farming the input types (compost, cover crop, crop residue, manure and other organic inputs) incorporated into the farming activities are directly related to yield levels, i.e. 113% higher yields can be obtained in organic farms as compared to conventional systems.

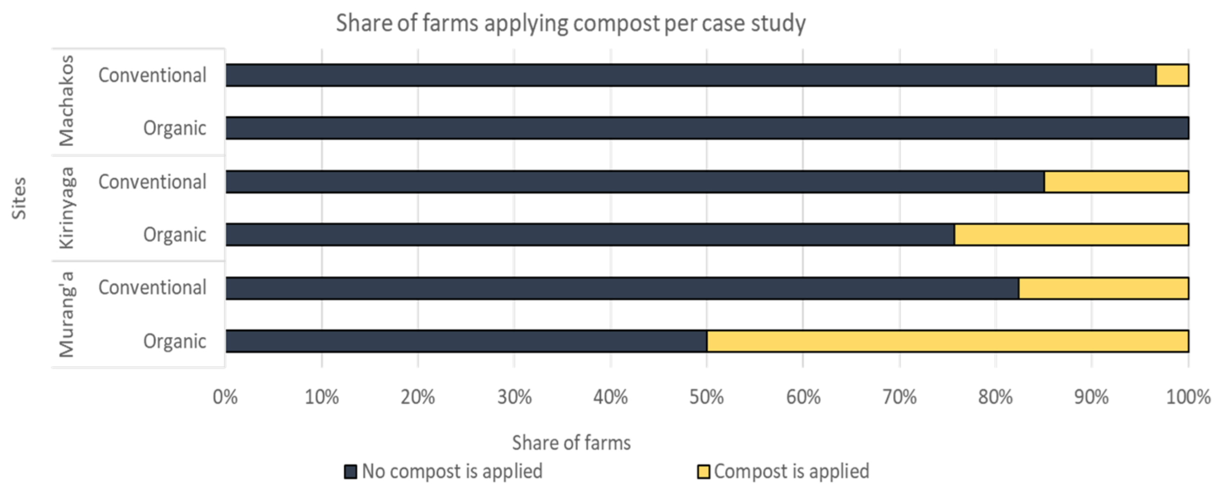


Figure 3.4-1: Share of farms applying compost per case study

Pesticide persistence in water: For this indicator, it was found that organic farms did not use any while many conventional farms reported use of water persistent pesticides such organochlorines and organophosphates. (Figure 3.4-2). The active substances of these pesticides are those considered to be very persistent in water (half-life > 60 days). This indicator has impacts on water quality and species diversity.

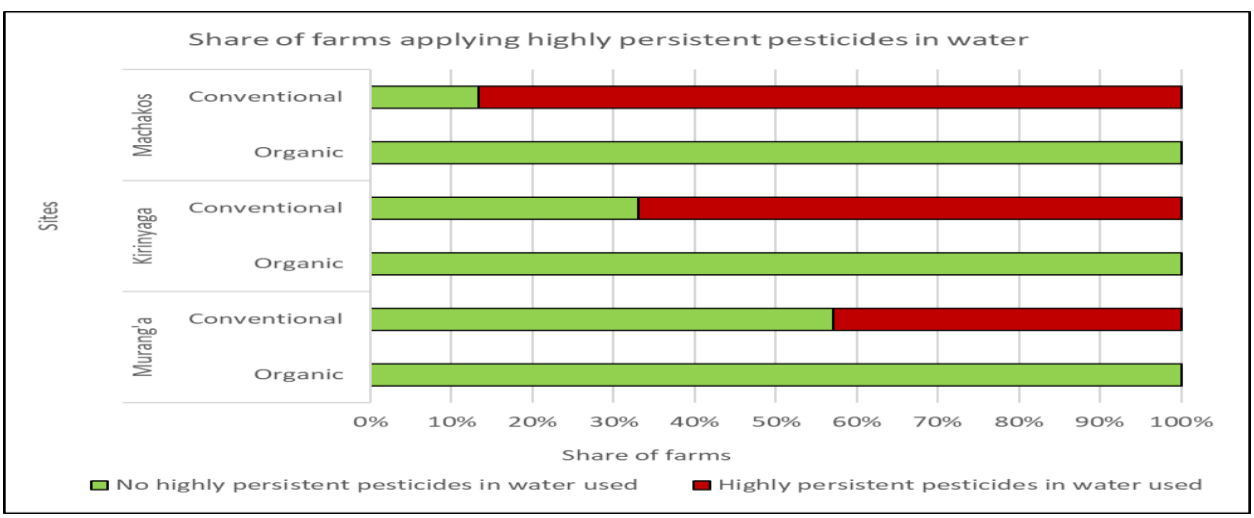


Figure 3.4-2: Share of farms applying pesticides that are highly persistent in water

Diversification of products and value addition: The average number of crops grown on farms was eight to eighteen. Farmers, at times, plant many crops to spread the risk of crop failure but as a result, do not fully utilize recommended practices to reap the full benefits of each crop. Farmers sell most of the farm produce in the raw state thus, only get low prices. Yet with value addition, they could earn twice or more for the same crop.

Markets, market information and channels: Farmers sell their farm produce at farm-gate prices determined by the buyer. Most sell individually, yet with group or cooperate sales, the prices would be better due to economics of scale and negotiation ability of corporates. Exploring alternative markets such as niche markets for rare and unique crops, or institutional markets such as learning institutions and hospitals, could be an alternative. Another area is market intelligence to get current market prices and locations for the commodities. Few farmers know where and how to get this information, thus they rely on what the buyer offers.

The regulatory and institutional framework that supports organic farming: An enabling environment is where organic farming can flourish when farmers adhere to the rules governing the sector. Organic policy documents and organic standards like EAOPS 2007 are available to guide the sector. Identifying sector actors and holding joint stakeholders' meetings with the inclusion of government and NGOs is important in driving measures to enhance the organic sector. In Kenya, the Kenya Organic Agriculture Network promotes the organic sector, yet only a few agricultural staff at the county level know farmers who practice organic farming.

In improving farming practices, it is important to also enhance the capacity of farmers to adopt better farming practices.

Capacity building initiatives for both organic and conventional farmers: Training on good agricultural practices as well as in areas of environmental protection (conservation measures and safe use of pesticides) were considered when interviewing farmers. The training modes used, whether farmer field schools, training of trainers or farm visits, should focus on the best and effective methods of delivery for farmers to adopt improved farming practices. For example, farmers were asked if they received any training related to the use of plant protection products (Figure 3.4-3). This has impacts on the sub-themes quality of life and capacity development. Organic farms in Murang'a 40%, Machakos 8%, and conventional farms in Kirinyaga 20%, Murang'a 12%, Machakos 10%, had received some training on the use of plant protection products. In Kirinyaga the organic farmers reported that they had not received any training on plant protection.

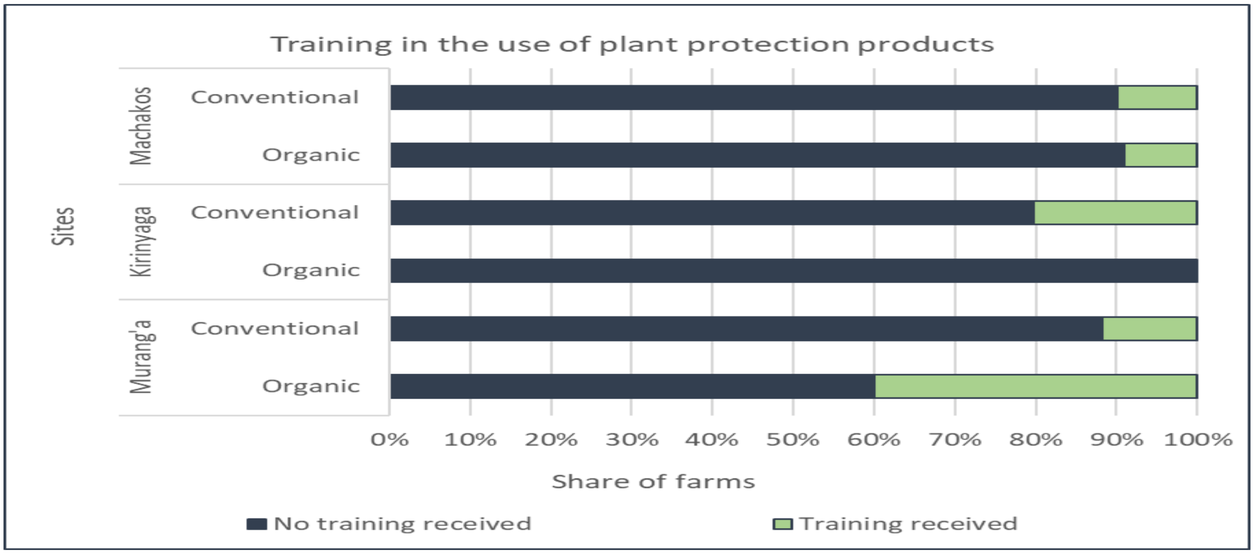


Figure 3.4-3: Training in the use of plant protection products

3.5 Conclusions

The analysis in this chapter assessed the sustainability performance of organic and conventional farming systems in Murang'a, Kirinyaga, and Machakos counties in Kenya. The results show that organic interventions had positive and significant sustainability performance in environmental integrity, economic resilience, and governance. In the social well-being dimension, the sub-themes with significantly higher scores for organic farms were responsible buyers, rights of suppliers, workplace safety and health provisions, public health, and indigenous knowledge while for conventional farming systems, the sub-theme employment relations was significantly higher than for organic interventions.

There were similar scores between organic and conventional farms for many of the sub-themes across all four dimensions: mission statement, sustainability management plan, full cost accounting, water withdrawal, animal health, freedom from stress, profitability, the stability of production, value creation, local procurement, quality of life, capacity development, forced labour, child labour, non-discrimination, gender equity, support to vulnerable people and food sovereignty.

The performance at the county level showed that overall, farms in Kirinyaga were more sustainable, followed by Murang'a and Machakos. The higher sustainability performance for Kirinyaga County was expected as there was a certification system in existence and some farms were organically certified. One recommendation is that other counties should seek ways of getting farms organically certified to enjoy the benefits that this brings.

When compare farming system and county at the indicator level the results show that there are agronomic differences that are responsible for the difference in performance. Some are very specific to organic and some seem to be random or due to one of the specific interventions used by the farmers.

Despite its encouraging findings, this study also identified some sustainability challenges among the smallholder farms that require to be addressed. These low scores (either for indicators or sub-themes) can be addressed through improving farming practices such as knowing the correct fertilizer requirements, and for plant protection products, correct input use, use of recommended dosage, and observance of pre-harvest intervals to ensure safe and nutritious foods produced in both farming systems.

Capacity building of farmers requires that a program for regular training and extension support for farmers be implemented, which can also take into account the continued improvement and maintenance of the set of evolving organic standards. The existence of a traceability system and better prices (premiums) further encourages organic practices in Kirinyaga County. Despite the constraints and potential for improvement of the SMART-Farm Tool approach, it gives a prompt way to bench-mark farms across farm types and regions at the dimensions, themes, and sub-themes levels. As a sustainability assessment tool, it offers support to decision-makers, policy, and development experts.

This study recommends the strengthening of the capacity of farmers to implement sustainability measures and decisions that help to improve the future status of their farms based on the identified sustainability gaps. The Kenya government should provide support for the development of smallholder organic initiatives across the country, and address technical and policy-related bottlenecks and the need for multi-stakeholder engagement in organic agriculture development.

4. Chapter : Farmer's perceptions and suggestions of intervention measures to address sustainability gaps in Kenya

4.1 Introduction

Farmers manage and control many aspects of their farms. At the same time, other factors such as the weather, market changes, and laws are outside their control (Compagnone *et al.*, 2018). Farmers are faced with an array of abiotic constraints, including limited access to inputs and high input costs, a lack of output market linkages, financial credit, and information and technology, and low farm-gate prices (Ochola *et al.*, 2013). Climate change has led to less stable and predictable weather patterns requiring farmers to adopt coping strategies in farming (Ndukhu *et al.*, 2016). Farmers also face an increasing number of national and regional regulations of their activities that may be helpful or restricting (Spaling *et al.*, 2011).

In sub-Saharan Africa (SSA), utilization of agricultural technology and participation in new programs remains low (Mwangi & Kariuki, 2015). The low adoption of technology by farmers partly explains the lagging agricultural productivity growth in SSA (Morris *et al.*, 2007). Studies show that a majority of farmers do not adopt the required best practices for increased food security and higher incomes (Jha *et al.*, 2020; Morris *et al.*, 2007; Tittonell *et al.*, 2010; Tittonell, 2014). Farmers' decisions to adopt new agricultural technologies or practices depend on a complex array of factors. Studies show that the best predictors of adoption practices were farmers' perception of the practices (Ochola *et al.*, 2013; Obayelu *et al.*, 2017; Tatlidil *et al.*, 2009).

If farmers are to adopt sustainable agricultural practices, they first need to understand that the methods are essential and beneficial (Creemers *et al.*, 2019). The uptake of new rules that offer better incomes and target innovations call for resources efficiency, economic viability and environmental sustainability (Creemers *et al.*, 2019). According to Creemers *et al,* (2019) existing supply chain arrangement have lower policy intentions and unbalanced power leading to increased competitive pressures on primary producers. New type of relationships are thus required between producers and buyers which have potential to regulate markets and less reliant on the management of markets. One of the objectives in sustainability assessment is to detect opportunities to improve sustainability (Jouzi *et al.*, 2017). The sustainability assessment identifies superior strategies and technologies form a sustainable point of view. Empirical applications are still needed not only to get the quantities but also to identify the paths for improvement (Vogel *et al.,* 2019). Therefore, it is important to find out what farmers' perception are in regard to sustainable agricultural practices (Coteur *et al.,* 2018; Jha *et al.,* 2020; Obayelu *et al.,* 2017).

Evaluation of farmer perceptions on specific farm management practices, and in particular the socio-economic characteristics that influence these perceptions, are critical in developing and introducing extension programs that promote sustainability among farmers and rural populations (Tatlidil *et al.,* 2009). In light of the limited adoption of practices that are proven to increase yield, change agents promoting 'best practices' in agricultural practices should seek ways of understanding what drives the farming community's behavior and decision-making processes (Isaac *et al.,* 2009). It is recognized that farmers have valuable knowledge about their farming activities and that they do their own agricultural 'research', and that agronomists, ecologists, and development scientists would benefit from close collaboration with them (Jha *et al.,* 2020; Krueger & Casey, 2015).

Farmers' adoption of technologies and practice is based on farmers' knowledge or willingness to seek information or specific services they require in farming, since they must believe that the technologies or practices are important if they are to adopt them (Creemers *et al.,* 2019).The sustainability assessment farm-reports thus provide such information and the actions farmers must take to improve in the areas or sections found to be under-performing. Not to put off the farmers, the farm reports were designed to 'indirectly' suggest corrective actions. Based on the outcomes of the sustainability assessment (Chapter 3), the objective of the research presented in this chapter was to identify the sustainability gaps and the measures that farmers are likely to adopt to address those gaps. The other objective was to determine the potential challenges, strategies, and responsibilities for the implementation of the defined intervention measures in each of the three counties.

4.2 Literature review

Studies examining organic farming have looked at the perception of farmers either in relation to the comparison of ecological and non-organic farming, or the adoption of agricultural technologies and practices in the two systems. Khoy *et al*. (2017) examined farmers' perceptions regarding the opportunities and challenges in organic rice production in Cambodia. They categorized farmers into three groups: pool sample, organic and conventional farmers. In the pooled sample farmers believed that price premiums, health and environmental benefits, and market opportunities provided the greatest benefits. They found that for organic farmers, intensive labour, lack of organic fertilizer, and pest/disease problems were the key issues of concern. Conventional farmers believed that market instability, lack of organic fertilizer, and labour -intensive production were the main obstacles (Khoy *et al.* 2017). Agidew and Singh's (2019) study on understanding farmer perceptions focused on the effectiveness of sustainable land management in Ethiopia. The study found that constraints related to land management practices (lack of incentives, poverty, and lack of awareness about the long-term benefits of such practices) hindered the adoption of new technologies (Agidew & Singh, 2019). Patidar and Patidar (2015), in their study of the perceptions of farmers towards organic farming in India, found that the gap between knowledge or perception and practice can be bridged by a better understanding of the system and policy regulations that provide an enabling environment to farmers (i.e. credit facilities, capacity building of change agents). Kings and Ilbery (2012) used a behavioral approach to explore the perceptions and attitudes of farmers, loosely labeled as 'organic' and 'conventional', towards environmental aspects of agricultural sustainability. The behavioral approach recognizes farmers as independent environmental managers who often make decisions about the management of resources on their farms independently from the state and other actors outside of their farms (Kings & Ilbery, 2012).

Other studies have evaluated farmers' knowledge and awareness of particular farming practices. In doing so, such studies have identified factors as broad as education level, gender, economic status, knowledge of natural resources, and feeling of social responsibility as important indicators of motivation to learn new farming practices (Muzari & Muvhunzi, 2012). Ustriyana and Dewi (2017), in their analysis of perceptions of chili farmers on sustainable development, established that farmers' education level had a direct relationship with their perception of sustainable agriculture. Oyedele *et al.* (2018) studied the benefits, perceptions, and constraints of organic farming in Nigeria looking at, for four different communities, gender, age, education level, household size, and crops grown. The study found that if farmers were encouraged and motivated through adequate training in production techniques (e.g. use of organic manure) they were likely to adopt organic farming practices (Oyedele *et al.*, 2018). Soire et al. (2016) determined farmers' perceptions on the dissemination of agricultural technologies through a farmer's group approach, finding it was effective by 96.4% and sustainable by 66.7% when continued support in farmer skills development, community participation, utilization of innovative farming technologies and farm inputs was provided. According to a study by Nautiyal (2011), which promoted both improved livelihoods and the conservation and management of natural resources in the India Himalayas, people are looking for more viable solutions to improve their livelihoods, facilitate ecosystems conservation and support existing biodiversity (Nautiyal, 2011).

Studying the perceptions of farmers, Anantanyu *et al.* (2018) found they were anxious about the availability of agricultural inputs and that this anxiety subsides on the provision of agricultural information. Oudtanivanh *et al.* (2018) studied farmers' knowledge and perceptions of sustainable soil conservation practices in maize production in Lao, finding a direct relationship between knowledge and practice. The strategy of capacity building and technical advice included in programs on techniques of farm production and practices, led to an increased adoption of agricultural technologies by farmers (Oudtanivanh *et al.*, 2018). De Ponti *et al.* (2012) found that, when considering whether or not to adopt organic farming, economic factors were very important to farmers in non-industrialized countries. In a needs assessment study in Burkina Faso, Andrieu *et al.* (2015) found that technical and socioeconomic interventions help farmers to choose appropriate strategies to improve their productivity and incomes. My study seeks to measure farmer's perception on a selected sustainability improvement areas. Also identify the potential challenges, strategies, and responsibilities for the implementation of the defined intervention measures in Murang'a, Kirinyaga and Machakos counties.

4.3 Methodology

4.3.1 Research design and approach

With the aim of understanding the perceptions of farmers in regard to the sustainability assessment improvement measures, potential challenges, strategies, and responsibilities for the implementation the study utilized the following research design (Table 4.3-1).

Table 4.3-1: Research design and approach used in farmer perception study

Methodology	Involved stakeholders/sources	Targeted focus
Extensive Literature review	internet and bibliographic search and review of projects reports, peer reviewed publications	• To gather secondary data that has been used as baseline for this study
Stakeholder meeting	Public organizations, NGOs, Private institutions and researchers	• Data verifications • Draw-up key message areas • To capture perspectives of possible improvement pathways
Farmer feedback workshops	farmers extension agents	• Give farmer reports and presentation of interpretation of what is contained in the report

		Insights on possible intervention measures
In-depth meetings	farmers extension agents facilitators	• challenges/ constraints identifications • improvement measures • mechanisms for implementation

We carried out this study between July to October 2019 in three counties, each with different agro-ecological, climatic, and farming characteristics (see Chapter 1). A stakeholder meeting was first held to verify and validate the data and results from the farm-level sustainability assessments and to select key messages to be discussed during the farmer feedback workshops. Secondly, farmers were invited for feedback workshops (three workshops per county; a total of nine), where they received reports about their farms. The farm reports contained a) information about the productivity and profitability of all the crop and livestock activities a farmer practiced, the inputs and operations necessary to conduct those activities, and the outputs and sales resulting from these activities; and b) as the last section of the report, the sustainability assessment of the results for the farm. Thirdly, nine in-depth farmer discussion meetings were held (three per county) to identify and discuss the measures recommended to improve agricultural sustainability on their farms and the constraints to their implementation.

Stakeholder meeting

A one-day stakeholder meeting was held at the Kenya Agricultural and Livestock Research Organization (KALRO) in Thika to verify and validate the data and results collected in the farm sustainability assessments. The location, 45 km from Nairobi, was selected because of its centrality to the three study counties. A total of 30 (including 13 female) stakeholders took part, representing the following organizations: MoAL&F (representatives from the three counties), NGOs, the Limbua group, OACK, KOAN, the Participatory Ecological Land Use Management (PELUM) Kenya, Hivos East Africa, International Institute for Tropical Agriculture (IITA), FiBL, organic training institutions like KIOF, International Centre for Insect Physiology and Ecology (ICIPE), and the implementing team from KALRO. Other participants included the site managers from each SMART-Farm Tool auditor team (who had assisted the SMART-Farm Tool assessment in the field).

The objective was to validate the data results and draw-up the next steps for the farmer feedback meetings and in-depth discussions. The overall sustainability results per county were presented to stakeholders and discussed. The stakeholders validated the outcomes, gave recommendations for engaging farmers and listed areas of interest for discussion with farmers. Some of the key points to guide discussions with farmers in the feedback meetings were drawn-up (Table 4.3-2). The discussion focused on sustainability gaps, i.e. the unacceptable (0 to 20%) or limited (21 to 40%) outcomes for each county in the four sustainability dimensions.

Table 4.3-2: List of key areas for farmer discussion for each sustainability dimension.

Environmental Integrity	Economic Resilience	Social well-being	Governance
Ecosystem Water withdrawal Soil Quality	Stability of markets Profitability Investments Food safety	Capacity development Workplace and safety & health Provision Public Health	Full Cost accounting Holistic audit Transparency

Note: See Annex 10 and 11 for a detailed description

Farmer feedback workshops

The second stage was the farmer feedback workshops. Nine were held in total: three one day-long meetings in each county. A total of 578 farmers (including 312 females) participated in the workshops (Table 4.3-3). A program for the farmer feedback workshop was prepared beforehand (see Annex 11). The content of the farm report and how to read it was explained to the farmers. Question and answer sessions were encouraged to improve farmer understanding of the reports.

Table 4.3-3: Participating farmers who attended the farmer feedback workshops

County	Number of workshops	Participants %	Female %	Male %
Murang'a	3	72.3	75.0	67.6
Kirinyaga	3	65.9	89.1	59.0
Machakos	3	64.9	76.9	51.4
Total	9	67.7	78.0	58.6

Note: Expressed as % of the farmers whose data was analyzed in the sustainability assessment

The farmers provided feedback on the farm report and sustainability outcomes in the four dimensions (environmental integrity, economic resilience, social well-being, and governance). The feedback by farmers was on measures they were likely to take to improve sustainability on their farms with respect to the given sub-themes. For example, to reduce water withdrawal, farmers would embrace better irrigation technologies, plant more trees to attract rains and reduce run-off, or take-up water harvesting techniques. This process assisted the review and refining of the questions for the in-depth farmer discussions (see Annex 10 and 11)

Farmer feedback workshops in Murang'a and Kirinyaga

Farmer feedback workshop in Machakos

In-depth farmer discussions

Focus group discussions or interviews are interactions that encourage members to express their opinions and to discuss them with one another (Hennink, 2014; Potter *et al.*, 2004). They generate a considerable quantity of data in a relatively short period from a significant number of people, and allow for the recording and analysis of the reactions of different group members (Bloor *et al.*, 2012; Krueger *et al.*, 2015; Schensul & LeCompte, 2013). Focus group discussions have been used to collect information on farmer perceptions of various agricultural practices (Agidew & Singh, 2019; Jha *et al.*, 2020; Patidar & Patidar, 2015; Prihtanti, 2016; Soire *et al.*, 2016; Wartenberg *et al.*, 2018).

The in-depth farmer discussion workshops took place one and a half months after the farmer feedback workshops, to give farmers time to look through their farm reports and digest and reflect upon the information (Table 4.3-4). Each workshop was a half-day meeting lasting a maximum of five hours, with about 30 farmers in each group. A total of nine in-depth discussion groups, three per county, were held with an overall total of 270 farmers.

Table 4.3-4: participants to the in-depth farmer discussion groups in the three counties

County	Organic	Conventional	Total	Female	Male
Machakos	15	75	90	42	48
Kirinyaga	30	60	90	27	63
Murang'a	34	56	90	49	41
Total	**79**	**191**	**270**	**118**	**152**

A representative number of farmers were selected to represent the other farmers. The 270 farmers were shortlisted from the 578 farmers who had participated in the farmer feedback workshops with the assistance of the project site managers from each of the counties. The in-depth discussions were used to follow-up on the actions that farmers had said they would take to improve on sustainability gaps. In particular, the support and incentives required for them to adopt the measures and the strategies. The discussions were facilitated by a team that included the lead researcher, a representative of the MoAL&F, and a representative of an organic institute where applicable. The outcome of each discussion was documented on a flipchart, an audio recorder and by a meeting secretary who took notes (Annex12). Existing secondary information from the ProEcoAfrica project about the socioeconomic and farm characteristics of the participants, such as age, gender, education level, farm size, marital status, membership of a farmer organization, number of household members, soil quality rating, bank savings account, off-farm income, and farming experience, was recorded. The information was used as descriptive statistics to understand the participants involved in each in-depth discussion.


In-depth farmer discussion meetings in Kirinyaga County and Murang'a counties

MoAL&F representative addressing farmers in Machakos County after a discussion session

4.3.2 Analytical approach

A checklist of questions and a reporting template guided the in-depth discussions (Annex 10). The generated data were aggregated in thematic areas (Bloor *et al.*, 2012; Hennink, 2014; Krueger *et al.*, 2015; Schensul & LeCompte, 2013) and grouped into different topics for analysis. The topics aid in making reference points while referring to the contributions of participants as individual statements or group contributions (Hennink, 2014; Krueger *et al.*, 2015; Schensul & LeCompte, 2013). With the above in mind, the qualitative data generated from the farmer feedback workshops and in-depth farmer discussions were grouped into different topics. With the list of identified gaps for each of the four sustainability dimensions and 12 sub-themes (Annex 11), the topics reported were grouped under the following titles: a) evaluate performance and gaps identification (identifying the low sustainability scores); b) suggested ways to improve by farmers (from key gaps); c) investigate problems that need addressing (constraints/challenges perceived by farmers); and d) design and implement interventions and strategies (improvement measures or strategies) with those who proposed the measures (Figure 4.3-1). Some statements from the participants elicited further discussion, and voting was used to gauge the importance of such contributions or comments. The participants were asked to indicate by a show of hands how many supported the sentiments raised by a fellow participant. A scale of many, average, and low (high, some, and few; or highly important, somewhat important and important) was applied to the comments made by the participants to qualify their statements (Hennink, 2014; Krueger *et al*., 2015; Schensul & LeCompte, 2013). Only a few of the sub-theme areas (those with low sustainable scores, 0-20%) could be covered because of time and resource limitations during farmer in-depth discussions.

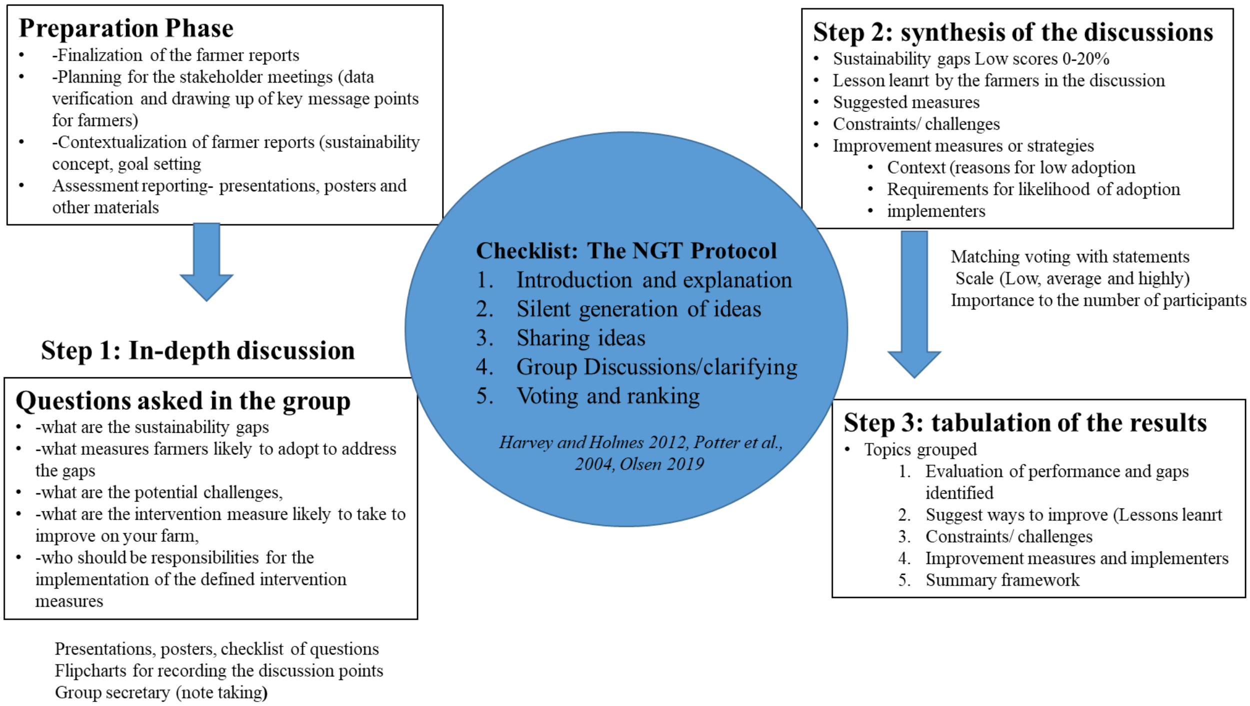


Figure 4.3-1: Steps in the analytical approach borrowing from (Harvey &Holmes, 2012; Potter et al 2004; Olsen 2019).

According to Harvey and Holmes, 2012 and Olsen 2019 the steps taken in the in-depth discussion is what they refer to as the Nominal Group Technique (NGT). The technique allows for interrogation of issues by participants, and inquiries into issues that may have previously been unidentified. It also allows groups to identify, rank and rate critical problem dimensions without interference of unbalanced involvement. Potter *et al.*, 2004 adds that the NGT process allows for generation of high quality ideas, produces more unique ideas at a relatively low cost, in a short amount of time and generates a high yield of data.

Many authors combine both qualitative and quantitative approaches as a way to strengthen the outcomes or results of their studies. Jha *et al.* (2020) carried out farmer focus group discussions using a scaling out assessment framework on organic seeds, because private sector seeds are mostly treated with fungicides, to assess the perception of farmers on the sustainability, adoption, and up-scaling of some selected agricultural technologies. Adebiyi *et al.* (2019) adopted individual interviews, focus group discussion, and expert interviews to collect data for analysis. Interviews and focus group discussions were recorded, transcribed verbatim, and coded manually and electronically

(Adebiyi *et al.,* 2020). A study by Prihtanti (2016) used key informant interviews, focus group discussion, a semi-structured and in-depth interview, and field visits. Descriptive statistics and crosstabs with Somers' procedure were used to analyze the data. Agidew and Singh (2019) collected data using survey key informant interviews, questionnaires, focus group discussions, and field observations. Oudtanivanh *et al.* (2018) collected data using a combination of methods (key informant interviews, focus group discussion, and a semi-structured questionnaire for households) (Oudtanivanh *et al.,* 2018). Yanakittkul and Aungvaravong (2020) evaluated farmers' intentions towards organic farming in rice farming by utilizing a questionnaire and focus group discussion for data collection.

When a combination of qualitative and quantitative approaches are used, the qualitative aspects (key informant interviews, focus group discussion) mostly begin or are incorporated within a semi-structured questionnaire to gauge opinions (e.g. using a five-point Likert scale response to questions) (Oudtanivanh *et al.,* 2018, Yanakittkul & Aungvaravong, 2020; Patidar & Patidar, 2015). Various researchers have used similar approaches to collect data. Jha *et al.* (2020) carried-out farmer focus group discussions using a scaling out assessment framework to assess the perceptions of farmers on sustainability, adoption and upscaling of some selected agricultural technologies. Information on farmer characteristics was collected (gender, age, main crop, household size, land size, inputs availability, and labour type). Kings and Ilbery (2012) used qualitative interview methods to collect data from organic and conventional farmers about their life histories, work routine and farm practices, noting their age, farm size, and education level. Recorded data was analyzed using a textual approach of words and meanings. Any interesting or unusual quotations and paraphrases made by respondents were highlighted to demonstrate attitude similarities or differences. Laepple and Donnellan (2008) assessed farmers' attitudes towards converting to organic farming, using face-to-face interviews to elicit the opinion and perceived problems of this alternative production system. They used mean scores on a scale of 1 to 5 generated during the analysis, and correlated attitude statements and intentions in their results. Patidar and Patidar (2015) in their study on the perception of farmers towards organic farming in India, used descriptive statistics and factor analysis. The theory of planned behavior (Ajzen, 1985; Beedell & Rehman, 2000) was used to analyze the data on a five-point Likert scale (Patidar & Patidar, 2015; Prihtanti, 2016). Pinthukas (2015) used a semi-structured questionnaire and focus group discussion and analyzed organic farming and farm practices using a three-point scale method.

Evaluation of performance and key gaps

The objective here was to evaluate how the farms are performing regarding the objectives or milestones set in the sustainability assessment against the set verifiable indicators, sub-themes, themes, and dimensions. We evaluated the scores in the sustainability assessment and rated them from 0-100%. The areas that scored between 0-20% (unacceptable range) were given a closer look to identify the reasons for such low scores. The process of learning regards the areas that need improvement and the steps required to improve low scores. A needs assessment was carried out to prioritize the areas where the topics were too many, to scale them down to the most important one(s) that can drive the whole change process.

Farmers' suggestions for improvement areas

For change to occur, there must be a willingness to change or do better. After evaluating the performance and the areas that did not perform well, the identified areas for improvement were broken down into ideas that would result in the changes taking place. The acknowledged improvement areas included immediate changes, short or long-term shifts, and what is best for the farms based on available resources.

Constraints (Investigation of the problems that need to be overcome)

The challenges that farmers face concerning production, harvesting and the marketing of farm produce are also likely to be the areas that may interfere with the adoption of intervention measures or strategies. Therefore, it was paramount that these were discussed before the final stage (see below).

Design and implementation of interventions and strategies

These are the measures that farmers pledged to take to improve the performance of their farms. Farmers listed the actions they would take up. They also discussed at which level, i.e. individual farmer or community, the said strategies would be implemented.

4.4 Results and discussion

This section presents the results of the farmer feedback workshops and in-depth farmer discussion meetings on the ways to improve the identified sustainability gaps. The results and discussion is structured using the four headings mentioned above as the analytical approach, i.e. evaluation of performance and learning; farmers' suggestions for improvement measures; investigation of the problems that need to be overcome; and design and implementation of interventions and strategies. 12 sub-themes from the four major dimensions (environmental integrity, economic resilience, social well-being, and governance) were selected for discussion with farmers.

4.4.1 Evaluation of performance and key gaps

The sustainability assessment reports of the SMART-Farm Tool rated scores as a percentage using a five-scale scoring method ranging from 0-100%: 0-20% as unacceptable, 21-40% as limited, 41-60% as moderate, 61-80% as good, and 81-100% as best (FAO, 2013a; Schader *et al.*, 2016; Ssebunya *et al.*, 2017). The unacceptable scores of 0-20% for the farms in Murang'a, Kirinyaga, and Machakos are summarized in Figure 4.4-1. The fewer the number of farms in the 0-20% range, the better the county performance. The areas deemed unacceptable are those for which greater efforts are required to improve farms' sustainability performance.

The sub-themes were drawn from the sustainability assessment's four dimensions (environmental integrity, economic resilience, social well-being, and governance) and 21 themes (FAO, 2013a). See Annex 13 for the full list of dimensions, themes, and sub-themes. Of the themes in the environmental dimension, 2 out of 6 had low scores, whereas for the social well-being dimension, 4 out of 6 had low ratings. All the themes in economic resilience and good governance had low ratings. At the sub-theme level, the following had low scores: 2 of the 14 sub-themes in the environmental integrity dimension, 7 out of 14 in the economic resilience dimension, 10 out of 16 in the social well-being dimension, and 9 out of 14 in the governance dimension.

The 28 sub-themes with low scores form the table are: water withdrawal, ecosystem diversity (environmental integrity), internal investment, community investment, long-ranging investment, stability of market, liquidity, product information, local procurement (economic resilience), capacity development, fair access to means of production, responsible buyers, rights of suppliers, forced labour, child labour, freedom of association and right to bargaining, non-discrimination, gender equality, support to vulnerable people (social well-being), and mission statement, due diligence, holistic audits, responsibility, transparency, grievance procedures, civic responsibility, sustainability management plan, and full-cost accounting (governance).

Discussion during the stakeholders meeting and farmer feedback meetings led to the regrouping of the sub-themes of interest. 12 of the 28 sub-themes where performance was low (0-20%, i.e. unacceptable) were selected for farmer feedback discussion and in-depth discussions:

- Environmental integrity: the sub-themes selected were: biodiversity (under ecosystem diversity), water withdrawal, and soil quality
- Economic resilience: stability of markets, profitability and community investments, and food safety
- Social well-being: capacity development, workplace and safety and health provision, and public health
- Governance: full cost accounting, holistic audit and transparency

Environmental Intergrity	Biodiversity
	Water
Economic Resilience	Local Economy
	Product Quality and Information
	Vulnerability
	Investment
Social Well-being	Equity
	Labour Rights
	Fair Trading Practices
	Decent Livelihood
Good Governance	Holistic Management
	Rule of Law
	Participation
	Accountability
	Corporate Ethics

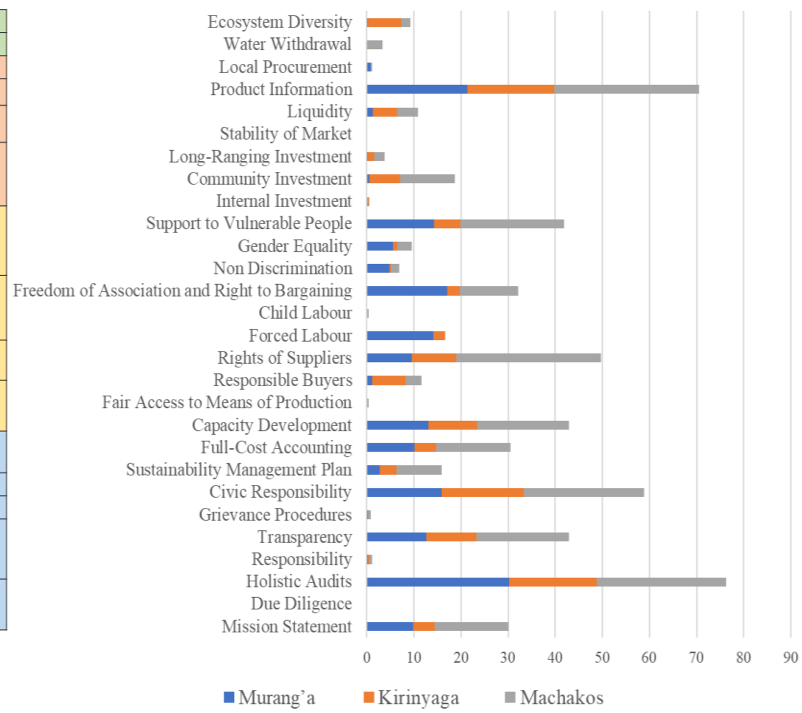


Figure 4.4-1: Percentage share of farmers within a case study with unacceptable scores per sub-theme

4.4.2 Farmers' suggestions for improvement measures

The farmer feedback meetings focused on the measures required to improve the areas with unacceptable scores. The farmers' suggestions are discussed below, listed by sub-theme under the different sustainability dimensions.

Environmental integrity:

Reduce water withdrawal: The farmers suggested that improved irrigation technologies could reduce water use/minimize water loss, would be less expensive to run, and more efficient to use. The use of drip irrigation and foot-pumps was discussed, as well as the pros and cons of different technologies. Farmers pledged to avoid planting water-draining trees, such as eucalyptus, near water sources. They pledged to adopt various water harvesting methods, including surface run-off harvesting (such as contour ridges, semi-circular bunds), Zai pits, rooftop harvesting, ponds or dams, and storage reservoirs such as water tanks, to improve the availability of water during dry spells. A few farmers suggested the construction of small dams to harvest water in Machakos County.

> *"…we have invested in foot water pumps and bought better PVC pipes that are helping to reduce the cost we used to incur buying petrol and reduce water wastage when irrigating." (Farmer from Kithimani in Machakos)*

Reduce biodiversity loss: The farmers have taken up some practices that enhance biodiversity conservation, that protect and preserve the wealth and variety of species, habitats, ecosystems, and genetic diversity around their farms, by reducing the use of pesticides, and avoiding loss of micro-organisms in the soil by reducing or stopping the practice of burning crop residues. Farmers also suggested avoidance of cultivation along riparian areas which has led to a loss of organic matter by water erosion and the washing away of soils. Another suggestion was planting more trees, especially indigenous types, and avoiding the clearing of bushes where unnecessary. Indigenous trees are better adapted to the local prevailing climatic and geographic conditions.

> *"…we have invested in tree planting on my farm, and this has helped in conserving water, improving air quality around my farm." (Farmer from Machakos)*

> *"…having indigenous trees on my farm has helped as a windbreak for my tea plantation and as firewood for home use." (Farmer from Murang'a)*

Improve soil quality: Practicing mulching, crop rotation, soil erosion control measures, and the use of organic manures promotes soil quality. Farmers encouraged one another to prioritize soil testing to know the quality of their soils before planting to avoid under or over nutrient application for the crops grown. The use of quality farmyard manure on the farm was also suggested. The way the farmyard manure is stored to reduce nutrient loss was stressed. Farmers suggested they should avoid excessive use of synthetic fertilizers to reduce making the soil acidic.

> *"...last year (2018) I had the soils on my small farm tested, and the results revealed that there was less nitrogen and dry matter in the soil. The measure recommended we addressed this, and the crops performed better. We sold more vegetables and are happy with the results. I would encourage other farmers to get their soils tested." (Farmer from Murang'a)*

Economic resilience: The four key message areas discussed include the stability of markets, improve profitability by keeping records, community investments, and food safety.

Stability of markets: The supply of sufficient farm produce to local markets throughout the year requires that farmers work together as a group to stagger production and ensure that each month crops are being produced. The suggested action-plan was to have a production plan showing a schedule of farmers and the time to start planting, to ensure continuous production to sustain the local market. Off-season production of crops using irrigation and reducing dependence on rain was also discussed.

> "…*with irrigation we are able to grow green maize throughout the year and sell at a higher price per cob than when we depend on rains only." (Farmer from Murang'a)*

> *"...having irrigation water enabled farming throughout the year. We grow many different leafy vegetables that sell in the local markets, and traders come from far to purchase them since they know we have them throughout the year." (Farmer from Mamba in Machakos)*

Improve profitability by keeping records: Getting higher profits requires several aspects to be considered, and key among them is having records of what inputs were used, labour costs, prices of various items, dates of when crops were planted, and use of a cropping calendar. Keeping track of the various farm activities requires record-keeping to avoid reliance on recalling the many details of every crop operation, inputs prices, and revenue from produce. Record-keeping assists farmers to assess the cost of production and calculate which crops are profitable, allowing them to reduce the number of crops they grow to only those that they can manage profitably. Also, the documents assist in planning farming activities to decide on where to re-invest to grow their farm enterprise.

"…watermelons were ready for harvesting around January, and as the only farmer in that area, we got excellent prices as there were so few farms with melons in the market." (Farmer from Matuu in Machakos)

Community investments: Most development activities and facilities are set up by the government. Farmers working in groups can work together to improve community standards by maintaining the infrastructure that benefits them (in areas such as link roads from farm to farm, community health centers, local markets, etc.). Farmers' projects to improve the community's environment were discussed.

"…working together as a group we can ensure more is done together to benefit group members and share ideas on investment options that favor the group." (Farmer from Murang'a)

Food safety: Rising number of cancer cases has led farmers to question the safety of the products they use on their crops and livestock. The safe and hygienic measures taken in handling farm produce to reduce high post-harvest losses were also discussed. The need to observe laid down procedures after spraying crops or giving livestock medication to reduce residual levels in crops and milk was discussed.

"…some farmers don't wait for the recommended duration after spraying the crop. They harvest some crops (tomato and French beans) before the lapse of the chemical effect since the buyer is on the farm and is giving good money for the crop…" (Farmer from Kirinyaga)

Social well-being: The need to improve capacity development, work safety and health provisions, and public health were discussed.

Improve capacity development: The organization of farmer training meetings or workshops to enable farmers to learn new farming practices should become a continuous process. The change to demand-driven agricultural services and fewer extension service providers has led to changes in how extension services are provided in the counties. Cooperatives organize training for crops like tea and coffee and for milk production. Farmer field days are held in each area every year. Farmers also visit each other and learn by sharing knowledge with those who are not informed on better crop production techniques.

"…in the field days we attended, we learned a lot and picked up a few new ideas which we now practice on our farms. We encourage the Ministry of Agriculture and the Organic Agriculture

Centre of Kenya to hold many more such field days each farming season…" (Farmer from Murang'a)

Improve work safety and health provisions: The work environment for farmworkers and their families must be conducive to enable good working conditions and relations. The persons working on a farm should have the correct equipment and tools. In the spraying of crops against pests and diseases, the correct spraying outfit is mandatory. The recommended practices include availability of a secure first aid kit and the marking of all dangerous areas on the farm that are risky and should be avoided. When using chemical pesticides, one should never spray against the wind, not eat or smoke while spraying, and one should take a bath and drink water after spraying.

"…we get farmhands (casual labour) for spraying our tomato crop, but they don't listen to us on wearing the full protective gear. Some say wearing the overall is uncomfortable…" (Farmer from Kirinyaga)

"…we noticed that when we hire farmhands (casual labour) for spraying our crop, they don't wear the full protective gear. Some smoke in the field while spraying crops, and when asked why they are doing so contrary to safety procedures, they say it's something small, just one or two puffs…" (Farmer from Kirinyaga)

Improve public health: There is a need to protect crops and livestock against pests and diseases. The inputs used for pests and disease control should be stored in line with recommendations on storage to ensure viability is maintained as well as to minimize their harmful effects due to poor handling. After use, the chemical containers should be destroyed or returned to Agro-vets where applicable. Other measures to follow include; avoid dumping farm waste in rivers, avoid cleaning knapsack pesticide sprayers in rivers, and observe pre-harvest intervals after spraying to stop the supply of harmful products to the community.

"…sometimes as farmers we take it for granted that the crops we sell after spraying are good to sell to the public but forgetting that our children living in the urban areas are the ones consuming the crops we sold that are full of chemicals…" (Farmer from Kirinyaga)

Governance: The key message areas discussed were civic responsibility (community involvement) and full-cost accounting (improving record-keeping, holistic audits, and transparency).

Civic responsibility (community engagement): The devolved governments at the county level plan development activities. Public participation in this planning, including the budget-making process, is encouraged as entrenched in the Constitution of Kenya (2010). Each citizen, apart from voting to elect representatives to various positions (Member of County Assembly, women representative, Member of Parliament, Senator, Governor, and President), can participate in activities that build the community, such as the planning and budgeting process in the county. The farmers suggested that they should take elected leaders to task on non-met initiatives which they committed to undertake.

> *"….we as citizens are encouraged to participate in the county budget-making process by contributing our views each year during the stakeholders' budget discussion meeting held before the county budget is passed in the county assembly." (Farmer from Kirinyaga)*

Full cost accounting (improving record-keeping, holistic audits, and transparency): Farming is not just about the production of crops for food and sale of the excess to the market. Farmers are encouraged to consider it a business similar to other jobs that pay well. Investments in farming should consider the future of the enterprise with achievable, sustainable goals that family members can continue developing. Farmers should plan and involve their children in farming activities so that they can take over from them. The farmers suggested that well-kept records could enable them to secure investment capital for the development of the farm.

> *"…we were able to secure a bank loan from an agriculture finance cooperation since we had been keeping various farm records as support documents for the farm business plan…" (Farmer from Murang'a)*

4.4.3 Constraints/challenges (Investigation of the problems that need to be overcome)

The in-depth farmer discussions looked at aspects limiting the uptake of the suggested measures identified to improve sustainability in the identified areas. The challenges included the following (see also Annex 14).

Environmental integrity

Lack of irrigation: A high number of farmers across the three counties stated that they depend on rain-fed agriculture. The few that used irrigation lacked the technical knowledge to utilize the water efficiently and effectively. They learned through trial and error by either over or under watering their fields. Most farmers could not adopt efficient and effective methods of irrigation, such as drip irrigation, due to inadequate capital.

Eucalyptus trees along the side of water bodies: Discussions with farmers revealed that some tree species, such as eucalyptus trees, planted along the side of rivers and swampy areas were not ideal in their areas. The farmers cited a reduction of water levels since the trees are fast-growing. Eucalyptus tree suck up a lot of water (Ferreira *et al.*, 2019; Lara *et al.*, 2009). The trees are exotic to Kenya and partly contribute to the reduction of cropping activities in Murang'a and Kirinyaga counties where farmers depend on the river water. The farmers suggested they could replace the eucalyptus trees with indigenous varieties (Ototo & Vlosky, 2018).

Biodiversity loss on farms: Loss of beneficial animals (insects, earthworms), plants (black jack), and local crop varieties in the farms were discussed. Farmers shared that some insect species they used to see ten years ago on their farms had disappeared. Many farmers had not seen earthworms for a long time on their farms. Such insects are beneficial to the ecosystem and act as natural enemies, pollinators, weed killers, or soil builders (Adhikari & Menalled, 2020; Getanjaly *et al.*, 2015).

> *"….we practice organic farming, and since we started compost making after the training by organic experts, we started seeing earthworms in the soils and other worms in the manure. They had disappeared before converting to organic farming…" (Organic farmer from Murang'a)*

The farmers also commented on the crop varieties grown. Most farmers nowadays grow hybrids and stopped growing local varieties due to seed unavailability in Agro-vets. Other crop varieties like cassava that were popular in the past as a staple crop in Murang'a and Kirinyaga have been replaced by maize. Some plant species, like the black jack, which was considered a weed, are only found on a few farms nowadays.

> *"….we used to see a lot of black jack plants on the farm as we did weeding, but now the plant population has reduced and has been taken over by the nut-grass which gives us a problem if weeding is not done early…" (Farmer from Murang'a)*

Lack of proper knowledge and facilities for soil testing: Most farmers agreed that they did not carry-out soil testing to know what amounts of organic or chemical fertilizers to apply. A high number of farmers were unaware of where to seek soil test services and the location of such services. The agriculture extension officers present in the discussion elaborated on what is required and encouraged farmers to adopt a collective approach to conducting soil sampling and testing. Both public and private sector organizations are needed to offer these services to farmers at the county level.

Low soil quality leading to low crop yields. A high number of farmers agreed that low soil quality leads to low yields. Very few farmers leave crop residuals on the farm and use compost manure to improve soil fertility. Some farmers have adopted the use of animal manure, making compost to improve soil fertility, and use of ash to reduce soil acidity.

Economic resilience

Market-related challenges: All the farmers agreed that markets and market information were important to them. The issues of unstable markets, fluctuating prices, exploitation by intermediaries/brokers, lack of price controls, and lack of target/alternative markets generated a lot of heated debates among the participants. Farmers sell their produce individually, and the prices quoted by buyers were rarely shared with others. Group marketing involves the aggregation of produce at one central place to sell at a negotiated price. In Kithimani, Yatta sub-County, Machakos County, an organic group, that had aggregated its produce and used public transport to take it to a market in Nairobi, collapsed as members started withdrawing because of one reason or another. Macadamia nuts from organic farms in Kirinyaga are picked up from their farms to comply with the traceability system. The macadamia trees are marked and GPS coordinates are taken, and the harvest is recorded per tree.

Fluctuating farm produce prices are caused by several issues, which include flooding of local markets with crops from other counties, and overproduction of certain crops like mango and avocado in some seasons. Farmers mainly produce crops at the same time, such as tomatoes, watermelons, and green maize through rain-fed agriculture. Farmers' challenges were further compounded by exploitation by brokers or intermediaries due to farmers' minimal market research for their produce and lack of a marketing strategy. There is also a large and increasing number of brokers along the value chain leading to the exploitation of farmers.

Low investments in community activities: In the present day most development activities and facilities are set up and offered by the government. The dependency created means that farmers no longer chip into the development activities that make their community's life better, such as to improve and maintain infrastructure facilities that benefit them as farmers (for example, inaccessible or poorly designed link roads that cannot accommodate large produce vehicles, a lack of community health centers, or under-developed local markets).

Low farmer group formation: A high number of participating farmers agreed that there were too few farmer groups. The type of groups mentioned by the farmers as more common included table banking, self-help groups, and community-based organizations. These groups focus on the social welfare of the community, however in most of the groups, discussions and agendas on agriculture were not a priority. One farmer, happy that this study had brought farmers together, encouraged her peers to continue in the spirit of staying together, learning from one another, and exploring the different markets since, as a group, they have a better voice to negotiate with buyers for better product prices.

> "*…this study was able to bring farmers from different communities together for two and a half years with the agenda of sustainable agriculture." (Farmer from Kirinyaga)*

Food safety: Lack of proper handling of crops by farmers during harvest and storage leads to food losses. Some farmers mentioned that they lacked information on the processing of specific vegetables and on the packaging and labeling of farm produce required for sale to the market. Those who farmed under contract farming for crops like French beans are required to follow crop operations strictly, to avoid rejection of the harvest. Post-harvest losses in most horticultural value chain crops are generally in the range of 20-50% (Affognon *et al.,* 2015).

Social well-being

Inadequate capacity development: A high share of farmers in the discussion groups agreed on the limited access to information and capacity-building agricultural programs in their counties. There are a few extension officers within the counties which has resulted in inadequate knowledge on best agronomical practices for quality production, and for conventional farmers applying pesticides, limited information on pre-harvest intervals for food safety and proper techniques for chemical handling. Organic farmers face an information gap on the organic pesticides and fertilizers available for use and on the pathways to access projects or programs in their areas.

Indeed, most of the farmers in the discussion groups were not aware of the agricultural projects or programs earmarked for their sub-county or wards. The farmers agreed that the dissemination of information was inadequate, and that as a result, they did not participate or volunteer for such training when it took place.

Public health challenges: The majority of the farmers in the discussion groups did not have a separate storage space for pesticides and food crops harvested. Neither did they observe pre-harvest intervals when spraying chemical pesticides to ensure food safety for consumers. Another public health challenge is the contamination of water either during spraying or the cleaning of equipment. If spraying near the river, the farmer will clean the equipment in the river. Where tap water is used, the knapsack pesticide sprayers were washed where other household items are cleaned and sometimes, where drinking water or water used for cooking is sourced. Outfits worn during spraying were washed together with other clothes. Most farmers stored the chemical pesticide containers alongside farm produce or in the field (between a tree branch) or on top of the doorframe. Poor waste disposal was also another challenge. Farmers lack adequate information on how to dispose of containers and so on. Most of the time, apart from sorting the food-waste, everything else was lumped together (paper, plastic, expired batteries, etc.) and thrown in a pit or hole dug at the far end of the homestead.

Governance

Poor road networks: This is especially problematic when it rains, making it difficult to transport goods from the farm to markets. A high share of farmers in the discussion groups agreed that sparse road networks have sometimes forced them to carry their farm produce on their backs to a place where vehicles were available or to use ox carts, both of which leads to crop losses.

Lack of proper record keeping: Farmers blamed this on time constraints, forgetfulness, and the perception that it is a tedious process. Most of the farmers agreed that they were only keeping records during the project period to avoid being reprimanded. Some farmers said that assistance from the enumerators during the data collection period helped them to keep records. Farmers added that record-keeping aided them in knowing the expenses used and money generated.

> *"….we stopped keeping records after the project ended. As farmers, we put a lot of money and time into farming but the returns we see are little. We don't want to continue knowing how badly we are doing considering that the prices we get are bad…" (Farmer from Murang'a)*

Small farm size: Farms have become smaller due to the subdivision of land into smaller parcels. A father sub-divides his farm among his children, who end up with a small area that they cannot farm. Small farm size has led to a reduction in the number of crops cultivated and the quantity of harvest, or households abandoning farming altogether.

4.4.4 Interventions and strategies discussed and recommended by farmers

In this section the measures that farmers proposed to take to address the identified sustainability gaps are summarized. The proposed improvement measures (Table 4.4-1 and Annex 3) are shown in Figure 4.4-2, where the bar represents the number of farmers agreeing on whether the proposed measures were effective potential solutions. Record-keeping for improving profitability is the intervention that overwhelmingly received the most support of the participants, with almost all of the 270 farmer participants voting in favor of this measure. The other most popular measures, which received around two-thirds of the participants' votes, were improved irrigation, soil testing, forming producer and marketing groups, the need for and participation in community development programs, and proper waste disposal.

Figure 4.4-2: Potential intervention areas (solutions) expressed as the number of participants taking part in the discussions (low, average and high)

Environmental integrity: The six intervention measures and strategies proposed by farmers include:

1) Adoption of organic farming methods to promote biodiversity and soil quality. Farmers adopting organic farming need quality organic inputs such as seeds, organic fertilizers, plant protection inputs, as well as packaging materials for the harvested products. A value chain analysis for organic players/actors requires an understanding of the actors and gaps so that business investment opportunities linked to market analysis can catalyze a process that leads to higher organic food production.

Organic farming is labour -intensive due to the use of bulky organic fertilizers, manual weeding, and organic pesticide preparation and application. If the preparation of some of the organic fertilizers and pesticides were to be taken up by local or existing companies, this would release farm labour to other farming activities to increase farm production.

Farm monitoring is encouraged to monitor pests, diseases, and crop growth (concerning soil moisture, structure, and texture for aeration of the soil, the presence of organisms and beneficial insects in the soils and field).

2) The management of riparian strips. This is important for soil conservation and water quality. The cultivation of farmers on riparian strips is discouraged as it leads to ecosystem disruptions such as topsoil loss, lowering of water quality and interference with aquatic life. Farmers near water bodies are encouraged to foster better management of riparian strips along the riverbanks or streams to promote water quality. The riparian strips are usually low flat land that some farmers have taken advantage of to grow crops without observing the required 40 meter distance as required by the Agriculture Act (Cap.318) 2012, the Water Act (Cap.372) 2012, and the Water Act 2016; and if found guilty, this is an offense punishable by law (The Republic of Kenya, 2012a, 2012b, 2016). The law outlines strict measures to be taken against those violating the protection of catchment areas.

3) Tree planting initiatives. This would boost forest cover on farms and throughout the country and is strongly encouraged. Kenya's tree cover stands at 7.4% of the total land area of Kenya (GoK, 2019; Ototo & Vlosky, 2018); which is less than the required minimum of 10% forest cover. Initiatives by the government have encouraged tree-planting activities to boost Kenya's tree population. Such programs advocate tree planting and discourage the planting of trees that reduce water levels, such as Eucalyptus tree alongside water bodies. Farmers can get more information on local and appropriate trees to plant on their farms from Kenya Forest Services. Apart from the government institutions that have tree nurseries, farmers are encouraged to create certified tree nurseries that complement government initiatives. The communal nurseries should raise different varieties of trees that are indigenous and suitable for their agro-ecological zones. Farmers are also encouraged to plant fruit and nut trees, which provide an additional source of income.

4) The adoption of an efficient and effective method of irrigation. Use of new technologies like drip irrigation and renewable energy/solar efficient irrigation systems, can reduce water losses on farms and increase crop yields. Apart from government incentives that promote the reduction of the cost of equipment, tax exemption measures should be given on agricultural inputs to encourage farmers to adopt new technologies.

5) Develop a culture of soil testing to improve soil quality. Most farmers in the study sites have not had their soils tested. The farmers rely on the premise that their lands are good since they have been getting a crop each year. However the few farmers who have had their soils tested make a better judgment of input use and application on their farms. More farmers require training on the importance of soil testing and a list of organizations (with their contacts) that offer soil testing services was made available to the extension service providers and farmers. Setting up subsidized mobile soil testing labs that offer reduced costs for the service to the farmers would also benefit the farmers.

6) Improvement of soil quality on farms. Capacity building to farmers on Good Agricultural Practices (GAP) that include crop rotation, mulching, and applying both farmyard and compost manure enhances farmers' skills and leads to higher crop productivity. Follow-up and practical training where the farmers observe, learn, and practice what they have been taught is required to enhance learned skills. The practice of leaving a good percentage of crop residue on the farm after harvesting instead of removing everything should be encouraged. Farmers are also encouraged to avoid excessive use of synthetic fertilizers and pesticides to reduce the level of acidity in the soil.

In summary, the environmental strategies listed by farmers that need to be incorporated in the intervention plans include: biodiversity conservation measures to control biodiversity loss, tree planting, the establishment of tree nurseries, maintenance and enhancement of beneficial organisms, fertility management to improve soil quality, soil quality enhancement and soil testing, farmyard manure testing for quality and management to conserve the required nitrogen, water management especially irrigation techniques that promote efficiency in water use, alternative management options such as mulching and residual crop management to reduce water withdrawal from the soil, and appropriate application of water on the farm.

Economic resilience: The four intervention measures and strategies suggested by farmers include:

1) Forming of agricultural producer and marketing groups for market stability. Farmer producers and marketing groups promote the interests of the group and encourage farmers to come together and get trained on the importance of working together to achieving an economy of scale. Most farmers sell their farm produce individually and accept the farm-gate price offered by the buyer without negotiation. Group marketing and collection centers will reduce the poor negotiation of farm prices with buyers. From their outset, farmer groups should have clear objectives and a well-designed constitution to guide the achievement of the goals and aims of the group. Most government organizations and NGOs have projects that provide agricultural incentives to groups of farmers rather than to individuals.

2) Training farmers on Good Agricultural Practices (GAP). This will enhance farming skills and increase safe and healthy crop production. The sustainability benefits of GAP are realized by both farmers and consumers as there is control over production, lower costs (agrochemicals) and higher yields, and more income and better prices for quality food. The formation of farmer groups and collaboration with other farmer groups with common interests can improve economics of scale and the production of larger quantities of food to meet market demands.

3) Record-keeping is important to guide farmers' decision-making and improve the profitability of farms. Good record-keeping practices should be cultivated. This will help farmers to have a clear vision of what crops or livestock make profit or losses, and where to make cuts in production costs to minimize expenditure. A continuity of good farming practices and knowledge of where to improve are essential for sustainability.

4) Observation of Pre-Harvesting Intervals (PHI) when using chemical pesticides to ensure food safety. Regulations, monitoring and traceability of farm produce should not only be for export crops but also for the local market. Food quality and safety standards maintained for all crops grown on the farm are important for safe production. The produce of farms that do not meet the required quality and safety standards should be destroyed and legal action taken against the farmer. Strict measures should be put in place in the agriculture value chain to protect the consumers of farm produce.

To summarize, the economic strategies that farmers were most keen to incorporate in the intervention plans include the establishment of agricultural farmer groups and record keeping. Formation of farmer groups necessitates mobilization and sensitization meetings and the drawing up of farmer group constitutions with clear goals and objectives, including rules for conflict resolution mechanisms, the sharing of proceeds, reporting of achievements, and maintenance of sufficient number of members. Stabilization of the market area includes market analysis to understand the most suitable and profitable crops to be planted by farmers, market intelligence gathering, reporting to members, and the establishment of collection centers and product traceability systems. Furthermore, identification of alternative and niche markets for a diverse range of farm produce and fulfilling the required statutory requirements (standards and approvals). The importance of record-keeping was the most popular measure: different types of records are important on a farm, and especially the tracing of where losses or high expenses are incurred to improve the profitability of farms. Capacity building aspects that range from agronomic practices to harvesting, value addition and marketing.

Social well-being: The six intervention measures and strategies proposed by the farmers include:

1) The promotion of a good working environment. Important for farmworkers, employees, hired casual labour, and family members engaged on the farm. Provision of protective clothing and the demarcating of hazardous areas on the farm are two obvious actions. Strict action should be taken against farms that do not provide the necessary environment for an employee. A stricter follow-up, rather than a casual warning approach, is needed for farmworkers who do not wear protective clothing during crop or livestock spraying. Actions taken will promote adherence to labour laws and reduce the number of cases of respiratory health problems caused by poor handling and spraying using chemical pesticides or insecticides.

2) Farmers should be encouraged to diversify. By taking up the most profitable crops and livestock enterprises, farmers can maximize the use of their land. As most farmers are small-scale (1-2 acres), they should not have more than 15-20 different crops. Value addition can increase incomes by changing the form of a raw product, i.e. fresh, dried, processed, milled, or liquid form. Green maize cob fetches better returns than maize grain in most markets as consumers buy cobs for roasting, boiling, and mixing with beans, etc. The diversification and value addition measures followed must adhere to the set standards of quality and safety. Capacity building on the importance of diversification and types of value addition is required for different crops and livestock.

3) Proper waste disposal. Farmers should be trained on the best way to dispose of the various waste products generated by their farming activities. Some input companies provide recycling mechanisms and return of empty containers but not many of the farmers are aware of the existing options. Awareness creation and waste collection points and schedules should be advertised.

4) The correct storage and use of chemicals. This is included in the training schedules for both conventional and organic farmers. Most farmers overuse plant protection chemicals, and it is common for farmers to spray crops more times than required or to spray at the wrong time. Farmers need to be trained on the importance of wearing protective gear while using chemicals, and on the harmful health effects of exposure to chemicals and resultant need to store chemicals properly.

5) Capacity building on the principles of organic farming. This is required to remove misconceptions about organic agriculture. Organic principles include an awareness of the ecological context; and fairness for all relationships, care, and precautions for all. The traceability of all farm produce, not just organic produce, should be encouraged. Farmers should start by researching the market and then grow the crops the market demands. A market survey is important to identify the commodity buyers' demands so that farmers can produce what sells and not produce and later discover a lack of market.

6) Frequent capacity building meetings. These are necessary for farmers to understand agriculture value chains and the different players engaged, so that at every stage farmers are updated on the new emerging farming trends and technologies they can use to increase production and make farming more effective. Structured training may be conducted every quarter of the year and facilitation can be done through groups by extension officers or any other stakeholder in the value chain.

In summary, the strategies mentioned by farmers that need to be incorporated into intervention plans include capacity building programs, safe and proper use of crop protection measures, health and safety for farm employees and workers, and proper disposal of waste.

Governance: The two intervention measures and strategies proposed by farmers include:

1) Farmers' involvement in community development programs at the local and national levels. An example is participation in the budgeting process for the county at scheduled days for the sub-county. For this, a schedule of the planned presentations and discussion and location of the meeting venue need to be organized and shared with the public in good time to maximize attendance and participation.

Table 4.4-1: Improvement measures, reasons for low adoption, the requirement to stimulate adoption by farmers and strategies

Improvement measures proposed by farmers	Reasons for low adoption	Requirements to stimulate or increase the likelihood of adoption	Actions/ Strategies
Environmental integrity areas:			
Adoption of an organic farming system	Adopted fairly well by the present farmers	Establishment of local companies that produce organic farm inputs products. (Subsidies for organic inputs, incentives to companies producing organic inputs)	Enabling environment (policies), capacity building, market facilities, organic inputs, value addition
	High labour intensity due to the process of preparation of the organic fertilizers and pesticides		
Advocating tree planting and discouraging planting of trees that withdraw high volumes of water	Lack of strict enforcement measures by the concerned authorities	Cooperation between farmers and county government environmental officials	Biodiversity conservation, tree nurseries establishment, and enhancement of tree planting
	High demand for eucalyptus trees for timber	Establish communal nurseries of different varieties of trees	
	Lack of sensitization on the matter of climate change	Capacity building in climate change and coping mechanisms to adopt	
	Small farm size	Planting fruit trees and nut trees which will be an additional source of income	
	Cutting of trees for sale as charcoal and firewood due to financial constraints	Have communal nurseries of different varieties of trees	
Adopting an efficient and effective method of irrigation e.g. drip irrigation.	The high cost of improved modern irrigation technologies	Government can reduce the cost of equipment through tax exemption on agricultural inputs	Innovations in irrigation and water harvesting, enabling environment (policies), credit facilities
		Farmers can join up and support one another to ensure they adopt new technologies	
Develop a culture of soil testing to improve soil quality	Lack of finances to facilitate the process of soil sampling	Awareness creation on the benefits of soil testing	Enabling environment (policies), regulatory and institutional support, credit facilities
	Few farmers aware of organizations offering soil testing services	Government to subsidize the costs and initiate mobile testing labs	
	The high cost of soil testing	Service to be brought to the locality	
Improvement of soil quality		Practice crop rotation, mulching and apply both farmyard and compost manure	Capacity building,

Improvement measures proposed by farmers	**Reasons for low adoption**	**Requirements to stimulate or increase the likelihood of adoption**	**Actions/ Strategies**
	Inadequate knowledge of compost making and proper pesticide application methods	Leave a good percentage of crop residue on the farm after harvesting instead of removing everything	regulatory and institutional support
		Avoid excessive use of synthetic fertilizers and pesticides to reduce the level of acidity in the soil	
Economic resilience areas:			
Forming of agricultural producer and marketing groups for market stability	Most groups formed are social- not agriculture-oriented	Farmer group formation and capacity building	Capacity building
	Mistrust among one another	Conflict resolution mechanisms to build trust	
Market information, surveillance and traceability system	A high number of intermediaries/ brokers, low farm-gate prices, individual sales	Group marketing, price negotiations, access to market information (mobile applications)	Market facilities, capacity building
Record-keeping for improving profitability	Reluctance or inability by farmers	Capacity building on benefits of record-keeping, involvement of other partners (e.g. credit facilities) during training	Capacity building
	Failure to realize the importance of record-keeping		
Utilization of recommended Pre-Harvesting Intervals (PHI) rates when using chemical pesticides to promote food safety	Recommendations not adhered to (pesticides sprayed too late or crop harvested too early)	Strict regulatory framework, pre-inspection (sample testing), capacity building	Capacity building, regulatory and institutional support
Social well-being areas:			
Promote a good working environment on the farm by offering protective clothing and demarcating hazardous areas	Laxity in the relevant authorities concerned with the safety of workers	Strict action not taken on non-compliant farms	Regulatory and institutional support
Adopting Good Agricultural Practices (GAP)	Inadequate information on GAP due to a limited number of agricultural extension officers	Counties to hire more extension workers to replace retired staff, capacity build lead farmers (Training of Trainers concept)	Capacity building
Practice diversification and value addition	Small farm sizes	Availing information of the more profitable crops and livestock enterprises	

Improvement measures proposed by farmers	**Reasons for low adoption**	**Requirements to stimulate or increase the likelihood of adoption**	**Actions/ Strategies**
	Inadequate information	Capacity building, standards and protocols in value addition	Capacity building, regulatory and institutional support, innovations standard in value addition
Proper waste disposal	Lack of knowledge on the best ways of disposing of different farm wastes	Capacity building on the best methods of waste disposal	Capacity building
	Absence of a public service for waste handling and collection		
Proper storage and use of chemicals	Failure to adhere to the set Pre-Harvesting Intervals (PHI) period standards	Capacity building on benefits of wearing protective gear while using chemicals, and on the harmful effect of chemicals on farmer and consumer health.	Regulatory and institutional support
	Ignorance of the dangers of pesticides and lack of use of protective gear		
Practice organic farming	Inadequate information on organic farming	Capacity building to remove misconceptions about organic agriculture	Capacity building
	Misconceptions around organic farming, for example, that organic crops take a longer time to maturity		
Frequent capacity building in all areas of the agriculture value chain	Lack of coordinated structured training	Organizational structures, plans, programs of capacity building, monitoring and evaluation of the usefulness of initiatives to retain important ones	Regulatory and institutional support, capacity building
Governance areas:			
Financial accountability, holistic audit and sustainability plans	Few farms have a sustainability plan and keep proper records	Capacity building on the importance and benefits of succession farm plans	Capacity building
Water projects as a community investment	Lack of trust and cooperation due to factors such as corruption has led to project's stalling	Collaborations between farmers, government, and other well-wishers in coming up with sustainable water projects	Regulatory and institutional support
Involvement in community development programs, participation in budgeting process in the county	Lack of interest in such forums or events	Capacity building to farmers to help them understand the importance of such forums	Capacity building

Advertisements are required that call for farmer participation in such meetings to discuss the development of the community at the ward and county level. The advertisements can be placed in local churches, social halls, and the chief's camp, as well as in the print media. Capacity building helps farmers to understand the importance of such forums.

2) Water projects that provide access to clean, safe and reliable water at the community level. These need to be incorporated in the case study sites. The different agro-ecological zones means that the water needs differ across the study sites. Yatta sub-County in Machakos County has infrastructure for water canals but the flow of water has been reducing over the years making farming using the water unsustainable. Frequent de-siltation activities should be carried-out. Water harvesting initiatives in the three study sites should be promoted to harvest rainwater for both domestic use and farming

Involvement of youth: A cross-cutting theme

To ensure the sustainability of farming practices in the longer term, sustainability measures need to be implemented by current farmers with an emphasis on the participation of the younger generation who will, one day, takeover farming activities. The younger generation need to learn about farming from the older generation, both to ensure there are no gaps in the takeover but also so that good traditional practices and knowledge are not lost forever (the introduction of conventional farming has led to the loss of traditional knowledge). Farming should be promoted as a career like any other job among the younger generation. The youth agro-entrepreneurs are encouraged to select the crops and value chains that best suit them, especially because they are generally more comfortable with new technologies as compared with the older generation.

Implementation

It was agreed that the strategies identified were to be implemented by either the community or individual farmer or by both parties (Table 4.4-2). The results show that individual farmers expect to take up the following measures: adopting an efficient and effective method of irrigation, e.g., drip irrigation (water use and management), the development of a culture of carrying out soil tests to improve soil quality (soil fertility management), and record keeping for improving profitability. Farmers also felt that individuals must play a strong role in promoting a good working environment, for example, by offering protective clothing and demarcating hazardous areas on the farm.

The improvement measures that the community should implement are the formation of agricultural production and marketing groups, and community welfare projects, namely water projects as a community investment. The measures that require both individual and community engagement are biodiversity conservation, i.e. proper use of riparian strips along riverbanks or streams to promote water quality and avoidance of tree planting that affects water withdrawal, improvement of market stability, leadership, and product diversification and value addition.

Table 4.4-2: Implementation of improvement measures at all sites

	Improvement measures	Individual	Community	Both (Individual & community)	Number of farmers agreeing to statements during discussions
Environmental integrity	Adoption of organic farming method to promote biodiversity and soil quality.	270			270
	Use of riparian strips along the river banks or streams to promote water quality			270	270
	Avoid planting of trees that affect water withdrawal for example Eucalyptus tree.	90 (Mac)		180	270
	Adopting of efficient and effective method of irrigation e.g. Drip irrigation.	270			270
	Develop the culture of doing soil testing to improve soil quality	270			270
Economic resilience	Practice of Good Agricultural Practices (GAP).	270			270
	Forming of agricultural producer and marketing groups for the purpose of market stability		270		270
	Record keeping for improving profitability.	270			270
Social well-being	Ensuring that if pesticides are used the Pre Harvesting Intervals (PHI) are observed to promote food safety.	180		90 (Kir)	270
	Promote good working environment, for example by offering protective clothing, demarcating hazardous areas in the farm.	270			270
	Practice diversification and value addition.	90 (Mac)		180	270
Governance	Having a water project as a community investment		270		270
	Involvement in the community development programs, for example participating in the budgeting process for the county during the sub county scheduled days.			270	270

Note Mac- Machakos, Kir- Kirinyaga, and Mur- Murang'a

4.5 Limitations to the study

Several limitations to the methodology include the scope and duration of the research and the data collection approach (qualitative vs. quantitative).

Qualitative vs. quantitative approach: While a good number of authors prefer quantitative research methods, qualitative methods were used as they bring out issues that affect a community or farmers that cannot be quantified. If quantitative methods allow us to answer 'what' and 'how much' questions, it is qualitative methods that help us explain the results by answering 'why' and 'how' questions. The interactions and relationships of farmers, which pertain to their behavior, beliefs, norms, and taboos, are best measured by qualitative approaches.

The analysis in this chapter concentrated more on qualitative measures to draw information from farmers on the challenges, measures, and strategies the farmers would use to improve the sustainability gaps identified on their farms during the earlier sustainability assessment.

Time: The scope was limited in terms of the content during the in-depth farmer discussions, because only 12 of the 58 sub-themes were discussed. The duration of each meeting (4-5 hours) limited the depth to which each of the points could be discussed. Nevertheless, the methodology used allowed us to cover many aspects each with multiple dimensions.

Language: The language of communication with the farmers varied from location to location. Local language was used in most of the farmer discussion meetings, however the written materials were in English. In the interpretation from English to local languages and vice versa, some of the intended meaning may have been lost. In other cases, there is no equivalent one-word for an English word in the local language but rather a group of words. The inclusion of frontline extension staff and the SMART-Farm Tool auditors in the facilitation team aided the discussion with the farmers as this ensured all the participants felt comfortable and were at the same level; thus, free interactions and conversations were achieved.

Composition of in-depth discussion groups: The in-depth farmer discussion meetings differed in each county in terms of proportion of represented farming systems and gender make-up. The proportion of organic to conventional farmers was unequal: 34 organic to 56 conventional farmers in Murang'a, 30 organic to 60 conventional in Kirinyaga, and 15 organic to 75 conventional in Machakos. However, perhaps this better represents the reality. The breakdown in terms of gender was Murang'a 49 females to 42 male farmers, Kirinyaga 27 females to 63 males, and in Machakos, 42 females to 48 males. Mixed group discussions were considered ideal as the farmers had already, on many occasions, interacted with one another, including in previous meetings organized by the project (Krueger *et al.*, 2015; Schensul & LeCompte, 2013). Studies by other authors discuss the need to hold gender-disaggregated meetings if one gender will not freely speak in the presence of the other, or if the topics are too sensitive (Hennink, 2014). In our mixed-gender meetings however, there was a balanced expression of opinion by both men and women. The inclusion of both women and men in the facilitation team also strengthened the group discussions, as it also indicated that men and women were treated as equals by the study.

Murang'a and Kirinyaga farmers receiving participation certificates at the end of meeting

4.6 Conclusions

The sustainability assessment using the SMART-Farm Tool (Chapter 3) elicited great discussion among farmers since, for most of them, this was the first time they were getting feedback from surveys involving them. The sustainability reports about their farms and the discussions showed that it is essential to return feedback to the end-user, not just for policy development but also to enrich decision-making by farmers on matters concerning their farms. Prioritization and limiting the areas for discussion to focus on primary key message areas was essential for the discussions with farmers.

The inclusion of farmers in the sustainability assessment should be all inclusive as sustainability assessments are complex. Inclusivity of farmers who are the decision making in their farms is a major benefit to them as expected to support in interpreting the assessment results while developing and implementing new farm strategies.

This study on the perception of farmers on the sustainability gaps, constraints and improvement measures shows that farmers are knowledgeable about the factors affecting them (constraints) as also they have an idea of potential solutions in solving them but lack the support to go further on ways to implementing the changes required. The challenges mentioned by farmers bring out some limitations that farmers face, especially small land holdings which mean that farmers can only produce a limited quantity of crops (Mishra *et al.*, 2018). Most farmers grow between 8-18 different crops as a mechanism to cope with risk in case of crop failure. By planting many crops, this limits the specialist knowledge that can be developed on optimal crop requirements for the maximization of crop returns. The crop knowledge of the farmer is thus limited as they only pick up a few ideas for each crop, modify them, and implement a limited number of recommendations for their crops. The challenges reported by farmers in the study sites are consistent with studies done elsewhere (Greer & Hunt, 2011; Jouzi *et al.*, 2017; Levin *et al.*, 2012; Nieberg *et al.*, 2003).

Summary of recommendations

a) Technical and physical inputs

High yielding quality seeds for both organic (organic seeds, because private sector seeds are mostly pretreated with fungicides) and conventional farmers, soil testing, and soil health interventions incorporated in farmer training programs, will enhance farmers' capacity to increase productivity. Broadening the scope of organic inputs for organic farmers: from seeds to pest and disease control interventions that make organic farming less labour -intensive and more sustainable.

b) Value addition

Farmers sell most of their farm produce in the raw form, thus getting low prices. The use of knowledge, technology, and training to create and innovate on new products by adding value to the organic raw materials will ensure that farmers sell at higher prices.

c) Marketing facilities

In Kenya, organic produce is mostly sold in Nairobi and Mombasa upmarket suburbs, frequented mainly by foreigners, while the organic producers are based in rural areas (Kledal, 2009). Thus, there is a need to increase awareness of the benefits of organic products in the country. The market outlets include supermarkets, specialized organic shops and restaurants, open-air markets, and basket delivery systems to consumers (Kledal, 2009). This niche can be expanded to include institutional markets like schools and hospitals for highly nutritious organic products. The support for vertical integration through market innovations such as warehousing receipt systems, group sales, and traceability systems will enhance the sale of farm products by farmer groups. Setting premium prices for certified farms linked through group marketing will enable farmers to increase their revenues for their crop products.

d) Capacity building

Many farmers have already been trained on crop production techniques both in conventional and organic farming systems. Farm performance can be improved through institutional support that builds on their capacity in farming and decision-making. Coordination to enhance linkages between the public and private sector can play a significant role to reduce duplication. The results are consistent with other studies done on attitude change and farmer institutional support (Godfray *et al*., 2010; Hazell & Wood, 2008), and stakeholder engagement (Ssebunya *et al.,* 2017). Farmers' understanding of the circumstances that affect them, directly and indirectly, enhances better decision-making on farming activities. Constant capacity building enriches their skills allowing farmers to not only produce food for themselves but also to generate a decent income (Yanakittkul & Aungvaravong, 2020). The results are relevant for policy and investment strategies for sustainability improvement in planning and decision-making. The benefits and incentives that accompany an enabling organic environment set by governments is strongly recommended as such policies will support more farmers to join organic farming groups and motivate already existing members to continue with their organic groups (Jha *et al.,* 2020). The use of knowledge dissemination and value addition will enhance the food and livelihood security of farmers.

The findings presented in this study are derived from smallholder farms in Murang'a, Kirinyaga and Machakos counties; nevertheless, the methods can be applied to other counties, countries, and farming systems. Future follow-up studies can investigate which measures the farmers were able to take-up and the reasons why they were able or unable to improve their farm performance.

Further studies linking support to value chain assessments (opportunities, constraints, interventions measures) leading to prioritization of the main factor(s) that will catalyze change at farm level for improved farm performance will go a long way to improving farmers livelihoods.

5. Chapter: Research Synthesis and Conclusions

5.1 Summary of the study

This study contributes to the bank of knowledge generated by empirical studies of farming systems, farm management, and sustainable farming. The evaluation of the sustainability performance of small-scale farms using a sustainability assessment framework with a range of indicators covering environmental, economic, social, and governance dimensions is of practical relevance at the farm and regional (county) level. The results provide an overview of intervention opportunities that can be used by different actors to overcome specific sustainability gaps for the betterment of farming systems.

Additionally, the sustainability assessment presented in this thesis provides knowledge and learning opportunities on the challenges in organic and conventional farming systems in Kenya. Limited information on the economic benefits of organic production hinders farmers' ability to make decisions in favor of adopting an organic production system, coupled with the limited support available by the government and other development agencies (Ndungu *et al.*, 2013; Taylor, 2006; UNEP-UNCTAD, 2008). This study contributes to the knowledge gap in aid of better decision making, in the policy sector and at the farm level for Kenyan farmers, on the profitability, economic resilience and environmental sustainability of organic and conventional farming systems. The study provides evidence-based research to back Kenya's organic policy framework as well as improve decision making at the farm level on sustainable farming. This study is among just a few carried out to compare organic and conventional organic farming systems in Kenya. Through its coverage of a large number of farms, farmers and counties in Kenya, it is the largest in its scale and scope. The data was collected from 864 farms in three counties (Murang'a, Kirinyaga and Machakos).

This study assessed the sustainability performance of organic and conventional farming systems. Data on farming practices regarding land preparation, harvest, storage and sales were collected for a two-year period for the analysis of productivity and profitability of the farms (Chapter 2). In the sustainability assessment, the SMART-Farm Tool was used to evaluate the farms across four dimensions: economic resilience, environmental integrity, social well-being and governance (Chapter 3). Lastly, the results on the productivity and profitability of each farmer and of the sustainability assessment were synthesized and shared with farmers in the form of a farm report. The results were discussed in farmer feedback workshops and in-depth farmer discussion groups to ensure the farmers understood the results, and to bring out the farmers' perceptions on the sustainability gaps and the measures farmers could realistically adopt to improve the management of their farms (Chapter 4). Apart from conducting this study for academic purposes, the results were shared with the farmers who were involved in the study. In this respect, this research can be considered a form of action research. The farm reports included a summary of farming activities, outputs and sustainability results of the farms in a comparative manner, such that farmers could see how their farm compared with the farms of their peers. Three farmer feedback workshops and three in-depth farmer discussions were held in each county to discuss the results and allow the farmers to understand how to interpret the results for their use in making better decisions on farming practices and farm management.

5.1.1 Productivity and profitability in organic and conventional farming systems in Kenya

Since organic farming systems have some positive significant impacts on yield and profitability, some of the crops grown under organic farming systems should be promoted among small scale producers as a way of improving their livelihoods. Murang'a, Kirinyaga and Machakos counties, together with other counties where organic farming is practiced, should consider promoting organic systems as an alternative way of improving incomes. It should be noted that farmers take management decisions not only to maximize yield, but also based on a variety of factors such as market demand, cost of production and ease of management (Shennan *et al.,* 2017). Yield maximization becomes less important when considering overall production factors, i.e. if a crop is grown primarily for rotation value or as part of a diverse product supply for direct marketing avenues. The consideration of other factors should therefore be included in analyses, to help farmers make the right farm management choices.

5.1.2 Sustainability performance of organic and conventional smallholder farms in Kenya

The comparative assessment of the sustainability performance of organic and conventional farming systems in Murang'a, Kirinyaga and Machakos counties in Kenya covered four sustainability dimensions. On-farm characteristics such as soil types, cropping systems and scale were similar for both management systems (Shennan *et al.,* 2017). This made it possible to compare the two systems. The results revealed that although organic initiatives performed better than conventional farms for some practices at the sub-theme and indicator level, there remains room for improvements in all four sustainability dimensions.

For example, in both the 'environmental integrity' and 'economic resilience' dimensions, organic farms had higher mean scores for 10 out of the 14 sub-themes, and in the 'governance' dimension, for 11 of the 14 sub-themes. Yet in the 'social well-being' dimension, only 5 of the 16 sub-themes had higher mean scores in organic than conventional farms. In the sub-theme employment relations, for example, the degree of goal achievement scores was significantly different and higher for conventional systems as compared to organic interventions.

For Kirinyaga County, the results are confirmed by the existence of organic certified farms among the sampled organic farms. Certification standards and the existence of an export-orientated marketing system with premiums has led farmers to manage their farms in line with the set organic standards. Non-compliance leads to sanctions imposed on farmers and a loss of revenue for the period of non-conformity. In Murang'a County, the average sub-themes scores under governance, environmental integrity, economic resilience and social well-being were higher in organic farms than in conventional ones. In this county most of the organic farms are non-certified and have no organized organic market and therefore sell at the same prices as conventional. In Machakos, the sub-theme scores for governance, economic resilience and social well-being were higher in conventional farms than organic ones. In this county, the number of organic farmers had been dropping, as organic farmer groups were no longer vibrant as they were before 2010. The farmer groups that was once organic certified has shrunk in size with only a small group of farmers remaining (one reason is the inability to recruit younger members as elderly ones retire from farming).

Some of the indicators were positively significant for organic farming systems. The indicators with positive significance should be promoted and enhanced. The low indicator and sub-theme scores should be addressed to improve farming practices. For example, conventional farms need to know the correct fertilizer requirements, and how to properly use herbicides and pesticides including the need to observe pre-harvest intervals to ensure safe and nutritious foods. Likewise, organic farms need to understand the necessity, for example, of improving soils through use of manure. The study found that organic farmers do use some amounts of artificial fertilizer and plant protection products, therefore it is imperative that all Kenyan farmers improve their knowledge regarding the proper use of external farm inputs.

The study examined the use of mineral nitrogen (N) and phosphorus (P) fertilizers by farmers. In the sustainability assessment, this has impacts in the sub-themes soil quality, land degradation, ecosystem diversity, water quality, air quality, and energy use (Figure 5.1-1 and Figure 5.1-2). The use of the mineral nitrogen and phosphorus fertilizers by farmers was, lower on organic farms than on conventional ones.

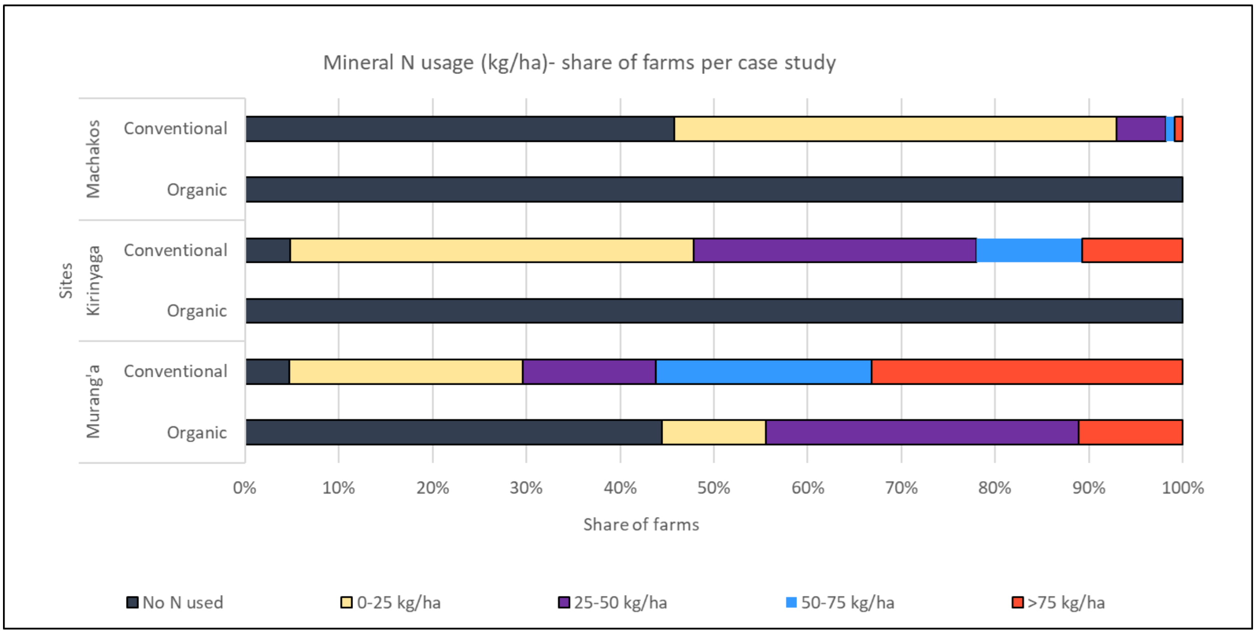


Figure 5.1-1: Mineral N usage in terms of Kg/ha is computed based on the fertilizer types and quantities entered by the enumerators.

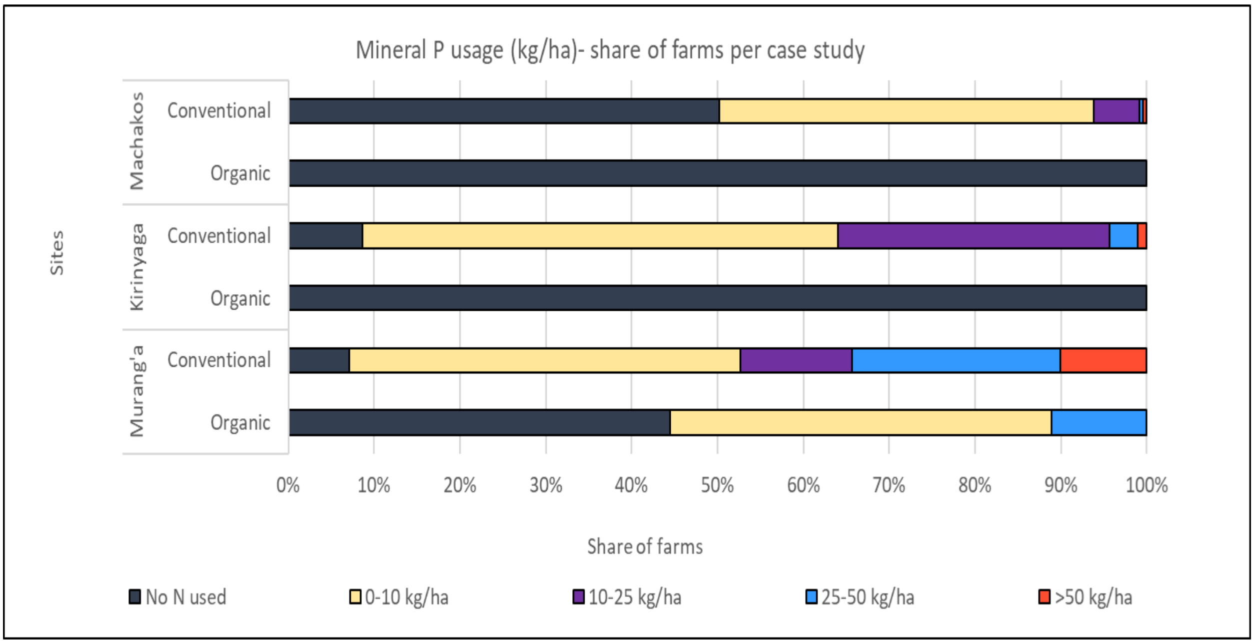


Figure 5.1-2: Mineral P usage in terms of Kg/ha is computed based on the fertilizer types and quantities entered by the enumerators

Organic farmers, both certified and non-certified, require regular training and extension support. Organic farms in Kirinyaga County were better in terms of sustainability scores than in the other counties. In Kirinyaga a good number of the organic farms were organic certified. The existence of a traceability system and better prices (premiums) seems to have encouraged the adherence to organic practices and standards in Kirinyaga County. Despite the constraints and potential for improvement of the SMART-Farm Tool approach, it gives a prompt way to bench-mark farms across farm types and regions at the dimension, theme, and sub-theme levels. Sustainability assessment tools offer support to decision-makers, policy, and development experts, and provide guidance to farmers as to how they may best manage their resources.

5.1.3 Farmers' perceptions of intervention measures to address sustainability gaps in Kenya

The sustainability assessment of the farms and subsequent farmer feedback workshops revealed some of the constraints facing farmers and discussed some of the intervention measures that farmers perceive would improve the sustainability (including profitability) of their farms. In these fora, the organic and conventional farmers explained that many of the farming decisions they take are constrained by the challenges they face and their inability to overcome them. Summarized, the constraints include limitations to technical and physical inputs (e.g. lack of irrigation systems and a high reliance on rain-fed agriculture, and lack of soil testing and low soil quality leading to low yields); market-related challenges (e.g. low and fluctuating prices, exploitation by intermediaries/brokers and lack of target or alternative markets); inadequate knowledge and skills (e.g. limited access to information and capacity building programs, lack of know-how on food safety issues, chemical usage, storage, spraying, and lack of proper record keeping); limited institutional support (e.g. poor infrastructure such as poor road networks to markets); and small farm sizes.

External factors faced by organic farmers included low levels of consumer awareness of organic farm products, limited availability of organic inputs, and insufficient support to enable them to certify themselves as organic producers. It is still the case that organic markets in Kenya are mostly found in Nairobi and Mombasa upmarket suburbs, frequented mainly by expatriates, while the organic producers are in the rural areas (Kledal, 2009). Thus there is a need to increase public awareness of organic products and their health benefits in the country. The market outlets include supermarkets, specialized organic shops, organic restaurants, organic farmers, open-air markets, and basket delivery systems to consumers (Kledal, 2009). These market channels could be expanded further to include niche and institutional markets (such as schools, hospitals). Organic farmers working in groups can develop collection points and organize and advertise market days to get the end consumers to buy directly from them. The Community Supported Agriculture (CSA) movement serves as a direct-marketing model that could be taken up in Kenya (Hayden & Buck, 2012).

The intervention areas and strategies detailed in Chapter 4 offer opportunities to farmers that can be implemented to improve the sustainability of their farms. These include: strategies for biodiversity conservation, water resource use and management, and soil fertility management (environmental); establishment of farmer groups, product diversification, creation of alternative markets, and record keeping (economic); strategies of capacity development and public health and safety measures (social well-being); and strategies of leadership, community welfare, and financial accountability (governance).

5.2 Synthesis summary of the objectives/ Chapters

The analysis of the data from the productivity and profitability show that organic can be productive and profitable for some crops and more sustainable in different sustainability dimensions, subthemes and indicators yet a few farmers practicing it. In the farmers workshops farmers have list a good number of constraints from production challenges to marketing. Additionally with the low sustainability scores, the improvement measures need to be prioritized to the main factors that would catalyze the change process to boost and make organic farming the go to system by farmers.

In the sustainability assessment farmers generally did well on the environmental, economic and governance dimension but poorly in the social dimensions. Addressing these issues might solve a good number of the challenges farmers face. For example by working together in groups farmers will be able to consolidate farm products and market their product by eliminating middle men who take advantage and offer low prices.

Another area is as build capacity of farmers' awareness creation on the cost of production is necessary During data collection in the productivity and profitability aspects the farmer were trained on record keeping and basic accounting aspects (sales, costs, and profits calculations) to know where their expenses were incurred. Reducing the cost of production can improve farm returns and farmers knowledge about which areas to reduce costs one area for inclusion in intensive training program.

In my study a combination of qualitative and quantitative methods were used in the three counties (Kirinyaga, Murang'a and Machakos) in Kenya. Productivity and profitability quantitative data collection while sustainability and farmer perceptions used both qualitative (scores, ratings and scale) and qualitative methods. The case studies selected give a good picture of organic farming in Kenya up to a certain point since the sector is mostly dominated by NGOs who take the lead in organizing and sourcing for markets. NGOs can only operationalize their activities up to a certain point depending on financing and objectives. A case in point are the farmers in Kithimani in Yatta sub-county who were introduced to organic farming and were trained and certified through a NGOs but after the end of the program and certification period the farmers unable to raise the required capital to renew the organic certification. The group disintegrated and only a few of the farmers remained selling as organic non-certified.

Documentation of the study gives important insights into organic activities in Kenya and provides the supporting evidence to enable policy makers make informed policy registration for the sector. Additionally work by Kamau et al, 2018 merged together will strengthen the sectors evidence as the study on the typology of organic farmers gives the different dimensions of organic farmers. The agro ecological practices and emerging trends to promote the sector is not only left to the private sector but added to the public extension services. Farmers have tend to approach public and frontline extension staff first for answers on their farming bottlenecks or agrovets which are established at local level.

Organic farming has a place in Kenya and can be a competitive options for farmers. The higher and almost similar yields to conventional farming, better and also almost similar scores in the sustainability assessment all point to engaging in the sector. The challenges faced by organic farmers if addressed by policy actors can go a long way in improving the livelihoods of farmers as it also improve on the environment. Also other benefits directly and indirectly such as health and nutritional benefits accrue from use of the system (Note not documented in this study but mentioned by a good number of non-certified farmers in Murang'a).

5.3 Recommendations for both organic and conventional systems

The recommendations are discussed under five groupings: enabling environment, physical inputs, diversification and value addition, marketing, and capacity building

Enabling environment

A regulatory and legal framework that can guide the organic farming sector needs to be put in place. Policies and strategies that enable the organic sector to grow and be competitive with conventional farming systems are needed. Farmers in the organic sector in Kenya are faced with many constraints and challenges. Support from the government is often lacking from production to marketing unlike in conventional farming where policy frameworks and guidelines have been developed. In Kenya, a proposed organic policy is yet to be passed by Parliament. Organic standards exist from 2007 but require review as interventions and practices have since evolved. More broadly, the regulatory and legal framework governing agriculture needs to be updated and farming practices effectively regulated. Training of farmers and the relevant public sector workers is needed so that they understand the law and regulations. An example that highlights the necessity of this is that of plant production products, which are currently sold on the private market and wrongly used by farmers, which negatively affects public health. Government policy to create an enabling organic environment would lead to benefits and incentives that would encourage more farmers to join organic farming (Jha *et al.*, 2020).

Physical inputs

The quantities of inputs such as mineral fertilizer, organic pesticides, used by organic farmers in the study county were low. The labour hours on the other hand were also higher for some crops than in conventional farms. Physical inputs such as small machines and equipment (e.g. for preparing land, planting, weeding), seeds and seedlings, natural fertilizers, natural or safer plant protection products, and sustainably-sourced packaging materials are needed to improve farm production. An alternative form of production that is less labour intensive and time demanding should be achieved and infrastructure along the value chain needs to be developed. High yielding quality seeds and seedlings (ideally not coated in fungicide) for organic and conventional farmers, soil testing and other soil health interventions, and farmer training programs will enhance farmers' capacity to increase crop productivity. Availability and access to organic inputs should be increased and promoted. Although composting and other techniques should be encouraged on-farm, externally-produced organic inputs are also required, for which suppliers are currently limited in scale and scope; such that only a few farmers practicing organic farming know of their existence. Awareness creation via advertising, as practiced for private and public sector conventional inputs, should be encouraged for organic inputs. Farmers in Kirinyaga have gained from the operations of an NGO that not only buys their macadamia nuts and avocado fruits for export but also provides them with farming inputs, extension services as well as offering employment to family members during the processing of the nuts. Such support ought to be provided by the government and other NGOs, for production for the domestic market too.

Diversification and value addition

Crop diversification among small-scale farmers should be promoted for risk management and resilience management during dry spells. Farmers in the study area not only produced a wide range of crops but also kept different livestock (cattle, sheep, goats, ducks, and chicken) both as an integrated part of their farming operations and for sustenance (also considered a risk management strategy that reduces their vulnerability to environmental and economic shocks). Some farmers had off-farm sources of income which boosts their farming activities as they were able to access additional land, equipment or hire labour with the earnings. The farm produce of most farms were sold in their raw form with minimal processing (sorting or grading) or for quick access to cash. As a result they receive low prices. Value addition would increase farm incomes as processed goods fetch higher prices than raw products. The use of knowledge, technology, and training to create and innovate on new products by adding value to organic raw materials will ensure that farmers sell at even high prices.

Marketing

The support for vertical integration through market innovations such as warehousing receipt systems, group sales, and traceability systems will enhance the sale of farm produce by farmer groups. The setting of premium prices for certified farms linked through group marketing will enable farmers to get better prices for their crop products. There is an unmet demand for organic products in the Kenyan and export markets. Warehousing storage receipting systems and traceability systems, together with information communication technology, should be encouraged for farmers to get better prices for their farm produce. Besides, if traceability systems and random checking for pesticide levels were to be applied to the entire agricultural system, the public would understand the benefits of organic production, and conventional farmers may be inclined to switch to organic production.

Capacity building

Many organic and conventional farmers have already received training in certain crop production techniques. The use of agro ecological practices by organic farmers is limited as shown by results from the study. Limited capacity building in different ecological practices such as training on pesticide use was reported amongst the farmers. To improve farm performance, farmers require institutional support that builds on their capacity in farming and decision-making. Coordination between the public and private sectors will enhance farmer training and play a significant role in duplication reduction and the monitoring of projects' and programs' impacts on society. Farmers' understanding of the circumstances that affect their farming practices, both directly and indirectly, leads to better decision-making in farming activities (Godfray *et al.*, 2010; Hazell & Wood, 2008). The diversification of skills, such as proper record keeping, planning, budgeting, and evaluation, if encouraged during training, would enable farmers to do what they do best (crop production). Constant capacity building would enrich the skills of farmers to not only produce more food and generate more income for themselves but also to create jobs and lead to other knock-on effects in their local area (Yanakittkul & Aungvaravong, 2020).

5.4 Further research

This study on the sustainability performance of organic and conventional farming systems in Kenya used the SMART-farm tool to conduct its sustainability assessment. A deeper analysis was performed on only 12 of the 58 sub-themes. Further research can include the other 46 sub-themes. In the sustainability assessment, some variables that could be best measured quantitatively, e.g. greenhouse gases, were measured qualitatively. Another area that deserves attention is a comparison of farming management systems with a focus on women and youth. Finally, this study mostly concentrated on crops and thus, an analysis of the aspects of sustainability in the livestock value chain is another area for further research.

This study included an assessment of productivity and profitability, a sustainability assessment, and a series of discussions with farmers to gain their perception on sustainability gaps. Thus, the entire cycle of starting with the farmer and ending with the farmer is captured. An adoption study is needed to gauge which of the measures the farmers take up, and to understand how the adoption of these measures impacts their livelihoods. Also studies on the impacts of time from organic conversion on the productivity, profitability and sustainability of the farming systems should be taken up. The sustainability assessment could also be repeated with the same farmers after some years, to check if the areas that scored lowly have improved.

Bibliography

Abadie, A., & Imbens, G. W. (2011). Bias-corrected matching estimators for average treatment effects. *Journal of Business and Economic Statistics*, 29(1), 1–11. https://doi.org/10.1198/jbes.2009.07333

Abdullah, M., Mustafa, F. B. B., & Chowdhury, Z. Z. (2020). Organic Farming a viable option for the global food supply and livelihood sustainability. *Researchgate.Net*, (July), 31. https://doi.org/: https://www.researchgate.net/publication/343141033 Organic

Adamtey, N., Musyoka, M. W., Zundel, C., Cobo, J. G. Karanja, E., Fiaboe, K.K.M., Muriuki, A., Mucheru-Muna, M., Vanlauwe, B., Berset, E., Messmer, M.M., Gattinger, A., Bhullar, G.S., Cadisch, G., Fliessbach, A., Mäder, P., Niggli, U., & Foster, D (2016). Productivity, profitability and partial nutrient balance in maize-based conventional and organic farming systems in Kenya. *Agriculture, Ecosystems and Environment*, 235, 61–79. https://doi.org/10.1016/j.agee.2016.10.001

Adebiyi, J. A., Olabisi, L. S., Richardson, R., Liverpool-Tasie, L. S. O., & Delate, K. (2020). Drivers and constraints to the adoption of organic leafy vegetable production in Nigeria: A livelihood approach. *Sustainability (Switzerland)*, 12(1), 1–21. https://doi.org/10.3390/SU12010096

Adhikari, S., & Menalled, F. D. (2020). Supporting beneficial insects for agricultural sustainability: The role of livestock-integrated organic and cover cropping to enhance ground beetle (Carabidae) communities. *Agronomy*, 10(8), 1–15. https://doi.org/10.3390/agronomy10081210

Adinya, O., Ajayi, S., & Idiege, D. (2009). Economic Analysis of Cassava Production in Akwa Ibom State, Nigeria. *Journal of Agriculture, Forestry and the Social Sciences*, 5(2). https://doi.org/10.4314/joafss.v5i2.46704

Affognon, H., Mutungi, C., Sanginga, P., & Borgemeister, C. (2015). Unpacking postharvest losses in sub-Saharan Africa: A Meta-Analysis. *World Development*, 66, 49–68. https://doi.org/10.1016/j.worlddev.2014.08.002

Agidew, A. A., & Singh, K. (2019). Factors Affecting the Adoption of Sustainable Land Management Practices at Farm Level in the North eastern Highlands of Ethiopia: The Teleyayen Sub-Watershed Case Study. *Journal of Environmental Pollution and Management.* Retrieved from https://www.researchgate.net/publication/332621763_Factors_Affecting_the_Adoption_of_Sustainable_Land_Management_Practices_at_Farm_Level_in_the_Northeastern_Highlands_of_Ethiopia_The_Teleyayen_Sub-Watershed_Case_Study_Citation_Alem-meta_Assefa_Agidew_

Ahmad, K., & Heng, A. C. T. (2012). Determinants of agriculture productivity growth in Pakistan. *International Research Journal of Finance and Economics*, 95(January), 163–172.

Ajzen, I., 1985. From intentions to actions: a theory of planned behavior. In: Kuhle, J., Beckmann, J. (Eds.), *Action-control: From Cognition to Behavior*. Heidelberg, Springer, pp. 11-39

Alcock, D., & Hegarty, R. S. (2006). Effects of pasture improvement on productivity, gross margin and methane emissions of a grazing sheep enterprise. *International Congress Series*, 1293, 103–106. https://doi.org/10.1016/j.ics.2006.01.080

Alvarez, J.F.O., Valero, J.A.D., Martin-Benito, J.M.T., Mata, E.L., (2004). MOPECO: an economic optimization model for irrigation water management. *Irrigation Science* 23, 61–75

Amudavi, D. M., Ombati, J. M., Nkurumwa, A. O., & Ngigi, M. (2014). Technical, economic and social gaps and information needs among smallholder farmers in practice of ecological organic agriculture in Kenya. *International Journal of Agriculture Innovations and Research,* 3(1), 198–209.

Anantanyu, S., Suwarto, & Suminah. (2018). Farmers's perception and strategies for the development of sustainable livelihoods in disaster prone areas. *IOP Conference Series: Earth and Environmental Science, 142*(1). https://doi.org/10.1088/1755-1315/142/1/012054

Andrieu, N., Descheemaeker, K., Sanou, T., & Chia, E. (2015). Effects of technical interventions on flexibility of farming systems in Burkina Faso: Lessons for the design of innovations in West Africa. *Agricultural Systems, 136,* 125–137. https://doi.org/10.1016/j.agsy.2015.02.010

Anyanwu, S. O. (2013). Determinants of aggregate agricultural productivity among high external input technology farms in a harsh macroeconomic environment of Imo state, Nigeria. *African Journal of Food, Agriculture, Nutrition and Development,* 13(5), 8238–8248.

Ash, A., Gleeson, T., Hall, M., Higgins, A., Hopwood, G., MacLeod, N., Paini D., Poulton P., Prestwidge Di, Webster T., Wilson, P. (2017). Irrigated agricultural development in northern Australia: Value-chain challenges and opportunities. *Agricultural Systems*, 155(March), 116–125. https://doi.org/10.1016/j.agsy.2017.04.010

Auerbach, R. (2013) Transforming African Agriculture: Organics and Agra. Organic Agriculture: African Experiences in Resilience and Sustainability. *Natural Resources Management and Environment* Department Food and Agriculture Organization of the United Nations, Roma, 16

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 Development*, 67, 27–37. https://doi.org/10.1016/j.worlddev.2014.10.005

Beal, S. J., & Kupzyk, K. A. (2014). An Introduction to Propensity Scores: What, When, and How. *Journal of Early Adolescence*, 34(1), 66–92. https://doi.org/10.1177/0272431613503215

Beedell, J., & Rehman, T. (2000). Using social-psychology models to understand farmers' conservation behaviour. UK. *Journal of Rural Studies*, 16, 117–127. Retrieved from https://ac.els-cdn.com/S0743016799000431/1-s2.0-S0743016799000431-main.pdf?_tid=9fdf52e9-0bcc-43a4-8ce5-ca3164785090&acdnat=1551863521_accd70f1e45cc2a72c0d85b50d24346c

Beltrán-Esteve, M., & Reig-Martínez, E. (2014). Comparing conventional and organic citrus grower efficiency in Spain. *Agricultural Systems*, 129, 115–123. https://doi.org/10.1016/j.agsy.2014.05.014

Berhane, M., Abreha, Z., & Fitiwy, I. (2015). Farmer's Perception of Productivity and Profitability of Organic and Conventional tef [Eragrostis tef (Zucc .) Trotter] Production : *Journal of Agricultural Science and Food Technology*, 1(7), 88–93.

Binder, C. R., Feola, G., & Steinberger, J. K. (2010). Considering the normative, systemic and procedural dimensions in indicator-based sustainability assessments in agriculture. *Environmental Impact Assessment Review*, 30(2), 71–81. https://doi.org/10.1016/j.eiar.2009.06.002

Binta, B. A. A., & Barbier, B. (2015). Economic and Environmental Performances of Organic Farming System Compared to Conventional Farming System: A Case Study of the Horticulture Sector in the Niayes Region of Senegal. *Procedia Environmental Sciences*, 29(Agri), 17–19. https://doi.org/10.1016/j.proenv.2015.07.132

Bloor, M., Frankland, J., Thomas, M., & Robson, K. (2012). Focus Groups in Social Research. *Focus Groups in Social Research*. https://doi.org/10.4135/9781849209175

Bon, H. De, Temple, L., Malézieux, É., Bendjebbar, P., Fouilleux, È., & Silvie, P. (2018). *Organic agriculture in Africa: A source of innovation for agricultural development*.

Bosshard, A., Reinhard, B., & Taylor, S. (2009). *IFOAM Guide to Biodiversity and Landscape Quality in Organic Agriculture*. Retrieved from http://www.ecology.ch/BiodiversityGuide_Jul09_Preview.pdf

Bouagnimbeck Hervé. (2011). Organic Farming in Africa. In *The World of Organic Agriculture. Statistics and Emerging Trends* Willer, H. and Kilcher (Ed.), (pp. 104–110). Bonn & Frick: IFOAM & FIBL.

Broad, S. T., Lisson, S. N., & Mendham, N. J. (2009). Agronomic and gross margin analysis of an insect pest suppressive broccoli cropping system. *Agricultural Systems*, 102(1–3), 41–47. https://doi.org/10.1016/j.agsy.2009.06.007

Brundtland, H. G. (1987) *"Our Common Future."* Report of the World Commission on Environment and Development. Geneva, UN-Dokument A/42/427. https://doi.org/10.1080/07488008808408783

Brzezina, N., Kopainsky, B., & Mathijs, E. (2016). Can organic farming reduce vulnerabilities and enhance the resilience of the European food system? A critical assessment using system dynamics structural thinking tools. *Sustainability (Switzerland)*, 8(10), 32. https://doi.org/10.3390/su8100971

Busch, L. (2012). Standards governing agricultural innovation. Where do we come from? Where should we be going? In É. Coudel, H. Devautour, C.-T Soulard, G. Faure & B. Hubert, eds. *Renewing innovation systems in agriculture and food. How to go towards more sustainability*? pp. 37–56. Paris, Editions Quae.

Cavigelli, M. A., Teasdale, J. R., & Spargo, J. T. (2013). Increasing Crop Rotation Diversity Improves Agronomic, Economic, and Environmental Performance of Organic Grain Cropping Systems at the USDA-ARS Beltsville Farming Systems Project. *Crop Management*, *12*(1), 1–4. https://doi.org/10.1094/cm-2013-0429-02-ps

Chatzinikolaou, P., & Manos, B. (2012). Review of existing methodologies and tools for measuring sustainability in rural areas. *Department of Agricultural Economics*, 1–19. Retrieved from http://www.feem-project.net/belpasso_2012/files/studpapers/Paper_Chatzinikolaou.pdf

Chianu, J. N., Chianu, J. N., & Mairura, F. (2012). Mineral fertilizers in the farming systems of sub-Saharan Africa. A review. *Agronomy for Sustainable Development*, *32*(2), 545–566. https://doi.org/10.1007/s13593-011-0050-0

Chiputwa, B., Qaim, M., & Spielman, D. J. (2014). RTG 1666 GlobalFood Food Standards, Certification, and Poverty among Coffee Farmers in Uganda Food Standards, Certification, and Poverty among Coffee Farmers in Uganda. *EAAE 2014 Congress 'Agri-Food and Rural Innovations for Healthier Societies*, 1–13. Retrieved from www.uni-goettingen.de/globalfood

Compagnone, C., Lamine, C., & Dupré, L. (2018). The production and circulation of agricultural knowledge as interrogated by agro-ecology: of old and new. *Revue d'Anthropologie Des Connaissances*, 12(2). https://doi.org/10.3917/rac.039.a

Connor, D. J. (2013). Organically grown crops do not a cropping system make and nor can organic agriculture nearly feed the world. *Field Crops Research*, *144*, 145–147. https://doi.org/10.1016/j.fcr.2012.12.013

Conway, G., & Wilson, K. (2012). *One Billion Hungry, can we feed the World? Cornell University*. New: Cornell University Press First. https://doi.org/10.1017/CBO9781107415324.004

Coteur, I., Marchand, F., Debruyne, L., Bijttebier, J., Triste, L. & Lauwers, L. (2014). Development and evaluation of an on-demand sustainability tool in Flanders. In 11th European IFSA symposium: Farming systems facing global challenges: Capacities and strategies, pp. 38–48. International Farming Systems Association, Europe; Leibniz Centre for Agricultural Landscape Research; Humboldt-Universität zu Berlin.

Coteur, I., Marchand, F., Debruyne, L., Dalemans, F., & Lauwers, L. (2016). A framework for guiding sustainability assessment and on-farm strategic decision making. *Environmental Impact Assessment Review*, 60, 16–23. https://doi.org/10.1016/j.eiar.2016.04.003

Coteur, I., Wustenberghs, H., Debruyne, L., Lauwers, L., & Marchand, F. (2020). How do current sustainability assessment tools support farmers' strategic decision making? *Ecological Indicators*, *114*(July 2019), 106298. https://doi.org/10.1016/j.ecolind.2020.106298

Creemers, S., Van Passel, S., Vigani, M., & Vlahos, G. (2019). Relationship between farmers' perception of sustainability and future farming strategies: A commodity-level comparison. *AIMS Agriculture and Food*, 4(3), 613–642. https://doi.org/10.3934/agrfood.2019.3.613

Crowder, D. W., & Reganold, J. P. (2015). Financial competitiveness of organic agriculture on a global scale. *Proceedings of the National Academy of Sciences of the United States of America*, 112(24), 7611–7616. https://doi.org/10.1073/pnas.1423674112

Dantsis, T., Loumou, A., Douma, C., Giourga, C., & Polychronaki, E. A. (2009). A methodological approach to assess and compare the sustainability level of agricultural plant production systems. *Ecological Indicators*, *10*(2), 256–263. https://doi.org/10.1016/j.ecolind.2009.05.007

Darnhofer, I. (2005). Organic farming and rural development: Some evidence from Austria. *Sociologia Ruralis*, 45(4), 308–323. https://doi.org/10.1111/j.1467-9523.2005.00307.x

De Bon H., Temple L., Malézieux É., Bendjebbar P., Fouilleux È., Silvie P., 2018. Organic agriculture in Africa: a source of innovation for agricultural development. CIRAD, Montpellier, *Perspective* 48. https://doi.org/10.19182/agritrop/00036

De Jager, A., Onduru, D., Van Wijk, M. S., Vlaming, J., & Gachini, G. N. (2001). Assessing sustainability of low-external-input farm management systems with the nutrient monitoring approach: A case study in Kenya. *Agricultural Systems*, 69(1–2), 99–118. https://doi.org/10.1016/S0308-521X (01)00020-8

De Olde E. M., Oudshoorn, F. W., Sørensen, C. A. G., Bokkers, E. A. M., & De Boer, I. J. M. (2016). Assessing sustainability at farm-level: Lessons learned from a comparison of tools in practice. *Ecological Indicators*, 66(July), 391–404. https://doi.org/10.1016/j.ecolind.2016.01.047

De Ponti, T., Rijk, B., & Van Ittersum, M. K. (2012). The crop yield gap between organic and conventional agriculture. *Agricultural Systems*, *108*, 1–9.

https://doi.org/10.1016/j.agsy.2011.12.004

Delate, K., Duffy, M., Chase, C., Holste, A., Friedrich, H., & Wantate, N. (2003). An economic comparison of organic and conventional grain crops in a long-term agroecological research (LTAR) site in Iowa. *American Journal of Alternative Agriculture*, 18(2), 59–69. https://doi.org/10.1079/AJAA200235

Dixon, J.A., Gulliver, A., Gibbon, D., & Hall, M. (2001). Farming Systems and Poverty Improving Farmers' Livelihoods in a changing World. FAO and World Bank Rome, Italy

Dobermann A and Nelson R (2013) Opportunities and Solutions for Sustainable Food Production. Sustainable Development Solutions Network Global Initiative of the United Nations.

Douthwaite B, Alvarez S, Cook S, Davies R, George P, Howell J, MacKay R, Rubiano J (2007a) Participatory impact pathways analysis: a practical application of program theory in research for development. *Can J Program Eval* 22(2):127–159

Douthwaite B, Schulz S, Olanrewaju AS, Ellis-Jones J (2007b) Impact pathway evaluation of an integrated Striga *hermonthica* control project in Northern Nigeria. *Agric Syst* 92(1–3):201–222. DOI: 10.1016/ j.agsy.2006.03.007

EAC. (2007). *AID-FOR-TRADE CASE STORY: UNEP Aid for Trade Case Story: The East African Organic Products Standard* AID-FOR-TRADE: CASE STORY UNITED NATIONS ENVIRONMENT PROGRAMME. Retrieved from https://www.oecd.org/aidfortrade/47719232.pdf

Ehrlich, P. R. (2008). Key issues for attention from ecological economists. *Environment and Development Economics*, 13(1), 1–20. https://doi.org/10.1017/S1355770X07004019

Elsaesser, M., Jilg, T., Herrmann, K., Boonen, J., Debruyne, L., Laidlaw, A.S., Aarts, F., 2015. Quantifying sustainability of dairy farms with the DAIRYMAN sustainability index, European Grassland Federation. *Grassland Science in Europe*, Wageningen, the Netherlands, pp. 367-376

Elzen, B., Geels, F. W., Leeuwis, C., & Van Mierlo, B. (2011). Normative contestation in transitions "in the making": Animal welfare concerns and system innovation in pig husbandry. *Research Policy*, 40(2), 263–275. https://doi.org/10.1016/j.respol.2010.09.018

EPOPA/Export Promotion of Organic Products from Africa (2007). Organic Exports – A Way to a Better Life? Agro Eco BV, Bennekom and Grolink AB, Hoje. Available at www.grolink.se/epopa/Publications/epopa-experience.htm

European Commission. (2013). Organic versus conventional farming, which performs better financially ? *Farm Economic Brief*, (4), 1–10. Retrieved from http://ec.europa.eu/agriculture/rica/pdf/FEB4_Organic_farming_final_web.pdf

Eyhorn, F., van den Berg, M., Decock, C., Maat, H., & Srivastava, A. (2018). Does organic farming provide a viable alternative for smallholder rice farmers in India? Sustainability (Switzerland), 10(12), 1–15. https://doi.org/10.3390/su10124424

FAPDA, & FAO. (2015). *Country Fact Sheet On Food And Agriculture Policy Trends Kenya*. Rome Italy. https://doi.org/http://www.fao.org/in-action/fapda/publications/country-fact-sheets/en/

FAO. (1988). Report of the FAO Council, 94th session. Rome FAO. (2007). Food Security District Profiles. Nairobi: FAO.

FAO. (1990). Sustainable Agricultural Resources Development. Available at: http://www.fao.org/nr/sustainability/sustainability-assessments-safa/en/

FAO. (1999). Agro-Ecological Zones, Farming Systems and Land Pressure in Africa and Asia. Environmental Research Group Oxford Ltd and TALA Research Group, Department of Zoology, University of Oxford, for the Animal Health Service of the Animal Production and Health Division, FAO, Rome, Italy.

FAO. (2011a). Save and Grow: A policymaker's guide to the sustainable intensification of smallholder crop production. Rome Italy: FAO. https://doi.org/10.16309/j.cnki.issn.1007-1776.2003.03.004

FAO. (2011b). Innovative policies and institutions to support agro-industries development. Rome.

FAO. (2012). Developing sustainable food value chains: guiding principles. FAO, 25(9), 51–55.

FAO. (2013a). SAFA Sustainability Assessment for Food and Agricultural Systems Guidelines: Version 3.0. (FAO, Ed.). Rome: FAO.

FAO. (2013b). Sustainability Assessment of Food and Agricultural System: indicators. Food and Agriculture Organization of the *United Nations* - Rome 2013, 271. https://doi.org/10.2144/000113056

FAO. (2014a). Building a common vision for sustainable food and agriculture. Principles and approaches. Rome.

FAO (2019). The State of the World's Biodiversity for Food and Agriculture, J. Bélanger & D. Pilling (eds.). FAO Commission on Genetic Resources for Food and Agriculture Assessments. Rome. 572 pp. Available at: http://www.fao.org/3/CA3129EN/CA3129EN.pdf.

FAO, & World Bank. (2001). *Farming Systems and Poverty Farming Systems and Poverty*. (M. Hall, J. Dixon, A. Gulliver, & D. Gibbon, Eds.).

Fayet, L., & Vermeulen, W. J. V. (2014). Supporting Smallholders to Access Sustainable Supply Chains: Lessons from the Indian Cotton Supply Chain. *Sustainable Development*, *22*(5), 289–310. https://doi.org/10.1002/sd.1540

Ferreira, V., Boyero, L., Calvo, C., Correa, F., Figueroa, R., Gonçalves, J. F., Goyenola G., Graça Manuel A.S., Hepp Luiz U.,Kariuki S., López-Rodríguez A., Mazzeo N., M'Erimba C., Monroy S., Peil A., Pozo J., Rezende R., Teixeira-de-Mello, F. (2019). A Global Assessment of the Effects of Eucalyptus Plantations on Stream Ecosystem Functioning. *Ecosystems*, 22(3), 629–642. https://doi.org/10.1007/s10021-018-0292-7

Fess, T. L., & Benedito, V. A. (2018a). Organic versus conventional cropping sustainability: A comparative system analysis. *Sustainability (Switzerland)*, *10*(1). https://doi.org/10.3390/su10010272

Firth, C. (2002). The use of gross and net margins in the economic analysis of organic farms. *Proceedings of the UK Organic Research* 2002, (Table 1), 285–288. Retrieved from http://orgprints.org/id/eprint/8290

Foley, J. A., Ramankutty, N., Brauman, K. A., Cassidy, E. S., Gerber, J. S., Johnston, M., Mueller N. D., O'Connell C., Ray D K., West P. C., Balzer Christian, Bennett E. M., Carpenter S. R., Hill J., Monfreda C., Polasky S., Rockström J., Sheehan J., Siebert S., Tilman D., Zaks D. P. M. (2011). Solutions for a cultivated planet. *Nature*, 478, 337. Retrieved from http://dx.doi.org/10.1038/nature10452

Food and Agriculture Organization of the United Nations (FAO). Sustainability Assessment of Food and Agriculture Systems (SAFA); FAO: Rome, Italy, (2014b). Available online: http://www.Fao.Org/nr/sustainability/sustainability-assessments-safa/en/

Forster, D., Andres, C., Verma, R., Zundel, C., Messmer, M. M., & Mäder, P. (2013). Yield and economic performance of organic and conventional cotton-based farming systems - Results from a field trial in India. *PLoS ONE*, *8*(12). https://doi.org/10.1371/journal.pone.0081039

Froehlich, A. G., Melo, A. S. S. A., & Sampaio, B. (2018). Comparing the Profitability of Organic and Conventional Production in Family Farming: Empirical Evidence From Brazil. *Ecological Economics*, *150*(April), 307–314. https://doi.org/10.1016/j.ecolecon.2018.04.022

Gabriel, D., Sait, S. M., Kunin, W. E., & Benton, T. G. (2013). Food production vs. biodiversity: Comparing organic and conventional agriculture. *Journal of Applied Ecology*, *50*(2), 355–364. https://doi.org/10.1111/1365-2664.12035

Garnett, T., Appleby, M.C., Balmford, A., Bateman, I.J., Benton, T.G., Bloomer, P., Burlingame, B., Dawkins, M., Dolan, L., Fraser, D., Herrero, M., Hoffmann, I., Smith, P., Thornton, P.K., Toulmin, C., Vermeulen, S.J. & Godfray, H.C.J. (2013). Sustainable intensification in agriculture. *Premises and policies. Science*, 341(6141): 33–34.

Gasparatos, A. (2010). Embedded value systems in sustainability assessment tools and their implications. *Journal of Environmental Management* 91(8): 1613–1622.

Gaviglio, A., Bertocchi, M., & Demartini, E. (2017). A Tool for the Sustainability Assessment of Farms: Selection, Adaptation and Use of Indicators for an Italian Case Study. *Resources*, 6(4), 60. https://doi.org/10.3390/resources6040060

Getanjaly, V. L. R., Sharma, P., & Kushwaha, R. (2015). Beneficial insects and their value to agriculture. *Research Journal of Agriculture and Forestry Sciences*, 3(5), 25–30. Retrieved from www.isca.me

Girma, J., & Gardebroek, C. (2015). The impact of contracts on organic honey producers' incomes in southwestern Ethiopia. *Forest Policy and Economics*, *50*, 259–268. https://doi.org/10.1016/j.forpol.2014.08.001

Gerrard, C. L., Smith, L. G., Pearce, B., Padel, S., Hitchings, R., Measures, M., & Cooper, N. (2012). Farming for Food and Water Security, Sustianble *Agriculture Reviews 10*. https://doi.org/10.1007/978-94-007-4500-1_1

Godfray, H. C. J., Beddington, J. R., Crute, I. R., Haddad, L., Lawrence, D., Muir, J. F., Pretty J., Robinson S., Thomas S. M.,& Toulmin C. (2010). Food security: The challenge of the present. *Science*, 327(5967), 812–818. https://doi.org/10.1016/j.geoforum.2018.02.030

GoK (2019). Government of Kenya. Agricultural Sector Transformation & Growth Strategy. Towards Sustainable Agricultural Transformation & Food Security in Kenya - 2019-2019

Gomiero, T., Pimentel, D., & Paoletti, M. G. (2011). Environmental impact of different agricultural management practices: Conventional vs. Organic agriculture. *Critical Reviews in Plant Sciences*, 30(1–2), 95–124. https://doi.org/10.1080/07352689.2011.554355

González de Molina, M. (2013). Agroecology and Politics. How to get Sustainability? About the Necessity for a Political Agroecology. *Agroecology and Sustainable Food Systems*, vol 37. Pp. 45-59.

Gopinath, K. A., Saha, S., Mina, B. L., Pande, H., Kundu, S., & Gupta, H. S. (2008). Influence of organic amendments on growth, yield and quality of wheat and on soil properties during transition to organic production. *Nutrient Cycling in Agroecosystems*, *82*(1), 51–60. https://doi.org/10.1007/s10705-008-9168-0

Goswami, R., Saha, S., & Dasgupta, P. (2017). Sustainability assessment of smallholder farms in developing countries. *Agroecology and Sustainable Food Systems*, *41*(5), 546–569. https://doi.org/10.1080/21683565.2017.1290730

Greene, W. H. (2003). *Econometric Analysis* (5th ed.). New York: Pearson Education, Inc., Upper Saddle River, New Jersey, 07458.

Greer, G., & Hunt, L. (2011). Comparison of the productivity and profitability of organic and conventional farms in the New Zealand sheep/beef and kiwifruit sectors. *18th International Farm Managment Congress Methven, Canterbury, New Zealand*, 111–121.

Grenz, J., Thalmann, C., Stampfli, A., Studer, C., & Häni, F. (2009). RISE – a method for assessing. Rural Development News, 1, 5–9. Retrieved from http://www.jdb.uzh.ch/24610/

Grin, J., Rotmans, J. & Schot, J. W. (2010). Transitions to Sustainable Development. New Directions in the Study of Long Term Transformative Change. New York, United States of America, Routledge.

Gurbir S. Bhullar, David Bautze, Noah Adamtey, Laura Armengot, Harun Cicek, Eva Goldmann, Amritbir Riar, Johanna Rüegg, Monika Schneider, Beate Huber (2021). What is the contribution of organic agriculture to sustainable development? A synthesis of twelve years (2007-2019) of the "long-term farming systems comparisons in the tropics (SysCom)". Research Institute of Organic Agriculture, Frick, Switzerland: https://systems-comparison.fibl.org/results/reports.html.

Hainmueller, J. (2012). Entropy balancing for causal effects: A multivariate reweighting method to produce balanced samples in observational studies. *Political Analysis*, 20(1), 25–46. https://doi.org/10.1093/pan/mpr025

Hamblin, A. (1992). How do we know when agricultural systems are sustainable? *In Environmental Indicators for Sustainable Agriculture*. Report on a national workshop, 28-29 November 1991, ed. A. Hamblin. Bureau of Rural Resources, Land and Water Resource Research and Development Corporation, Grains Research Corporation, Canberra, Australia, p. 90.

Hampl, F. (2020). A statistical analysis of the financial performance of organic and conventional farms in the Czech Republic with respect to their size. *Agricultural Economics (Czech Republic)*, *66*(1), 1–9. https://doi.org/10.17221/78/2019-AGRICECON

Häni, F., Braga, F., Stämpfli, A., Keller, T., Fischer, M. & Porsche, H. (2003). RISE: A tool for holistic sustainability assessment at the farm level. International Food and Agribusiness Management Review, 6(4): 78-90.

Hanuš, L. (2004). Sustainability analysis of agricultural systems. *Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis,* 52(1), 103–112. https://doi.org/10.11118/actaun200452010103

Harvey, N., & Holmes, C. A. (2012). Nominal group technique: An effective method for obtaining group consensus. *International Journal of Nursing Practice*, *18*(2), 188–194. https://doi.org/10.1111/j.1440-172X.2012.02017.x

Hayati, D., Ranjbar, Z., & Karami, E. (2010). Biodiversity, Biofuels, Agroforestry and Conservation Agriculture. *Biodiversity, Biofuels, Agroforestry, and Conservation Agriculture*, 5, 317–358. https://doi.org/10.1007/978-90-481-9513-8

Hayden, J., & Buck, D. (2012). Doing community supported agriculture: Tactile space, affect and effects of membership. *Geoforum*, *43*(2), 332–341. https://doi.org/10.1016/j.geoforum.2011.08.003

Hazell, P., & Wood, S. (2008). Drivers of change in global agriculture. Philosophical Transactions of the Royal Society B: *Biological Sciences*, 363(1491), 495–515. https://doi.org/10.1098/rstb.2007.2166

Hennink Monique M. (2014). *Focus group discussions: understanding Qualitative Research*. Oxford USA: Oxford university Press 2014.

Herath, C. S., & Wijekoon, R. (2013). Study on attitudes and perceptions of organic and non-organic coconut growers towards organic coconut farming. *IDESIA INVESTIGaCIONES*, 31(2), 5–14. https://doi.org/10.1007/BF01474163

Heckman, J. J. (2000). Causal Parameters and Policy Analysis in Economics: A Twentieth Century Retrospective. *The Quarterly Journal of Economics*, (February), 45–97.

Hennink Monique M. (2014). Focus group discussions: understanding Qualitative Research, 222.

Herath, C. S., & Wijekoon, R. (2013). Study on attitudes and perceptions of organic and non-organic coconut growers towards organic coconut farming. *IDESIA INVESTIGACIONES*, 31(2), 5–14. https://doi.org/10.1007/BF01474163

Ho, D. E., Imai, K., King, G., & Stuart, E. A. (2007). Matching as nonparametric preprocessing for reducing model dependence in parametric causal inference. *Political Analysis*, 15(3), 199–236. https://doi.org/10.1093/pan/mpl013

Hopkins, Alan and Morris, Carol (2002) Multi-functional roles of grassland in organic farming systems. In: Powell, Jane and et al., (Eds.) *Proceedings of the UK Organic Research 2002 Conference*, Organic Centre Wales, Institute of Rural Studies, University of Wales Aberystwyth, pp. 75-80. Accessed at http://orgprints.org/8287.

Hutcheson, G. D. (2011). Ordinary Least-Squares Regression. *The SAGE Dictionary of Quantitative Management Research*, 224–228. https://doi.org/10.4135/9781446251119.n67

IBM SPSS. (2014). IBM SPSS Advanced Statistics 22. Local License for Version 22.0, 118.

IFOAM. (2012). The IFOAM norms for organic production and processing Version 2012. IFOAM, 18(13), 1–134. https://doi.org/10.1017/S1368980015002529

IFOAM. (2018). Productivity and Profitability of Organic Farming Systems in East Africa, (August).

Isaac, M. E., Dawoe, E., & Sieciechowicz, K. (2009). Assessing local knowledge use in agroforestry management with cognitive maps. *Environmental Management*, 43(6), 1321–1329. https://doi.org/10.1007/s00267-008-9201-8

Israel, G. D. (1992). Determination of sample size (No. Fact Sheet PEOD-6), *a series of the Program Evaluation and Organizational Development, Florida Cooperative Extension Service*, Institute of Food and Agricultural Sciences, University of Florida. Florida.

Jaetzold, R., Schmidt, H., Hornetz, B. and, & Shisanya, C. (2011a). Farm Management Handbook of Kenya. Vol II – Natural conditions and farm management information 2nd Edition Part C East Kenya. Subpart C1. Eastern Province Machakos & Makueni County (2nd ed., Vol. II). Nairobi Kenya: Ministry of Agriculture, German Agricultural Team.

Jaetzold, R., Schmidt, H., Hornetz, B., & Shisanya, C. (2011b). Farm Management Handbook of Kenya. Vol II – Natural conditions and farm management information 2nd Edition Part B Central Kenya. Subpart B2. Central Province: Murang'a County (2nd ed., Vol. II). Nairobi Kenya: Ministry of Agriculture, German Agricultural Team.

Jaetzold, R., Schmidt, H., Hornetz, B., & Shisanya, C. (2011c). Farm Management Handbook of Kenya. Vol II – Natural conditions and farm management information 2nd Edition Part B Central Kenya. Subpart B2. Central Province: Kirinyaga County - Kenya (Vol. II). Nairobi Kenya: Ministry of Agriculture, German Agricultural Team.

Jassogne, L., van Asten, P. J. A., Laderach, P., Craparo, A., Wanyama, I., Nibasumba, A., & Bielders, C. (2014). *Climate-smart perennial systems*, 12–16.

Jha, S., Kaechele, H., Lana, M., Amjath-Babu, T. S., & Sieber, S. (2020). Exploring farmers' perceptions of agricultural technologies: A case study from Tanzania. *Sustainability* (Switzerland), 12(3), 1–21. https://doi.org/10.3390/su12030998

Jouzi, Z., Azadi, H., Taheri, F., Zarafshani, K., Gebrehiwot, K., Van Passel, S., & Lebailly, P. (2017). Organic Farming and Small-Scale Farmers: Main Opportunities and Challenges. Ecological Economics, 132, 144–154. https://doi.org/10.1016/j.ecolecon.2016.10.016

Kamau, J. W., Stellmacher, T., Biber-Freudenberger, L., & Borgemeister, C. (2018). Organic and conventional agriculture in Kenya: A typology of smallholder farms in Kajiado and Murang'a counties. *Journal of Rural Studies*, 57(December 2017), 171–185. https://doi.org/10.1016/j.jrurstud.2017.12.014

Kannan, P., Saravanan, A., Krishnakumar, S., & Natarajan, S. K. (2005). Biological Properties of Soil as Influenced by Different Organic Manures. *Research Journal of Agriculture and Biological Sciences*, 1(2), 181–183.

KCIDP (2017) Kirinyaga County Integrated Development Plan 2018-2022 County government of Kirinyaga

Kerselaers, E., Cock, L. De, Lauwers, L., & Huylenbroeck, G. Van. (2007). Modeling farm-level economic potential for conversion to organic farming, *Agricultural Systems* 94, 671–682. http://doi.org/10.1016/j.agsy.2007.02.007

Khoy, R., Nansek, T., & Chomei, Y. (2017). Farmers' Perceptions of Organic Rice Farming in Cambodia: Opportunities and Challenges. *International Journal of Humanities and Social Science,* 7(4), 92–103. Retrieved from http://www.ijhssnet.com/journals/Vol_7_No_4_April_2017/9.pdf

Kings, D., & Ilbery, B. (2012). Farmers' Attitudes towards Organic and Conventional Agriculture: A Behavioural Perspective. *Intech*, i, 13. https://doi.org/10.1016/j.colsurfa.2011.12.014

Kirchmann, H., Kätterer, T., Bergström, L., Börjesson, G., & Bolinder, M. A. (2016). Flaws and criteria for design and evaluation of comparative organic and conventional cropping systems. *Field Crops Research*, *186*, 99–106. https://doi.org/10.1016/j.fcr.2015.11.006

Kledal, P. R., Oyiera, H. F., Njoroge, J. W. and, Kiarii, E. (2009). Organic Food and Farming in Kenya. The World of Organic Agriculture - Statistics and Emerging Trends 2009, (May), 127–132. https://doi.org/10.1063/1.2653669

Kleemann, L. (2016). Organic Pineapple Farming in Ghana - A Good Choice for Smallholders? *The Journal of Developing Areas*, *50*(3), 109–130. https://doi.org/10.1353/jda.2016.0096

KNBS. (2015a). County Statistical Abstract 2015 Machakos County, Nairobi Kenya

KNBS. (2015b). County statistical abstract Kirinyaga County 2015, Nairobi Kenya.

KNBS. (2015c). County Statistical Abstract Murang'a County 2015. Nairobi Kenya. Retrieved from https://www.knbs.or.ke/?page_id=3142&wpdmc=county-statistical-abstracts

KNBS. (2019a). Kenya Population and Housing Census Volume 1: Population by County and Sub-County. 2019 Kenya Population and Housing Census (Vol. I). Retrieved from https://www.knbs.or.ke/?wpdmpro=2019-kenya-population-and-housing-census-volume-i-population-by-county-and-sub-county

KNBS. (2019b). Economic Survey 2019. Nairobi Kenya: Kenya National Bureau of Statistics. https://doi.org/10.16309/j.cnki.issn.1007-1776.2003.03.004

KNBS. (2020). *Economic survey 2020*. Nairobi Kenya: Kenya National Bureau of Statistics. https://doi.org/10.4324/9781315016702

KOAS 2018 KENYA ORGANIC AGRICULTURE SECTOR strategy plan 2019-2023 Nairobi Kenya

KOAN 2019 Kenya Organic Agriculture Network institutional profile Nairobi Kenya

KOAN 2019 ECOLOGICAL ORGANIC AGRICULTURE DIRECTORY 2018 Kenya Organic Agriculture Network www.koan.co.ke

KS ARS/AES 01:2014 The Agriculture-Sustainability and eco-labelling-Requirements. https://webstore.kebs.org/index.php?route=product/product&product_id=14594 accessed on 2nd July 2021

KS EAS 456:2019 Organic production standard http://onlinecatalogue.kebs.org/webquery.dll?v1=pbMarc&v4=0&v5=5A&v8=380648&v9=4&v10=N&v13=4A&v20=4&v22=4A@KS%20145:1983&v23=0&v25=ORGANIC%20and%20%20FARMING%25&v27=15862&v29=5A&v34=5&v35={]0[}{]0[}{]0[}{]0[}&v40=380646&v46=380648 accessed on 2nd July 2021

Krause, J., & Machek, O. (2018). A comparative analysis of organic and conventional farmers in the czech republic. *Agricultural Economics (Czech Republic)*, *64*(1), 1–8. https://doi.org/10.17221/161/2016-AGRICECON

Krueger Richard A. and Casey Mary Anne. (2015). Focus Groups: A practical Guide for applied research. Sage, 560.

Laepple, D., & Donnellan, T. (2008). Farmer attitudes towards converting to organic farming. Teagasc Organic Production Research Conference Proceedings, 114–121. Retrieved from http://orgprints.org/18624/

Lara A., Little C., Urrutia R., McPhee J., Álvarez-Garretón C., Oyarzún C., Soto D., Donoso p., Nahuelhual L., Pino M., Arismendi, I. (2009). Assessment of ecosystem services as an opportunity for the conservation and management of native forests in Chile. *Forest Ecology and Management*, 258(4), 415–424. https://doi.org/10.1016/j.foreco.2009.01.004

Latruffe L., Diazabakana A., Bockstaller C., Desjeux Y., Finn J., Kelly E., Uthes S. (2016). Measurement of sustainability in agriculture: a review of indicators. *Studies in Agricultural Economics,* 118(3), 123–130. https://doi.org/10.7896/j.1624

Le Rohellec, C., & Mouchet, C. (2008). Efficacité économique de systèmes laitiers herbagers en agriculture durable (RAD): Une comparaison avec le RICA. *Fourrages,* 2008(193), 107–113.

Lee, H., & Fowler, S. (2002). Methodologies for the comparison of organic and conventional farming systems. *International Journal of Agricultural Sustainability*, 3(2), 122–129. https://doi.org/10.1080/14735903.2005.9684750

Lee, H., and Fowler, S. (2002). A critique of methodologies for the comparison of organic and conventional farming systems. Retrieved July 20, 2011, from Http://orgprints.org/8234: www.orgprints.org

Lee, J., Hwang, S., Ha, I., Min, B., Hwang, H., & Lee, S. (2015). Comparison of bulb and leaf quality, and antioxidant compounds of intermediate-day onion from organic and conventional systems. *Horticulture Environment and Biotechnology*, 56(4), 427–436. https://doi.org/10.1007/s13580-015-1036-7

Levin, K., Cashore, B., Bernstein, S., & Auld, G. (2012). Overcoming the tragedy of super wicked problems: Constraining our future selves to ameliorate global climate change. *Policy Sciences*, 45(2), 123–152. https://doi.org/10.1007/s11077-012-9151-0

Li, G. D., Singh, R. P., Brennan, J. P., & Helyar, K. R. (2010). A financial analysis of lime application in a long-term agronomic experiment on the south-western slopes of New South Wales. *Crop and Pasture Science*, 61(1), 12–23. https://doi.org/10.1071/CP09103

Li, X. (2014). The making of organic agriculture in China. Boundaries, standards, and controversies. United States of America, Michigan State University. (Ph.D. thesis)

López-Ridaura, S., Masera, O. & Astier, M. (2002). Evaluating the sustainability of complex socio-environmental systems. The MESMIS framework. *Ecological Indicators* 2(1): 135–148.

Lu, H. ling, Chang, Y. H., & Wu, B. Y. (2020). The compare organic farm and conventional farm to improve sustainable agriculture, ecosystems, and environment. *Organic Agriculture*, (91). https://doi.org/10.1007/s13165-020-00278-3

Luttikholt, L. W. M. (2007). Principles of organic agriculture as formulated by the International Federation of Organic Agriculture Movements. NJAS - Wageningen *Journal of Life Sciences*, 54(4), 347–360. https://doi.org/10.1016/S1573-5214 (07)80008-X

Majewski, E. (2013). Measuring and Modelling Farm Level Sustainability. *Visegrad Journal on Bioeconomy and Sustainable Development*, 2(1), 2–10. https://doi.org/10.2478/vjbsd-2013-0001

Malcolm, B., Makeham, J., & Wright, V. (2005). *The Farming Game: Agricultural Management and Marketing*. (B. Malcolm, J. Makeham, & V. Wright, Eds.) (2nd ed.). Cambridge UK: Cambridge University Press. Retrieved from http://repositorio.unan.edu.ni/2986/1/5624.pdf

Maltchik, L., Stenert, C., & Batzer, D. P. (2017). Can rice field management practices contribute to the conservation of species from natural wetlands? Lessons from Brazil. Basic and Applied Ecology, 18, 50–56. https://doi.org/10.1016/j.baae.2016.10.002

Marchand, F., Debruyne, L., Triste, L., Gerrard, C., Padel, S., & Lauwers, L. (2014). Key characteristics for tool choice in indicator-based sustainability assessment at farm level. *Ecology and Society*, 19(3). https://doi.org/10.5751/ES-06876-190346

Muzari, W., Gatsi, W., & Muvhunzi, S. (2012). The Impacts of Technology Adoption on Smallholder Agricultural Productivity in Sub-Saharan Africa: A Review. *Journal of Sustainable Development*, *5*(8), 69–77. https://doi.org/10.5539/jsd.v5n8p69

MCIDP (2017) Machakos County Integrated Development Plan 2018-2022 County government of Machakos

MCIDP (2017b) Murang'a County Integrated Development Plan 2018-2022 County government of Murang'a

Meemken, E.-M., & Qaim, M. (2018). Organic Agriculture, Food Security, and the Environment. *Annual Review of Resource Economics*, 10(1), 39–63. https://doi.org/10.1146/annurev-resource-100517-023252

Mendoza, T. C. (2004). Evaluating the benefits of organic farming in rice agroecosystems in the Philippines. Journal of Sustainable Agriculture, 24(2), 93–115. https://doi.org/10.1300/J064v24n02

Meul, M., Passel, S. Van, Nevens, F., Dessein, J., Rogge, E., Mulier, A., & Hauwermeiren, A. Van. (2008). MOTIFS: A monitoring tool for integrated farm sustainability. *Agronomy for Sustainable Development*, 28(2), 321–332. https://doi.org/10.1051/agro:2008001

Milliken, G. A., & Johnson, D. E. (2009). *Analysis of Messy Data Volume 1 Designed Experiments* (2nd Editio). Broken Sound Parkway NW: CRC Press Taylor & Francis Group.

Mirko, D. M., Olsen, K. H., Dong, Y., Pedersen, M. B., & Hauschild, M. Z. (2019). Sustainable development impacts of nationally determined contributions: assessing the case of mini-grids in Kenya. *Climate Policy*, 0(0), 1–17. https://doi.org/10.1080/14693062.2019.1644987

MoALF-Kenya. (2015). *Economic Review of Agriculture (ERA) 2015* (Vol. 20). Nairobi Kenya: Central Planning and Project Monitoring Unit Ministry of Agriculture Livestock and Fisheries. https://doi.org/10.5089/9781513543284.002

Mohamad, R. S., Verrastro, V., Cardone, G., Bteich, M. R., Favia, M., Moretti, M., & Roma, R. (2014). Optimization of organic and conventional olive agricultural practices from a Life Cycle Assessment and Life Cycle Costing perspectives. *Journal of Cleaner Production*, *70*, 78–89. https://doi.org/10.1016/j.jclepro.2014.02.033

Morris, J. B., V. Tassone, R. De Groot, M. Camilleri, and S. Moncada. (2011). A Framework for Participatory Impact Assessment: involving stakeholders in European policymaking, a case study of land-use change in Malta. *Ecology and Society* 16(1): 12. [online] URL: http://www.ecologyandsociety.org/vol16/iss1/art12/

Morris, M., Kelly, V. A., Kopicki, R. J., & Byerlee, D. (2007). *Fertilizer Use in African Agriculture. Lessons Learned and Good Practice Guidelines*. *Experimental Agriculture* (Vol. 44). https://doi.org/10.1017/S0014479707005777

Mueller, N. D., Gerber, J. S., Johnston, M., Ray, D. K., Ramankutty, N., & Foley, J. A. (2012). Closing yield gaps through nutrient and water management. *Nature*, *490*(7419), 254–257. https://doi.org/10.1038/nature11420

Mugivhisa, L. L., Olowoyo, J. O., & Mzimba, D. (2017). Perceptions on organic farming and selected organic fertilizers by subsistence farmers in Ga-Rankuwa, Pretoria, South Africa. African Journal of Science, Technology, Innovation and Development, 9(1), 85–91. https://doi.org/10.1080/20421338.2016.1269459

Müller, C., Elliott, J., Pugh, T. A. M., Ruane, A. C., Ciais, P., Balkovic, J., Deryng, D., Folberth, C., Izaurralde C. R., Jones C. D., Khabarov N., Lawrence P., Liu W., Reddy A. D., Schmid E. and Wang X. (2018). Global patterns of crop yield stability under additional nutrient and water inputs. *PLoS ONE*, 13(6), 1–14. https://doi.org/10.1371/journal.pone.0198748

Mutisya, E., & Yarime, M. (2014). Moving towards urban sustainability in Kenya: A framework for integration of environmental, economic, social and governance dimensions. *Sustainability Science*, 9(2), 205–215. https://doi.org/10.1007/s11625-013-0223-7

Mwangi, M., & Kariuki, S. (2015). Factors Determining Adoption of New Agricultural Technology by Smallholder Farmers in Developing Countries. *Issn*, 6(5), 2222–1700. Retrieved from www.iiste.org

Mwaura, F. (2007). Organic agriculture in Kenya: An integrated assessment for policy advocacy. Geneva: UNEP-UNCTAD.

Mwirigi, J. W., Makenzi, P. M., & Ochola, W. O. (2009). Socio-economic constraints to adoption and sustainability of biogas technology by farmers in Nakuru Districts, Kenya. *Energy for Sustainable Development*, 13(2), 106–115. https://doi.org/10.1016/j.esd.2009.05.002

Nautiyal, S. (2011). Can conservation and development interventions in the Indian Central Himalaya ensure environmental sustainability? A socioecological evaluation. *Sustainability Science*, *6*(2), 151–167. https://doi.org/10.1007/s11625-011-0126-4

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. *British Journal of Applied Science & Technology*, *17*(6), 1–22. https://doi.org/10.9734/bjast/2016/16270

Ndungu, S., Macharia, I., Kahuthia, R., & Wahome, R. (2013). Impact of Organic Vegetable Production System in Kiambu and Kajiado Counties of Kenya. *Journal of Environmental Science and Engineering,* A2(4), 256–266.

Nemes, N. (2009). Comparative Analysis of Organic and Non-organic Farming Systems: A critical Assessment of Farm Profitability. *Food and Agriculture Organization*, (June), 1–33.

Ngungiri R. (2017). Organic farming in Kenya: Promising growth and a bright future in Willer, Helga and Jilia Lemoud (Eds) 2017, *The World of Organic Agriculture: Statistics and Emerging Trends 201*8 Research Institute of Organic Agriculture FiBL- Frick and IFOAM Organic International Bonn pg 167-168.

Nzila, C., Dewulf, J., Spanjers, H., Tuigong, D., Kiriamiti, H., & van Langenhove, H. (2012). Multi criteria sustainability assessment of biogas production in Kenya. *Applied Energy*, 93, 496–506. https://doi.org/10.1016/j.apenergy.2011.12.020

Obayelu, A. E., Ajayi, O. D., Oluwalana, E. O. A., & O, O. O. (2017). What Does Literature Say about the Determinants jig of Adoption of Agricultural Technologies by Smallholders Farmers? *Agricultural Research & Technology: Open Access Journal*, 6(1). https://doi.org/10.19080/artoaj.2017.06.555676

Oberč, B.P. & Arroyo Schnell, A. (2020). Approaches to sustainable agriculture. Exploring the pathways towards the future of farming. Brussels, Belgium: IUCN EURO. DOI: https://doi.org/10.2305/IUCN.CH.2020.07.en

Ochola, D., Jogo, W., Ocimati, W., Rietveld, A., Tinzaara, W., Karamura, D. A., & Karamura, E. B. (2013). Farmers' awareness and perceived benefits of agro-ecological intensification practices in banana systems in Uganda. African *Journal of Biotechnology*, 12(29), 4603–4613. https://doi.org/10.5897/ajb12.2868

Odhiambo, W., Nyangito, H., & Nzuma, J. (2004). Source and Determinant of Agricultural Growth and Productivity in Kenya, (34), 67.

OECD. (2008). *Environmental performance of agriculture at a glance. Environmental Performance of Agriculture at a Glance* (Vol. 9789264046). https://doi.org/10.1787/9789264046788-en

OECD. (2001). Environmental indicators for agriculture: Methods and Results. Paris.

Offermann, F., & Nieberg, H. (2000). Profitability of organic farming in Europe, (November).

Oloo J.E.O. (2015). Food Safety and Quality Management in Kenya: An overview of the roles played by various stakeholders. African *Journal of Food Agriculture, Nutrition and Development*, 10(11), 4379–4397. https://doi.org/10.1007/978-3-319-09650-6

Olsen, J. (2019). The Nominal Group Technique (NGT) as a Tool for Facilitating Pan-Disability Focus Groups and as a New Method for Quantifying Changes in Qualitative Data. *International Journal of Qualitative Methods*, *18*, 1–10. https://doi.org/10.1177/1609406919866049

Onduru, D. D., De Jager, A., Hiller, S., & Van den Bosch, R. (2012). Sustainability of smallholder tea production in developing countries : Learning experiences from farmer field schools in Kenya. *International Journal of Development and Sustainability*, 1(3), 1–29.

Ostapenko, R., Herasymenko, Y., Nitsenko, V., Koliadenko, S., Balezentis, T., & Streimikiene, D. (2020). Analysis of production and sales of organic products in ukrainian agricultural enterprises. *Sustainability (Switzerland)*, *12*(8), 1–15. https://doi.org/10.3390/SU12083416

Oudtanivanh, O., Limnirankul, B., & Kramol, P. (2018). Farmers' knowledge and perceptions of sustainable soil conservation practices in Paklay district, Sayabouly province, Lao PDR. Kasetsart *Journal of Social Sciences*, 40(3), 650–656. https://doi.org/10.1016/j.kjss.2018.07.006

Ototo, G., & Vlosky, R. P. (2018). Overview of the forest sector in Kenya. *Forest Products Journal*, 68(1), 6–14. https://doi.org/10.13073/0015-7473.68.1.4

Oyedele, G. T., Owolabi, K. E., & Okunlola, J. O. (2018). Small – Scale Farmers Perception on Organic Farming Status in Ondo State , Nigeria. *American Journal of Agriculture and Forestry*, *6*(6), 186–190. https://doi.org/10.11648/j.ajaf.20180606.15

Panneerselvam, P., Halberg, N., Vaarst, M., & Hermansen, J. E. (2012). Indian farmers' experience with and perceptions of organic farming. *Renewable Agriculture and Food Systems*, 27(2), 157–169. https://doi.org/10.1017/S1742170511000238

Patidar, S., & Patidar, H. (2015). A Study of Perception of Farmers towards Organic Farming. International *Journal of Application or Innovation in Engineering and Management* (IJAIEM), 4(3), 269–277. Retrieved from www.ilaiem.org

Perez, C., Jones, E. M., Kristjanson, P., Cramer, L., Thornton, P. K., Förch, W., & Barahona, C. (2015). How resilient are farming households and communities to a changing climate in Africa? A gender-based perspective. *Global Environmental Change*, 34, 95–107. https://doi.org/10.1016/j.gloenvcha.2015.06.003

Pervanchon, F., Bockstaller, C., Amiaud, B., Peigné, J., Bernard, P., Vertès, F., Fiorelli, J., & Plantureux, S. (2005). A novel indicator of environmental risks due to nitrogen management on grasslands. *Agriculture, Ecosystems & Environment*, 105, 1-16.

Pimentel, D., Hepperly, P., Hanson, J., Douds, D., & Seidel, R. (2010). Environment, Energetic and Economic Comparisons of Organic and Conventional Farming Systems. *BioScience*, 55(7), 573–582.

Pinthukas, N. (2015). Farmers' Perception and Adaptation in Organic Vegetable Production for Sustainable Livelihood in Chiang Mai Province. Agriculture and Agricultural Science Procedia, 5, 46–51. https://doi.org/10.1016/j.aaspro.2015.08.007

Pollesch, N., & Dale, V. H. (2015). Applications of aggregation theory to sustainability assessment. *Ecological Economics*, 114, 117–127. https://doi.org/10.1016/j.ecolecon.2015.03.011

Ponisio, L. C., M'Gonigle, L. K., Mace, K. C., Palomino, J., de Valpine, P., & Kremen, C. (2014). Diversification practices reduce organic to conventional yield gap. *Proceedings of the Royal Society B: Biological Sciences*, *282*(1799), 20141396–20141396. https://doi.org/10.1098/rspb.2014.1396

Pope, J., Annandale, D. & Morrison-Saunders, A. (2004). Conceptualizing sustainability assessment. *Environmental Impact Assessment Review* 24(6): 595–616.

Pope, J., Morrison-Saunders, A., (2013). Pluralism in practice. In: Bond, A.J., Morrison- Saunders, A., Howitt, R. (Eds.), Sustainability Assessment: Pluralism, Practice, and Progress. Routledge, pp. 100–114

Potter, M., Gordon, S., & Hamer, P. (2004). The Nominal Group Technique: A useful consensus methodology in physiotherapy research. New Zealand *Journal of Physiotherapy*, 32(January 2004), 126–130.

Pottiez, E., Lescoat, P., & Bouvare, I. (2012). AVIBIO: a method to assess the sustainability of the organic poultry industry. *Producing and Reproducing Farming Systems. New Modes of Organisation for Sustainable Food Systems of Tomorrow. 10th European IFSA Symposium, Aarhus, Denmark, 1-4 July 2012*. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&db=lah&AN=20133410280&site=ehost-live%5Cnhttp://www.cabi.org/cabdirect/showpdf.aspx?PAN=http://www.cabi.org/cabdirect/showpdf.aspx?PAN=20133410280%5Cnhttp://ifsa.boku.ac.at/cms/index.php?id=ifsa2012

Power, A. G. (2010). Ecosystem services and agriculture: tradeoffs and synergies. Philosophical Transactions of the Royal Society B 365:2959-2971. http://dx.doi.org/10.1098/rstb.2010.0143

Pretty, J., & Bharucha, Z. P. (2014). Sustainable intensification in agricultural systems. *Annals of Botany*, 114(8), 1571–1596. https://doi.org/10.1093/aob/mcu205

Prihtanti, T. M. (2016). Farmer Group as Social Determinant of Farmer's Perceptions on Organic Farming Concepts and Practice. RA *Journal of Applied Research*, 2(02), 407–415. https://doi.org/10.18535/rajar/v2i2.03

Qiao, Y., Halberg, N., Vaheesan, S., & Scott, S. (2016). Assessing the social and economic benefits of organic and fair trade tea production for small-scale farmers in Asia: A comparative case study of China and Sri Lanka. *Renewable Agriculture and Food Systems*, *31*(3), 246–257. https://doi.org/10.1017/S1742170515000162

Ramesh, P., Panwar, N. R., Singh, A. ., Ramana, S., Yadav, S. K., Shrivastava, R., & Rao, A. S. (2010). Status of organic farming in India. *Current Science*, *98*(9), 1190–1194.

Rao, N.H. & Rogers, P.P. (2006). Assessment of agricultural sustainability. *Current Science* 91(4): 439–448.

Rasul, G. & Thapa, G.B. (2004). Sustainability of ecological and conventional agricultural systems in Bangladesh: An assessment based on environmental, economic and social perspectives. *Agricultural Systems* 79(3): 327–351.

Reganold, J. P., & Wachter, J. M. (2016). Organic agriculture in the twenty-first century. *Nature Plants*, 2(February), 15221. https://doi.org/10.1038/nplants.2015.221

Republic of Kenya. (2012). Water Act, 245. Kenya: Law society of Kenya

Republic of Kenya (2012b). Agriculture Act (Cap 318), Government Printers, Nairobi Kenya: Law society of Kenya. Retrieved from www.kenyalaw.org

Republic of Kenya. (2016). The Water Act 2016, Kenya: Law society of Kenya.

Rigby, D. & Caceres, D. (2001). Organic farming and the sustainability of agricultural systems. *Agricultural Systems*, 68, 21–40

Rhoades, R. E., & Booth, R. H. (1982). Farmer-back-to-farmer: A model for generating acceptable agricultural technology. *Agricultural Administration*, 11(2), 127–137. https://doi.org/10.1016/0309-586X (82)90056-5

Rockstrom, J., W. Steffen, K. Noone, A. Persson, F. S. Chapin, III, E. Lambin, T. M. Lenton, M. Scheffer, C. Folke, H. Schellnhuber, B. Nykvist, C. A. De Wit, T. Hughes, S. van der Leeuw, H. Rodhe, S. Sorlin, P. K. Snyder, R. Costanza, U. Svedin, M. Falkenmark, L. Karlberg, R. W. Corell, V. J. Fabry, J. Hansen, B. Walker, D. Liverman, K. Richardson, P. Crutzen, and J. Foley. (2009). Planetary boundaries: exploring the safe operating space for humanity. Ecology and Society 14(2): 32. [online] URL:http://www.ecologyandsociety.org/vol14/iss2/art32/. Rodrigues, D. B., Dalmarco, D. de A. S., Aoqui, C., & Marinho, B. de L. (2016). The meaning of the organic certification label for the consumer: a cluster analysis. REGE - Revista de Gestão, 36, 1–11. https://doi.org/10.1016/j.rege.2016.08.001

Rodrigues, G. S., Rodrigues, I. A., Buschinelli, C. C. de A., & de Barros, I. (2010). Integrated farm sustainability assessment for the environmental management of rural activities.

Environmental Impact Assessment Review, 30(4), 229–239. https://doi.org/10.1016/j.eiar.2009.10.002

Rodríguez-Bermúdez, R., Miranda, M., Orjales, I., Rey-Crespo, F., Muñoz, N., & López-Alonso, M. (2017). Holstein-friesian milk performance in organic farming in north Spain: Comparison with other systems and breeds. Spanish *Journal of Agricultural Research*, 15(1), 1–10. https://doi.org/10.5424/sjar/2017151-10037

Röös, E., Fischer, K., Tidåker, P., & Nordström Källström, H. (2019). How well is farmers' social situation captured by sustainability assessment tools? A Swedish case study. *International Journal of Sustainable Development and World Ecology*, 26(3), 268–281. https://doi.org/10.1080/13504509.2018.1560371

Rubin, D. B. (2006). Macthing Sampling for casual Effects. Cambridge: Cambridge University Press.

Schader, C.; Baumgart, L.; Landert, J.; Muller, A.; Ssebunya, B.; Blockeel, J.; Weisshaidinger, R.; Petrasek, R.; Mészáros, D.; Padel, S.; Gerrard, C.; Smith, L.; Lindenthal, T.; Niggli, U.; Stolze, M. (2016). Using the Sustainability Monitoring and Assessment Routine (SMART) for the systematic analysis of trade-offs and synergies between sustainability dimensions and themes at farm level. *Sustainability* (Switzerland), 8(3). https://doi.org/10.3390/su8030274

Schader, C., Grenz, J., Meier, M. S., & Stolze, M. (2014). Scope and precision of sustainability assessment approaches to food systems. *Ecology and Society*, 19(3). https://doi.org/10.5751/ES-06866-190342

Schensul J. J., & LeCompte. M. D. (2013). Essential Ethnographic Methods: A Mixed Method approach (2nd ed.) Lanham Maryland USA Aita Mira Press.

Schrama, M., de Haan, J. J., Kroonen, M., Verstegen, H., & Van der Putten, W. H. (2018). Crop yield gap and stability in organic and conventional farming systems. *Agriculture, Ecosystems and Environment*, 256(December 2017), 123–130. https://doi.org/10.1016/j.agee.2017.12.023

Schönhart, M., Schauppenlehner, T., Schmid, E., & Muhar, A. (2011). Integration of bio-physical and economic models to analyze management intensity and landscape structure effects at farm and landscape level. *Agricultural Systems*, 104(2), 122–134. https://doi.org/10.1016/j.agsy.2010.03.014

Sekhon, J. S. (2009). Opiates for the Matches: Matching Methods for Causal Inference. *Annual Review of Political Science*, 12(1), 487–508. https://doi.org/10.1146/annurev.polisci.11.060606.135444

Seufert, V., Ramankutty, N., & Foley, J. A. (2012). Comparing the yields of organic and conventional agriculture. *Nature*, *485*(7397), 229–232. https://doi.org/10.1038/nature11069

Seufert, V., & Ramankutty, N. (2017). Many shades of gray—the context-dependent performance of organic agriculture. *Science Advances*, 3(3). https://doi.org/10.1126/sciadv.1602638

Seufert, V., Ramankutty, N., & Mayerhofer, T. (2017). What is this thing called organic? – How organic farming is codified in regulations. *Food Policy*, 68, 10–20. https://doi.org/10.1016/j.foodpol.2016.12.009

Sgroi, F., Candela, M., Di Trapani, A. M., Foderà, M., Squatrito, R., Testa, R., & Tudisca, S. (2015). Economic and financial comparison between organic and conventional farming in Sicilian lemon orchards. *Sustainability (Switzerland)*, *7*(1), 947–961.

https://doi.org/10.3390/su7010947

Shadbolt, N., Kelly, T., Horne, D., Harrington, K., Kemp, P., Palmer, A. and Thatcher, A. (2009). Comparisons between organic & conventional pastoral dairy farming systems: cost of production and profitability. *Journal of Farm Management* 13, 671-685.

Sharma, M. (2020). Oragnic Framing; A Modern apporach for Cultivation of Medicinal and Aromatic plants. In W. Bank (Ed.), *IInternational Virtual Conference On Vermicomposting and Organic Farming, Organized by Dept Of Botany & Zoology*. Nepal: Narasingh Choudhury Autonomous College, Jajpur, Odisha and Dept. of Env Sc, Trichandra College, Tu, Nepal.

Shennan, C., Krupnik, T. J., Baird, G., Cohen, H., Forbush, K., Lovell, R. J., & Olimpi, E. M. (2017). Organic and Conventional Agriculture: A Useful Framing? *Annual Review of Environment and Resources*, 42, 317–346. https://doi.org/10.1146/annurev-environ-110615-085750

Sieber, S., Amjath-babu, T. S., Reidsma, P., Koenig, H., Piorr, A., Bezlepkina, I., & Mueller, K. (2018). Land Use Policy Sustainability impact assessment tools for land use policy advice : A comparative analysis of five research approaches. *Land Use Policy*, 71(November 2017), 75–85. http://doi.org/10.1016/j.landusepol.2017.11.042

Singh, R. K., Murty, H. R., Gupta, S. K., & Dikshit, A. K. (2012). An overview of sustainability assessment methodologies. *Ecological Indicators*, 15(1), 281–299. https://doi.org/10.1016/j.ecolind.2011.01.007

Smith, O. M., Cohen, A. L., Rieser, C. J., Davis, A. G., Taylor, J. M., Adesanya, A. W., Jones M. S., Meier A. R., Reganold J. P., Orpet R. J., Northfield T. D., Crowder, D. W. (2019). Organic Farming Provides Reliable Environmental Benefits but Increases Variability in Crop Yields: A Global Meta-Analysis. *Frontiers in Sustainable Food Systems*, 3(September), 1–10. https://doi.org/10.3389/fsufs.2019.00082

Soire, N., Maobe, S., Basweti, E., & Makone, S. (2016). Farmer's Perception on the Effectiveness and Sustainability of Disseminated Agricultural Technologies Through farmer groups approach in Kisii County, Kenya. *International Journal of Information Research and Review*, 03(02), 1856–1859.

Sottile, F., Fiorito, D., Tecco, N., Girgenti, V., & Peano, C. (2016). An interpretive framework for assessing and monitoring the sustainability of school gardens. *Sustainability* (Switzerland), 8(8). https://doi.org/10.3390/su8080801

Spaling, H., Brouwer, G., & Njoka, J. (2014). Factors affecting the sustainability of a community water supply project in Kenya. *Development in Practice*, 24(7), 797–811. https://doi.org/10.1080/09614524.2014.944485

Spaling, H., Montes, J., & Sinclair, J. (2011). Best practices for promoting participation and learning for sustainability:lessons from community-based environmental assessment in kenya and tanzania. *Journal of Environmental Assessment Policy and Management*, *13*(3), 343–366. https://doi.org/10.1142/S1464333211003924

Spedding, C. (2012). An introduction to agricultural systems. Netherlands: Springer Science and Business Media

Speelman, E. N., López-Ridaura, S., Colomer, N. A., Astier, M., & Masera, O. R. (2007). Ten years of sustainability evaluation using the MESMIS framework: Lessons learned from its application in 28 Latin American case studies. *International Journal of Sustainable*

Development and World Ecology, 14(4), 345–361. https://doi.org/10.1080/13504500709469735

Ssebunya, B. R., Altenbuchner, C., Schmid, E., Schader, C., Landert, J., Baumgart, L., & Stolze, M. (2018). Sustainability Performance of Certified and Non-certified Smallholder Coffee Farms in Uganda. *Ecological Economics*, 156(July 2016), 35–47. https://doi.org/10.1016/j.ecolecon.2018.09.004

Ssebunya, B. R., Schmid, E., Van Asten, P., Schader, C., Altenbuchner, C., & Stolze, M. (2017). Stakeholder engagement in prioritizing sustainability assessment themes for smallholder coffee production in Uganda. *Renewable Agriculture and Food Systems*, 32(5), 428–445. https://doi.org/10.1017/S1742170516000363

StataCorp. 2019. Stata Statistical Software: Release 16. College Station, TX: StataCorp LLC.

Suja, G., Byju, G., Jyothi, A. N., Veena, S. S., & Sreekumar, J. (2017). Yield, quality and soil health under organic vs conventional farming in taro. *Scientia Horticulturae*, *218*, 334–343. https://doi.org/10.1016/j.scienta.2017.02.006

Şurcă, D.-E. C. (2018). Comparative study on the economic efficiency of rice culture in a conventional and organic system. In Econstor (Ed.), *Agrarian Economy and Rural Development - Realities and Perspectives for Romania. 9th Edition of the International Symposium, November 2018, Buchares* (pp. 278–285). Bucharest: The Research Institute for Agricultural Economy and Rural Development (ICEADR), Bucharest). https://doi.org/http://hdl.handle.net/10419/205120

Tanrivermiş, H. (2006). The development of organic farming and its impacts on farms in Turkey: A discussion on research results. Pakistan *Journal of Biological Science*s. https://doi.org/10.3923/pjbs.2006.1192.1204

Tatlidil, F. F., Boz, I., & Tatlidil, H. (2009). Farmers' perception of sustainable agriculture and its determinants: A case study in Kahramanmaras province of Turkey. *Environment, Development and Sustainability*, 11(6), 1091–1106. https://doi.org/10.1007/s10668-008-9168-x

Taylor, A. (2006). Overview of the current state of organic agriculture in Kenya, Uganda and the United Republic of Tanzania and the opportunities for regional harmonization Geneva: United Nations

Te Pas, C. M., & Rees, R. M. (2014). Analysis of Differences in Productivity, Profitability and Soil Fertility between Organic and Conventional Cropping Systems in the Tropics and Sub-tropics. *Journal of Integrative Agriculture*, 13(10), 2299–2310. https://doi.org/10.1016/S2095-3119 (14)60786-3

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. *Agricultural Systems*, 103(2), 83–97. https://doi.org/10.1016/j.agsy.2009.10.001

Tittonell, Pablo. (2014). Livelihood strategies, resilience and transformability in African agroecosystems. *Agricultural Systems*, 126, 3–14. https://doi.org/10.1016/j.agsy.2013.10.010

Tobin, J. (1985). Neoclassical Theory in America: J. B. Clark and Fisher. *American Economic Review*, 75(6), 28–38. https://doi.org/10.2307/1914327

Triste, L., Marchand, F., Debruyne, L., Meul, M., Lauwers, L., (2014). Reflection on the development process of a sustainability assessment tool: learning from a Flemish case the MOTIFS case. Ecol. Soc. 19.

Tung, L. I. M. (2018). African Organic Product Standards for the African Continent ? Prospects and Limitations. *Pioneer in Peer-Reviewed*, 2018(21), 38. https://doi.org/http://dx.doi.org/10.17159/1727- 3781/2018/v21i0a4308

UNEP -UNCTAD 2008 Best practices for organic policy. What developing country Governments can do go promote the organic agriculture sector United Nations New York and Geneva

UNCTAD and UNEP (2008). 'Organic Agriculture and Food Security in Africa', New York, Geneva, United Nations Conference on Trade and Development, United Nations Environment Programme.

UNDP. (2018). *National Human Development Report 2018: Planning the Opportunities for a Youthful Population*.

UNDP. (2020). *Human Development Report 2020The next frontier Human development and the Anthropocene Human Development Report 2020*. New York, NY 10017 USA: United Nations Development Programme. Retrieved from http://hdr.undp.org.

UNEP-UNCTAD. (2008). Capacity-building Task Force on Trade, Environment and Development. Organic Agriculture and Food Security in Africa. Geneva and New York, United Nations. 21–44. Retrieved from https://unctad.org/en/docs/ditcted200715_en.pdf

UN-DE (2017) United Nations Department of Economics. Indicators of sustainable development: Guidelines and methodologies. United Nations Publications.

UN-SDSN (United Nations Sustainable Development Solutions Network), 2014b. Monitoring the performance of agriculture and food systems. GSDR 2015 Brief. UN-SDSN.

Upton M. (1964). A Development of Gross Margin Analysis. *Journal of Agricultural Economics*, 16(1), 111–117. https://doi.org/10.1111/j.1477-9552.1964.tb00484.x

Ustriyana, I. N. G., Ayu, I., & Dewi, L. (2017). Analysis Of Perception Of Chili Farmers On Sustainable Development. *American-Eurasian Journal of Sustainable Agriculture*, *11*(4), 23–29. Retrieved from http://www.aensiweb.com/AEJSA/

Van Cauwenbergh K Biala, Charles Bielders, V Brouckaert, L Francois, V Garcia Cidad, Martin Hermy, Erik Mathijs, Bart Muys, J Reijnders, Xavier Sauvenier, Jan Valckx, Marnik Vanclooster, B Van der Veken, Erwin Wauters, Alain Peeters (2007), SAFE—A hierarchical framework for assessing the sustainability of agricultural systems *Agriculture, Ecosystems and Environment* 120 229–242. https://doi:10.1016/j.agee.2006.09.006

Van der Werf, H. M. G., Knudsen, M. T., & Cederberg, C. (2020). Towards better representation of organic agriculture in life cycle assessment. *Nature Sustainability*, 3(6), 419–425. https://doi.org/10.1038/s41893-020-0489-6

Vandenberghe, V., & Robin, S. (2004). Evaluating the effectiveness of private education across countries: A comparison of methods. *Labour Economics*, 11(4), 487–506. https://doi.org/10.1016/j.labeco.2004.02.007

Vasilikiotis, C. (2000). Can Organic Farming “Feed the World”? *University of California, Berkeley ESPM-Division of Insect Biology*, *136*(11), 1324–1324.

https://doi.org/10.1001/archderm.136.11.1324

Virlanuta, F. O. (2011). Profitability Analysis for Agricultural Investment Projects. Risk in Contemporary Economy, 336–342.

Waas, T., Hugé, J., Block, T., Wright, T., Benitez-Capistros, F., & Verbruggen, A. (2014). Sustainability Assessment and Indicators: Tools in a Decision-Making Strategy for Sustainable Development, *Sustainability*, 6, 5512-5534. http://doi.org/10.3390/su6095512

Walaga, C. (2004). Organic agriculture in Kenya and Uganda STUDY VISIT REPORT. *Technical Centre for Agricultural and Rural Cooperation* (CTA), (8033), 19–30.

Waney, N. F. L., Soemarno, Yuliaty, Y., & Polii, B. (2014). Developing Indicators of Sustainable Agriculture at Farm Level. IOSR *Journal of Agriculture and Veterinary Science*, 7(2), 42–53. https://doi.org/10.9790/2380-07224253

Wankuru P. C., Dennis A. C. K., Umutesi A., Chege P. N., Mutie C. K., Sanya S. O., Chengula L. K.,Njagi T.,Pape U. J.,Haynes A. P. F., 2019. *Kenya Economic Update: Unbundling the Slack in Private Sector Investment – Transforming Agriculture Sector Productivity and Linkages to Poverty Reduction (English).* Kenya economic update; no. 19 Washington, D.C.: World Bank Group. http://documents.worldbank.org/curated/en/820861554470832579/Kenya-Economic-Update-Unbundling-the-Slack-in-Private-Sector-Investment-Transforming-Agriculture-Sector-Productivity-and-Linkages-to-Poverty-Reduction

Wartenberg, A. C., Blaser, W. J., Janudianto, K. N., Roshetko, J. M., van Noordwijk, M., & Six, J. (2018). Farmer perceptions of plant–soil interactions can affect adoption of sustainable management practices in cocoa agroforests: A case study from Southeast Sulawesi. Ecology and Society, 23(1). https://doi.org/10.5751/ES-09921-230118

Weidmann, Gilles, Kilcher, Lukas and Garibay, Salvador. (2004). IFOAM Training Manual for organic agriculture in the Tropics. Research Institute for Organic Agriculture (FIBL), Bonn: IFOAM.

Whitehead, J. (2017) Prioritizing Sustainability Indicators: Using Materiality Analysis to Guide Sustainability Assessment and Strategy. *Bus. Strat. Env*. 26: 399– 412. DOI: 10.1002/bse.1928.

Willer, H., & Lernoud, J. (2018). The world of organic agriculture. Statistics and Emerging Trends 2018. Fibl, Fricks, and IFOAM-Organics International. https://doi.org/10.4324/9781849775991

Willer, H., & Lernoud, J. (Eds.). (2015). *The World of Organic Agriculture. Statistics and Emerging Trends* 2015. Frick, Bonn: Research Institute of Organic Agriculture, and IFOAM – Organics International. Retrieved from https://shop.fibl.org/de/artikel/c/statistik/p/1663-organic-world-2015.html

Willer, H., & Lernoud, J. (Eds.). (2016). *The World of Organic Agriculture Statistics and Emerging Trends 2016*. Frick, Bonn: Research Institute of Organic Agriculture, and IFOAM – Organics International. https://doi.org/10.4324/9781849775991

Willer, H., & Lernoud, J. (Eds.). (2017). *The World of Organic Agriculture Statistics and Emerging Trends 2017*. Frick, Bonn: Research Institute of Organic Agriculture, and IFOAM – Organics International. https://doi.org/10.4324/9781849775991

Willer, H., & Lernoud, J. (Eds.). (2019). *The World of Organic Agriculture Statistics and Emerging Trends 2019*. Frick, Bonn: Research Institute of Organic Agriculture, and IFOAM – Organics International. https://doi.org/10.4324/9781849775991

Willer, H., Schlatter, B., Trávnicek, J., Kemper, L., & Lernoud, J. (Eds.). (2020). *The world of organic agriculture STATISTICS & EMERGING TRENDS 2020*. Frick Bonn: Research Institute of Organic Agriculture, and IFOAM – Organics International.

Williams, R. (2015). Using Stata 9 & Higher for OLS Regression. Retrieved from http://www3.nd.edu/~rwilliam/

Wooldridge, J. M. (2002). The threshold effects of energy efficiency on the elasticity of substitution between energy and non-energy factors, 741. https://doi.org/10.1007/s12053-016-9491-2

World Bank (2007). Enhancing Agricultural Innovation: How to Go Beyond the Strengthening of Research Systems. Washington, DC: World Bank. Available at https://openknowledge.worldbank.org/handle/10986/7184 License: CC BY 3.0 IGO

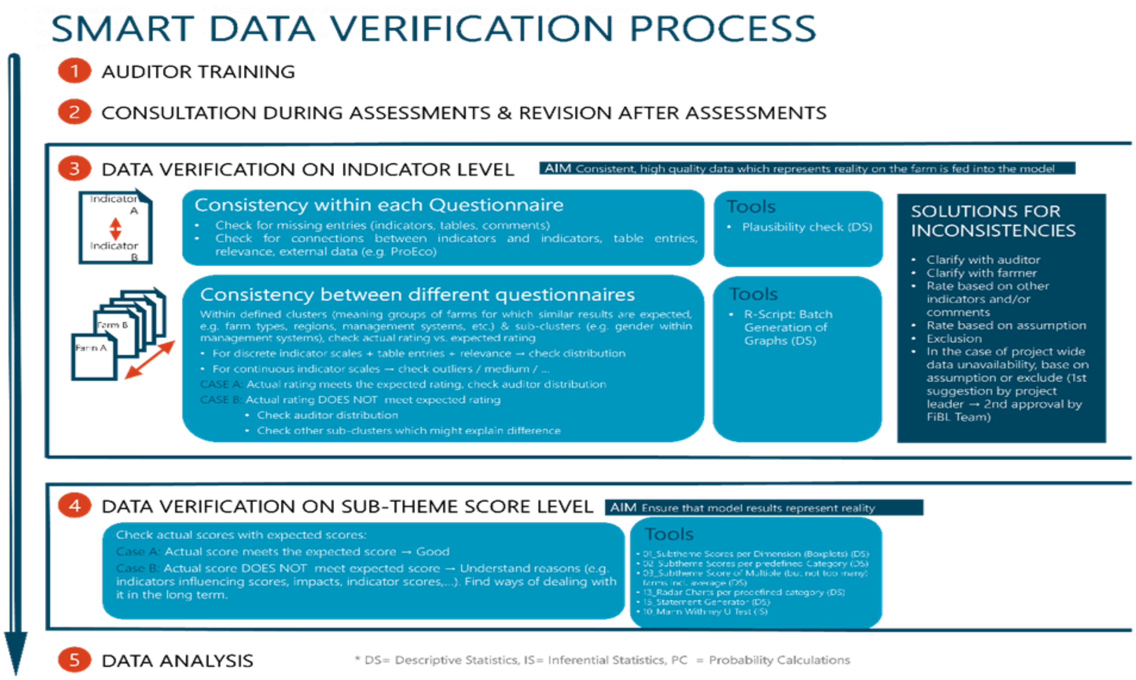
World Bank (2017). World Bank data atlas. https://data.worldbank.org/country/kenya. Accessed on 21/08/2019

Yanakittkul, P., & Aungvaravong, C. (2020). A model of farmers' intentions towards organic farming: A case study on rice farming in Thailand. *Heliyon*, 6(1), e03039. https://doi.org/10.1016/j.heliyon.2019.e03039

Zahm, F., Viaux, P., Vilain, L., Girardin, P., & Mouchet, C. (2008). Assessing Farm Sustainability Assessment using the IDEA Method: from the concept of farm sustainability to case studies on French farms. *Sustainable Development*, 16, 271–281. https://doi.org/978-1-894784-05-4

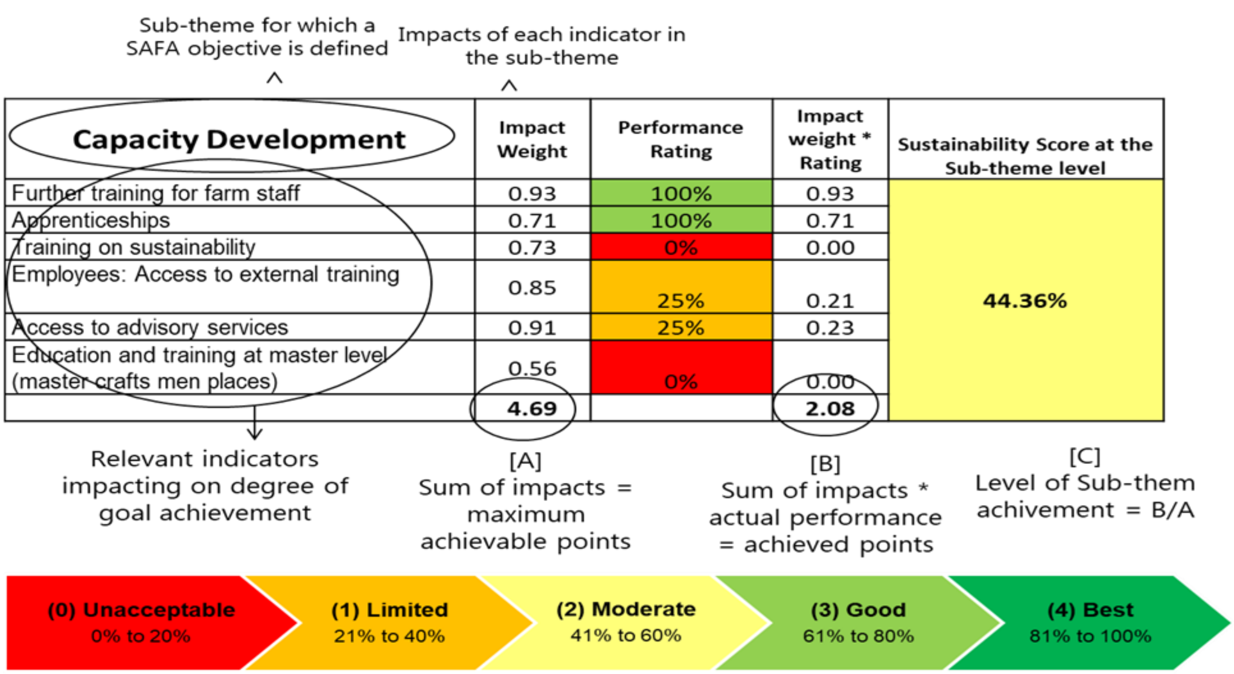
Annexes

Annex 1: Schematic SMART data verification process (Source: FiBL)



(Source: FiBL)

Annex 2: Calculation of a goal achievement score: Example of capacity development



Capacity Development	Impact Weight	Performance Rating	Impact weight * Rating	Sustainability Score at the Sub-theme level
Further training for farm staff	0.93	100%	0.93	44.36%
Apprenticeships	0.71	100%	0.71	
Training on sustainability	0.73	0%	0.00	
Employees: Access to external training	0.85	25%	0.21	
Access to advisory services	0.91	25%	0.23	
Education and training at master level (master crafts men places)	0.56	0%	0.00	
	4.69		2.08	

(Source: FiBL- SMART-Farm-tool method: Model, uses cases & assessment procedure-SMART training presentation Kenya 2019)

Annex 3: The 58 Sub-themes and sub-theme objectives

SAFA Dimension	Sub-theme	Sub-theme objectives
Environmental Integrity	Greenhouse gases	The emission of GHG is contained.
	Air quality	The emission of air pollutants is prevented and ozone depleting substances are eliminated.
	Water withdrawal	Withdrawal of ground and surface water and/or use does not impair the functioning of natural water cycles and ecosystems and human, plant and animal communities.
	Water quality	The release of water pollutants is prevented and water quality is restored.
	Soil quality	Soil characteristics provide the best conditions for plant growth and soil health, while chemical and biological soil contamination is prevented.
	Land degradation	No land is lost through soil degradation and desertification and degraded land is rehabilitated.
	Ecosystem diversity	The diversity, functional integrity and connectivity of natural, semi-natural and agri-food ecosystems are conserved and improved.
	Species diversity	The diversity of wild species living in natural and semi-natural ecosystems, as well as the diversity of domesticated species living in agricultural, forestry and fisheries ecosystems is conserved and improved.
	Genetic diversity	The diversity of populations of wild species, as well as the diversity of varieties, cultivars and breeds of domesticated species, is conserved and improved.
	Material use	Material consumption is minimized and reuse, recycling and recovery rates are maximized.
	Energy use	Overall energy consumption is minimized and use of sustainable renewable energy is maximized
	Waste reduction and disposal	Waste generation is prevented and is disposed of in a way that does not threaten the health of humans and ecosystems and food loss/waste is minimized.
	Animal health	Animals are kept free from hunger and thirst, injury and disease.
	Freedom from stress	Animals are kept under species-appropriate conditions and free from discomfort, pain, injury and disease, fear and distress.
Economic Resilience	Internal investment	In a continuous, foresighted manner, the enterprise invests into enhancing its sustainability performance.
	Community investment	Through its investments, the enterprise contributes to sustainable development of a community.
	Long-ranging investment	Investments into production facilities, resources, market infrastructure, shares and acquisitions aim at long-term sustainability rather than maximum short- term profit.
	Profitability	Through its investments and business activities, the enterprise has the capacity to generate a positive net income.
	Stability of production	Production (quantity and quality) is sufficiently resilient to withstand and be adapted to environmental, social and economic shocks.
	Stability of supply	Stable business relationships are maintained with a sufficient number of input suppliers and alternative procurement channels are accessible.
	Stability of market	Stable business relationships are maintained with a sufficient number of buyers, income structure is diversified and alternative marketing channels are accessible.
	Liquidity	Financial liquidity, access to credits and insurance (formal and informal) against economic, environmental and social risk enable the enterprise to withstand shortfalls in payment.
	Risk management	Strategies are in place to manage and mitigate the internal and external risks (i.e. price, production, market, credit, and workforce, social, environmental) that the enterprise could face to withstand their negative impact.
	Food safety	Food hazards are systematically controlled and any contamination of food with potentially harmful substances is avoided.

	Food quality	The quality of food products meets the highest nutritional standards applicable to the respective type of product.
	Product information	Products bear complete information that is correct, by no means misleading and accessible for consumers and all members of the food chain.
	Value creation	Enterprises benefit local economies through employment and through payment of local taxes.
	Local procurement	Enterprises substantially benefit local economies through procurement from local suppliers
Social Well-being	Quality of life	All producers and employees in enterprises of all scales enjoy a livelihood that provides a culturally appropriate and nutritionally adequate diet and allows time for family, rest and culture
	Capacity development	Through training and education, all primary producers and personnel have opportunities to acquire the skills and knowledge necessary to undertake current and future tasks required by the enterprise, as well as the resources to provide for further training and education for themselves and members of their families.
	Fair access to means of production	Primary producers have access to the means of production, including equipment, capital and knowledge.
	Responsible buyers	The enterprise ensures that a fair price is established through negotiations with suppliers that allow them to earn and pay their own employees a living wage, and cover their costs of production, as well as maintain a high level of sustainability in their practices. Negotiations and contracts (verbal or written) are transparent, based on equal power, terminated only for just cause, and terms are mutually agreed upon.
	Rights of suppliers	The enterprises negotiating a fair price explicitly recognize and support in good faith suppliers' rights to freedom of association and collective bargaining for all contracts and agreements.
	Employee relations	Enterprises maintain legally binding transparent contracts with all employees that are accessible and cover the terms of work and employment is compliant with national laws on labour and social security.
	Forced labour	The enterprise accepts no forced, bonded or involuntary labour, neither in its own operations nor those of business partners.
	Child labour	The enterprise accepts no child labour that has a potential to harm the physical or mental health or hinder the education of minors, neither in its own operations nor those of business partners.
	Freedom of association and right to bargaining	All persons in the enterprise can freely execute the rights to: negotiate the terms of their employment individually or as a group; form or adhere to an association defending workers' rights; and collectively bargain, without retribution.
	Non-discrimination	A strict equity and non-discrimination policy is pursued toward all stakeholders; non-discrimination and equal opportunities are explicitly mentioned in enterprise hiring policies, employee or personnel policies (whether written or verbal or code of conduct) and adequate means for implementation and evaluation are in place.
	Gender equality	There is no gender disparity concerning hiring, remuneration, access to resources, education and career opportunities.
	Support to vulnerable people	Vulnerable groups, such as young or elderly employees, women, the disabled, minorities and socially disadvantaged are proactively supported
	Workplace safety and health provisions	The enterprise ensures that the workplace is safe, has met all appropriate regulations, and caters to the satisfaction of human needs in the provision of sanitary facilities, safe and ergonomic work environment, clean water, healthy food, and clean accommodation (if offered).
	Public health	The enterprise ensures that operations and business activities do not limit the healthy and safe lifestyles of the local community and contributes to community health resources and services.
	Cultural diversity	Indigenous knowledge Intellectual property rights related to traditional and cultural knowledge are protected and recognized.

	Food sovereignty	The enterprise contributes to, and benefits from, exercising the right to choose and ownership of their production means, specifically in the preservation and use of traditional, heirloom and locally adapted varieties or breeds
Governance	Mission statement	The enterprise has made its commitment to all areas of sustainability clear to the public, to all personnel and other stakeholders through publishing a mission statement or other similar declaration (such as a code of conduct or vision statement) that is binding for management and employees or members.
	Due diligence	The enterprise is pro-active in considering its external impacts before making decisions that have long-term impacts for any area of sustainability. This is accomplished through the enterprise following appropriate procedures such as risk assessment and others that ensure that stakeholders are informed, engaged and respected.
	Holistic audits	All areas of sustainability in the SAFA dimensions that pertain to the enterprise are monitored internally in an appropriate manner, and wherever possible are reviewed according to recognized sustainability reporting systems.
	Responsibility	Senior management and/or owners of enterprise regularly and explicitly evaluate the enterprise's performance against its mission or code of conduct
	Transparency	All procedures, policies, decisions or decision-making processes are accessible where appropriate publicly, and made available to stakeholders including personnel and others affected by the enterprise's activities.
	Stakeholder dialogue	The enterprise pro-actively identifies stakeholders, which include all those affected by the activities of the enterprise (including any stakeholders unable to claim their rights). It ensures that all are informed, engaged in critical decision making, and that their input is duly considered.
	Grievance procedures	All stakeholders (including as stated above, those who cannot claim their rights, personnel, and any stakeholders in or outside of the enterprise) have access to appropriate grievance procedures, without a risk of negative consequences
	Conflict resolution	Conflicts between stakeholder interests and the enterprise's activities are resolved through collaborative dialogue (i.e. arbitrated, mediated, facilitated, conciliated or negotiated), based on respect, mutual understanding and equal power.
	Legitimacy	The enterprise is compliant with all applicable laws, regulations and standards voluntarily entered into by the enterprise (unless as part of an explicit campaign of non-violent civil disobedience or protest) and international human rights standards (whether legally obligated or not).
	Remedy, restoration and prevention	In case of any legal infringements or any other identified breach of legal, regulatory, international human rights, or voluntary standard, the enterprise immediately puts in place an effective remedy and adequate actions for restoration and further prevention are taken.
	Civic responsibility	Within its sphere of influence, the enterprise supports the improvement of the legal and regulatory framework on all dimensions of sustainability. It does not seek to avoid the impact of human rights, or sustainability standards, or regulation through the corporate veil, relocation, or any other means.
	Resource appropriation	Enterprises do not reduce the existing rights of communities to land, water and resources, and operations are carried after informing affected communities by providing information, and independent advice and building capacity to self- organize for the purposes of representation.
	Sustainability management plan	A sustainability plan for the enterprise is developed which provides a holistic view of sustainability and considers synergies and trade-offs between dimensions, including each of the environmental, economic, social and governance dimensions
	Full cost accounting	The business success of the enterprise is measured and reported taking into account direct and indirect impacts on the economy, society and physical environment (e.g. triple bottom line reporting), and the accounting process makes transparent both direct and indirect subsidies received, as well as direct and indirect costs externalized

Source: based on FAO, 2013a

Annex 4. Median Boxplot graph data

	Sub-theme	Farming System	min	Q1	Median	Q3	max	mean	SD	Range	Count
Environmental integrity	Greenhouse Gases	O	37	47	51	55	70	50.6	6.0	33	205
		C	35	46	51	55	68	50.9	6.8	33	651
	Air Quality	O	49	60	64	69	85	64.6	6.9	36	205
		C	44	57	62	67	83	61.9	6.9	39	651
	Water Withdrawal	O	12	42	50	58	80	50.5	12.3	68	205
		C	10	37	49	57	84	46.8	14.9	74	651
	Water Quality	O	38	50	56	61	76	55.3	7.9	38	205
		C	29	44	49	54	72	49.6	7.2	43	651
	Soil Quality	O	36	47	51	55	67	51.3	5.5	31	205
		C	34	46	49	53	63	49.0	5.0	29	651
	Land Degradation	O	34	49	53	57	72	52.6	6.2	38	205
		C	37	49	53	56	71	52.6	5.3	34	651
	Ecosystem Diversity	O	12	27	32	36	62	31.7	7.1	50	205
		C	10	24	29	33	55	28.7	7.0	45	651
	Species Diversity	O	31	42	47	53	70	47.2	7.4	39	205
		C	26	37	41	46	61	41.7	6.7	35	651
	Genetic Diversity	O	22	42	46	52	74	46.5	8.0	52	205
		C	21	38	43	49	65	43.8	7.6	44	651
	Material Use	O	30	52	59	63	74	57.3	8.2	44	205
		C	23	46	53	59	75	52.7	9.4	52	651
	Energy Use	O	53	63	67	72	85	67.7	6.2	32	205
		C	48	61.5	66	70	80	65.6	6.2	32	651
	Waste Reduction & Disposal	O	34	54	61	68	86	60.7	10.7	52	205
		C	25	45	53	65	86	54.8	12.5	61	651
	Animal Health	O	46	61.75	66.5	72	90	66.6	8.3	44	188
		C	39	61	67	73	94	66.9	9.3	55	606
	Freedom from Stress	O	35	58	63	69	87	63.5	8.4	52	188
		C	33	59	64	70	94	65.0	9.7	61	606
Economic resilience	Internal Investment	O	24	38	45	51	66	44.6	8.5	42	205
		C	14	36	42	47	63	41.5	7.8	49	651
	Community Investment	O	12	26	34	41	63	33.7	10.3	51	205
		C	9	21	27	33	55	27.4	8.3	46	651
	Long-Ranging Investment	O	17	33	41	51	71	42.2	11.9	54	205
		C	12	30	38	45	69	37.7	10.6	57	651
	Profitability	O	31	45	51	56	68	50.6	7.7	37	205
		C	30	45	50	55	69	50.2	7.0	39	651
	Stability of Production	O	31	45	50	55	66	49.7	7.1	35	205
		C	25	45	49	54	65	49.5	6.3	40	651
	Stability of Supply	O	48	63	70	76	90	69.5	9.0	42	205
		C	36	59	65	71	88	64.6	9.3	52	651

	Sub-theme	Farming System	min	Q1	Median	Q3	max	mean	SD	Range	Count
	Stability of Market	O	22	44	55	62	74	53.0	11.3	52	205
		C	19	41	47	53	77	47.2	9.3	58	651
		O	11	30	39	50	69	38.3	13.8	58	205
	Liquidity	C	0	24	34	43	61	34.6	13.0	61	651
		O	32	52	59	66	79	58.7	9.5	47	205
	Risk Management	C	26	46	51	58	76	52.2	8.9	50	651
		O	36	60	67	74	91	66.3	11.0	55	205
	Food Safety	C	33	49	56	66	85	57.2	10.4	52	651
		O	52	65	70	77	94	71.0	8.0	42	205
	Food Quality	C	36	61	67	73	90	67.0	8.4	54	651
	Product Information	O	0	13	21	30	52	21.4	11.8	52	205
		C	0	7	13	19	52	13.6	9.1	52	651
		O	21	36	40	45	65	40.4	7.8	44	205
	Value Creation	C	22	34.5	39	43	65	38.9	6.6	43	651
	Local Procurement	O	0	25	44	53	100	41.4	16.5	100	205
		C	0	25	42	49	100	40.7	13.1	100	651
		O	32	54	59	64	74	58.6	7.2	42	205
	Quality of Life	C	30	53	59	63	76	57.8	7.4	46	651
	Capacity Development	O	0	14	23	32	79	25.5	16.6	79	205
		C	0	9	23	35	79	23.2	17.5	79	651
	Fair Access to Means of Production	O	27	51	59	70	92	60.4	13.1	65	205
		C	13	48	58	67.5	92	58.5	12.6	79	651
	Responsible Buyers	O	14	30	35	40	66	35.4	8.1	52	205
		C	11	28	32	35	65	31.6	7.3	54	651
	Rights of Suppliers	O	0	14	24	36	79	24.2	10.9	79	205
		C	0	11	16	29	79	19.9	10.7	79	651
	Employment Relations	O	27	48	52	57	74	52.7	6.8	47	205
		C	27	49	55	58	76	53.7	6.9	49	651
Social wellbeing		O	0	19	35	39	57	28.7	16.3	57	205
	Forced Labour	C	0	22	35	39	58	28.2	16.2	58	651
		O	0	42	45	45	70	43.2	5.9	70	205
	Child Labour	C	0	42	45	45	76	43.9	5.4	76	651
	Freedom of Association and Right to Bargaining	O	0	16	33	38	69	27.6	16.5	69	205
		C	0	16	33	38	69	27.3	17.0	69	651
	Non Discrimination	O	0	38	53	64	74	50.1	19.9	74	205
		C	0	38	49	64	74	49.4	17.1	74	651
		O	0	41	52	72	87	52.4	23.6	87	205
	Gender Equality	C	0	41	46	72	87	50.8	21.0	87	651
	Support to Vulnerable People	O	0	14	30	35	57	26.0	16.6	57	205
		C	0	14	30	35	59	22.8	15.3	59	651
		O	33	54	62	71	86	62.6	11.2	53	205

	Sub-theme	Farming System	min	Q1	Median	Q3	max	mean	SD	Range	Count
	Workplace Safety and Health Provisions	C	33	52	58	65	85	58.6	9.3	52	651
		O	42	59	67	76	91	67.7	10.8	49	205
	Public Health	C	37	51	57	67	89	59.5	10.9	52	651
	Indigenous Knowledge	O	49	75	80	91	100	81.4	12.9	51	205
		C	41	58	80	83	100	75.1	16.6	59	651
		O	26	53	57	65	78	57.8	9.3	52	205
	Food Sovereignty	C	28	53	58	63	77	57.3	8.4	49	651
Governance	Mission Statement	O	0	18	26	50	100	34.3	25.5	100	205
		C	0	0	26	50	100	29.3	25.3	100	651
		O	24	48	55	64	80	55.5	11.5	56	205
	Due Diligence	C	19	42	48	54	76	48.3	9.7	57	651
		O	0	6	17	31	62	19.8	16.1	62	205
	Holistic Audits	C	0	6	13	20	53	13.0	9.6	53	651
		O	12	35	43	50	71	43.4	12.0	59	205
	Responsibility	C	12	29	36	43	73	37.0	9.6	61	651
		O	0	16	27	40	61	27.5	13.9	61	205
	Transparency	C	0	15	21	29	60	21.8	11.3	60	651
	Stakeholder Dialogue	O	33	66	75	80	100	72.6	11.4	67	205
		C	21	60	69	76	100	68.3	11.6	79	651
	Grievance Procedures	O	32	56	65	72	92	61.7	10.9	60	205
		C	0	50	57	67	87	58.2	13.1	87	651
	Conflict Resolution	O	44	80	84	91	100	83.9	9.9	56	205
		C	34	73	82	87	100	80.4	11.0	66	651
		O	32	58	64	71	93	64.6	10.4	61	205
	Legitimacy	C	32	52	58	64	96	58.3	10.7	64	651
	Remedy, Restoration & Prevention	O	43	70	79	93	100	79.9	13.1	57	205
		C	28	66	77	87	100	75.7	12.7	72	651
	Civic Responsibility	O	0	10	27	42	70	27.6	20.4	70	205
		C	0	0	15	27	74	17.1	15.4	74	651
	Resource Appropriation	O	32	58	62	66	78	61.5	7.7	46	205
		C	29	55	60	65	78	59.7	7.4	49	651
	Sustainability Management Plan	O	0	27	39	51	84	38.3	17.7	84	205
		C	0	23	34	45	80	34.7	16.2	80	651
	Full-Cost Accounting	O	0	12	26	50	100	34.0	25.5	100	205
		C	0	0	26	50	100	28.9	25.1	100	651

Annex 5: Means of degree of goal achievement for each sub-theme by farming system and significance levels in t-test P-values, and mean ranking through Mann Whitney U test

Dimension	Sub-theme	Mean					Mean Rank					
		Organic	Conv.	Diff O-C	t-test	P-Values	Organic (N=204)	Conv. (N=645)	Diff O-C	Mann-Whitney U	Z	Sig. (2-tailed)
Environmental Integrity	Greenhouse Gases	50.61	50.96	(0.35)	.660	.510	417.94	427.23	-9.30	64349.000	-.473	.637
	Air Quality	64.58	61.93	2.65	-4.800	.000***	489.09	404.73	84.36	52716.000	-4.287	.000***
	Water Withdrawal	50.51	46.88	3.63	-3.154	.002***	474.27	409.42	64.86	55738.000	-3.296	.001***
	Water Quality	55.29	49.60	5.69	-9.576	.000***	553.44	384.38	169.07	39587.500	-8.590	.000***
	Soil Quality	51.26	49.04	2.23	-5.370	.000***	494.70	402.96	91.75	51571.000	-4.665	.000***
	Land Degradation	52.62	52.65	(0.03)	.057	.954	424.13	425.28	-1.15	65611.500	-.059	.953
	Ecosystem Diversity	31.73	28.73	3.00	-5.338	.000***	501.55	400.79	100.76	50174.000	-5.120	.000***
	Species Diversity	47.22	41.79	5.43	-9.783	.000***	556.67	383.36	173.31	38929.500	-8.807	.000***
	Genetic Diversity	46.53	43.88	2.65	-4.308	.000***	489.92	404.47	85.46	52545.500	-4.342	.000***
	Material Use	57.20	52.79	4.41	-5.980	.000***	516.93	395.92	121.01	47036.000	-6.146	.000***
	Energy Use	67.73	65.63	2.09	-4.184	.000***	480.28	407.51	72.77	54512.000	-3.699	.000***
	Waste Reduction & Disposal	60.60	54.86	5.74	-5.881	.000***	514.28	396.76	117.52	47577.000	-5.968	.000***
	Animal Health	66.58	66.89	(0.31)	.408	.684	392.47	395.79	-3.32	55813.500	-.174	.862
	Freedom from Stress	63.45	65.00	(1.55)	1.965	.050	371.49	402.30	-30.81	51890.500	-1.616	.106
Economic Resilience	Internal Investment	44.54	41.60	2.94	-4.598	.000***	486.72	405.48	81.24	53199.500	-4.127	.000***
	Community Investment	33.64	27.42	6.21	-8.774	.000***	541.75	388.08	153.67	41973.500	-7.806	.000***
	Long-Ranging Investment	42.20	37.76	4.45	-5.057	.000***	488.58	404.89	83.68	52820.500	-4.250	.000***
	Profitability	50.62	50.15	0.47	-.821	.412	440.41	420.13	20.28	62646.500	-1.031	.303
	Stability of Production	49.68	49.47	0.21	-.399	.690	433.27	422.39	10.88	64103.500	-.553	.580
	Stability of Supply	69.49	64.68	4.81	-6.487	.000***	514.92	396.56	118.36	47447.000	-6.012	.000***
	Stability of Market	52.93	47.22	5.71	-7.233	.000***	528.63	392.23	136.40	44650.500	-6.928	.000***
	Liquidity	38.38	34.62	3.76	-3.545	.000***	475.17	409.13	66.04	55555.500	-3.356	.001***
	Risk Management	58.76	52.19	6.57	-8.990	.000***	556.49	383.41	173.07	38967.000	-8.791	.000***

Dimension	Sub-theme	Mean					Mean Rank					
		Organic	Conv.	Diff O-C	t-test	P-Values	Organic (N=204)	Conv. (N=645)	Diff O-C	Mann-Whitney U	Z	Sig. (2-tailed)
	Food Safety	66.32	57.22	9.10	-10.712	.000***	569.98	379.15	190.83	36214.500	-9.691	.000***
	Food Quality	70.94	67.05	3.89	-5.799	.000***	509.60	398.24	111.36	48531.500	-5.657	.000***
	Product Information	21.39	13.58	7.81	-9.980	.000***	551.82	384.89	166.93	39919.000	-8.493	.000***
	Value Creation	40.34	38.95	1.39	-2.503	.013**	460.63	413.73	46.90	58522.000	-2.383	.017***
	Local Procurement	41.47	40.76	0.70	-.625	.532	445.18	418.62	26.56	61674.000	-1.366	.172
Social Well-being	Quality of Life	58.65	57.84	0.81	-1.371	.171	447.76	417.80	29.96	61146.500	-1.522	.128
	Capacity Development	25.44	23.20	2.24	-1.614	.107*	455.11	415.48	39.64	59647.000	-2.018	.044**
	Fair Access to Means of Production	60.34	58.49	1.84	-1.795	.073**	454.30	415.73	38.57	59812.500	-1.961	.050**
	Responsible Buyers	35.36	31.63	3.73	-6.201	.000***	505.59	399.51	106.07	49350.500	-5.397	.000***
	Rights of Suppliers	24.16	19.89	4.26	-4.928	.000***	500.72	401.05	99.67	50342.500	-5.178	.000***
	Employment Relations	52.67	53.70	(1.03)	1.884	.060**	391.92	435.46	-43.54	59042.500	-2.219	.026**
	Forced labour	28.61	28.27	0.34	-.263	.793	440.22	420.19	20.03	62685.000	-1.033	.302
	Child labour	43.18	43.96	(0.78)	1.758	.079**	396.38	434.05	-37.67	59952.500	-2.092	.036**
	Freedom of Association and Right to Bargaining	27.58	27.40	0.18	-.137	.891	431.30	423.01	8.29	64505.500	-.424	.672
	Non Discrimination	50.04	49.46	0.58	-.405	.685	451.01	416.77	34.24	60484.000	-1.790	.073
	Gender Equality	52.31	50.84	1.47	-.846	.398	449.81	417.15	32.66	60728.500	-1.722	.085
	Support to Vulnerable People	25.93	22.81	3.12	-2.488	.013**	463.20	412.92	50.28	57997.500	-2.588	.010**
	Workplace Safety and Health Provisions	62.61	58.50	4.12	-5.258	.000***	494.89	402.89	92.00	51531.500	-4.673	.000***
	Public Health	67.68	59.49	8.18	-9.366	.000***	557.04	383.24	173.81	38853.000	-8.827	.000***
	Indigenous Knowledge	81.35	75.25	6.10	-4.818	.000***	481.85	407.02	74.83	54192.000	-3.837	.000***

Dimension	Sub-theme	Mean					Mean Rank					
		Organic	**Conv.**	**Diff O-C**	**t-test**	**P-Values**	**Organic (N=204)**	**Conv. (N=645)**	**Diff O-C**	**Mann-Whitney U**	**Z**	**Sig. (2-tailed)**
	Food Sovereignty	57.77	57.35	0.42	-.613	.540	432.78	422.54	10.25	64202.000	-.521	.603
Governance	Mission Statement	34.24	29.36	4.88	-2.401	.017**	463.22	412.91	50.30	57994.000	-2.629	.009***
	Due Diligence	55.47	48.31	7.17	-8.773	.000***	544.04	387.35	156.69	41506.500	-7.958	.000***
	Holistic Audits	19.67	13.04	6.63	-7.139	.000***	493.51	403.33	90.17	51814.500	-4.603	.000***
	Responsibility	43.45	37.04	6.41	-7.818	.000***	531.37	391.36	140.01	44091.500	-7.127	.000***
	Transparency	27.42	21.76	5.66	-5.860	.000***	502.77	400.40	102.37	49924.500	-5.200	.000***
	Stakeholder Dialogue	72.54	68.38	4.16	-4.458	.000***	494.44	403.04	91.40	51624.000	-4.644	.000***
	Grievance Procedures	61.67	58.27	3.40	-3.349	.001***	474.74	409.27	65.47	55643.000	-3.343	.001***
	Conflict Resolution	83.86	80.48	3.37	-3.895	.000***	488.90	404.79	84.11	52754.000	-4.278	.000***
	Legitimacy	64.60	58.34	6.26	-7.300	.000***	539.79	388.70	151.09	42373.500	-7.679	.000***
	Remedy, Restoration & Prevention	79.86	75.68	4.18	-4.061	.000***	489.04	404.74	84.30	52725.000	-4.306	.000***
	Civic Responsibility	27.67	17.16	10.51	-7.809	.000***	521.45	394.50	126.95	46115.000	-6.502	.000***
	Resource Appropriation	61.47	59.64	1.83	-3.034	.002***	476.59	408.68	67.91	55265.500	-3.454	.001***
	Sustainability Management Plan	38.32	34.73	3.59	-2.701	.007***	466.56	411.86	54.71	57311.500	-2.779	.005***
	Full-Cost Accounting	33.91	29.02	4.88	-2.411	.016**	463.72	412.75	50.97	57890.500	-2.661	.008***

Significance at ***0.01, **0.05 and *0.1. Conv. = Conventional

Annex 6: Mixed effect regression model

Mixed model with farm as a random factor for each variable in the valist (mission statement to food sovereignty). The mixed, Contrast and Margins for the interactions are present between organic and conventional farms, P<0.05, ns =not significant, Significant level of sub-theme scores for the system and interaction effects

Subtheme, system, county and system and county

Environmental Integrity

	System			County				System and County						
Sub-theme	**P**	**Org**	**Con**	**P**	**Ki**	**Mu**	**Ma**	**P**	**Org_Ki**	**Org_Mu**	**Org_Ma**	**Con_Ki**	**Con_Mu**	**Con_Ma**
Greenhouse Gases	<0.05	51.6(±0.4) a	50.6(±0.2)b	<0.05	49.7(±0.3)	46.2(±0.3)	56.2(±0.3)	p<0.05	50.3(±0.6)a	48.3(±0.5)	56.0(±0.8)b	49.6(±0.4)a	45.6(±0.3)	56.2(±0.3)b
Air Quality	<0.05	65.1(±0.5) a	61.6(±0.2)b	<0.05	60.0(±0.4)	61.3(±0.4)	66.0(±0.4)	p<0.05	63.1(±0.8)a	64.7(±0.7)ab	67.3(±1.2)c	58.9(±0.5)	60.1(±0.4)	65.6(±0.4)bc
Water Withdrawal	ns	49.0(±1.0)	47.1(±0.6)	<0.05	47.8(±0.8)	52.4(±0.7)	42.8(±1.0)	p<0.05	53.7(±1.1)c	51.1(±1.3)c	42.7(±2.3)ab	46.0(±0.9)b	52.8(±1.3)c	42.9(±1.0)a
Water Quality	<0.05	54.2(±0.6) a	49.7(±0.3)b	<0.05	48.9(±0.4)a	55.5(±0.4)	48.0(±0.4)a	p<0.05	54.2(±0.7)b	59.4(±0.8)	49.2(±1.2)a	47.2(±0.5)a	54.3(±0.4)	47.7(±0.4)a
Soil Quality	<0.05	51.0(±0.4) a	49.0(±0.2)b	<0.05	49.1(±0.3)a	50.3(±0.3)	49.0(±0.3)a	p<0.05	52.1(±0.6)d	51.1(±0.7)cd	50.0(±0.8)bc	48.2(±0.4)a	50.2(±0.4)c	48.8(±0.3)ab
Land Degradation	ns	52.6(±0.5)	52.6(±0.2)	<0.05	53.4(±0.3)a	51.4(±0.3)	53.1(±0.3)a	p<0.05	54.0(±0.7)b	51.1(±0.7)a	52.8(±1.0)ab	53.1(±0.4)b	51.5(±0.3)a	53.1(±0.4)b
Ecosystem Diversity	<0.05	31.8(±0.5) a	28.6(±0.2)b	<0.05	25.3(±0.4)	32.0(±0.3)	30.6(±0.4)	p<0.05	28.6(±0.7)a	34.9(±0.6)	31.8(±1.2)b	24.3(±0.5)	31.1(±0.4)b	30.1(±0.4)ab
Species Diversity	<0.05	46.8(±0.5) a	41.8(±0.2)b	<0.05	39.9(±0.4)	47.0(±0.4)	42.1(±0.4)	p<0.05	44.7(±0.7)a	51.1(±0.7)	44.5(±1.2)a	38.3(±0.5)	45.7(±0.5)a	41.2(±0.3)
Genetic Diversity	<0.05	46.7(±0.5) a	43.7(±0.3)b	<0.05	40.2(±0.4)	46.4(±0.4)a	46.3(±0.5)a	p<0.05	42.3(±0.8)	50.6(±0.7)	47.0(±1.2)a	39.6(±0.4)	45.1(±0.5)a	46.1(±0.5)a
Material Use	<0.05	55.7(±0.6) a	52.9(±0.3)b	<0.05	53.8(±0.5)	57.0(±0.4)	50.3(±0.6)	p<0.05	60.8(±0.6)	57.2(±0.8)b	49.6(±1.4)a	51.5(±0.6)a	56.9(±0.5)b	50.5(±0.7)a
Energy Use	<0.05	68.0(±0.4) a	65.5(±0.2)b	<0.05	66.2(±0.4)	63.7(±0.3)	68.3(±0.4)	p<0.05	68.7(±0.7)b	65.9(±0.6)a	69.5(±0.9)b	65.3(±0.5)a	63.0(±0.4)	67.9(±0.4)b
Waste Reduction & Disposal	<0.05	58,3(±0.6) a	55.2(±0.4)b	<0.05	52.0(±0.5)	66.9(±0.6)	49.1(±0.6)	p<0.05	59.2(±0.6)	68.2(±1.0)b	48.2(±1.4)a	49.8(±0.6)a	66.5(±0.7)b	49.5(±0.7)a
Animal Health	ns	66.0(±0.7)	66.7(±0.4)	<0.05	63.5(±0.4)	67.5(±0.6)a	68.6(±0.6)a	ns	67.1(±0.8)b	67.5(±1.0)b	63.7(±1.4)a	62.4(±0.5)a	68.9(±0.6)b	68.7(±0.6)b
Freedom from Stress	ns	63.6(±0.6)	64.6(±0.4)	<0.05	61.2(±0.4)	63.6(±0.6)	67.9(±0.6)	p<0.05	64.2(±0.8)b	62.3(±1.1)ab	64.2(±1.3)b	60.2(±0.5)a	64.1(±0.7)b	69.1(±0.6)

Note: margins showing letters in the group are significantly different at the 5% level

Economic Resilience

	System			County				System and County						
Sub-theme	**P**	**Org**	**Con**	**P**	**Ki**	**Mu**	**Ma**	**P**	**Org_Ki**	**Org_Mu**	**Org_Ma**	**Con_Ki**	**Con_Mu**	**Con_Ma**
Internal Investment	p<0.05	43.4(±)0.6	41.8(±0.3)	p<0.05	43.3(±0.5)a	44.2(±0.4)a	39.1(±0.5)	p<0.05	48.4(±0.8)	43.3(±0.9)bc	39.0(±1.2)a	41.7(±0.6)b	44.5(±0.4)c	39.2(±0.5)a
Community Investment	p<0.05	31.4(±0.6)	27.6(±0.3)	p<0.05	27.9(±0.5)	34.0(±0.4)	23.9(±0.4)	p<0.05	35.4(±1.0)b	37.7(±0.9)b	21.7(±1.0)	25.5(±0.6)a	32.8(±0.5)	24.6(±0.5)a
Long-Ranging Investment	p<0.05	41.0(±0.8)	37.9(±0.3)	p<0.05	33.8(±0.6)a	46.9(±0.6)	35.2(±0.6)a	p<0.05	40.6(±1.1)	47.3(±1.4)b	35.3(±1.6)a	31.7(±0.6)	46.8(±0.6)b	35.1(±0.5)a
Profitability	ns	49.5(±0.5)a	50.3(±0.3)a	p<0.05	52.0(±0.4)a	51.5(±0.4)a	47.0(±0.4)	p<0.05	53.9(±0.7)	50.2(±0.8)a	44.7(±1.1)	51.4(±0.5)a	51.9(±0.4)a	47.8(±0.4)
Stability of Production	ns	48.7(±0.5)a	49.6(±0.3)a	p<0.05	50.1(±0.3)a	50.6(±0.4)a	47.5(±0.4)	p<0.05	51.6(±0.6)c	50.1(±0.8)abc	44.8(±1.0)	49.6(±0.4)b	50.8(±0.4)c	48.3(±0.4)a
Stability of Supply	p<0.05	69.6(±0.6)	64.5(±0.4)	p<0.05	64.6(±0.6)a	64.4(±0.4)a	68.0(±0.6)	p<0.05	70.0(±1.1)c	68.8(±0.9)bc	70.0(±1.3)bc	62.8(±0.7)a	63.1(±0.5)a	67.3(±0.6)b
Stability of Market	p<0.05	50.9(±0.7)	47.5(±0.3)	p<0.05	53.3(±0.5)	48.5(±0.6)	43.5(±0.5)	p<0.05	57.3(±1.1)	53.7(±1.1)b	42.3(±1.5)a	52.0(±0.6)b	46.9(±0.7)	43.9(±0.5)a

Liquidity	p<0.05	37.2(±1.0)	34.6(±0.5)	p<0.05	31.8(±0.8)a	40.5(±0.7)	33.4(±0.8)a	p<0.05	38.5(±1.5)c	41.6(±1.4)c	31.8(±2.2)ab	29.7(±0.9)a	40.1(±0.9)c	33.9(±0.8)b
Risk Management	p<0.05	57.0(±0.6)	52.5(±0.3)	p<0.05	51.6(±0.4)	61.3(±0.5)	48.0(±0.5)	p<0.05	57.1(±0.7)	65.2(±0,7)	48.9(±1.5)ab	49.8(±0.5)b	60.1(±0.6)	47.7(±0.5)a
Food Safety	p<0.05	64.3(±0.8)	57.6(±0.3)	p<0.05	57.9(±0.5)	67.6(±0.5)	52.5(±0.6)	p<0.05	65.7(±0.9)c	72.5(±0.8)	55.1(±2.1)ab	55.4(±0.6)b	66.1(±0.6)c	51.6(±0.5)a
Food Quality	p<0.05	71.2(±0.6)	66.7(±0.3)	p<0.05	67.6(±0.4)	63.8(±0.4)	71.8(±0.6)	p<0.05	75.4(±0.7)c	65.3(±0.6)a	73.1(±1.5)bc	65.2(±0.5)a	53.4(±0.5)	71.3(±0.5)b
Product Information	p<0.05	19.1(±0.7)	13.7(±0.4)	p<0.05	17.6(±0.7)a	16.3(±0.5)a	11.4(±0.4)	p<0.05	26.9(±1.3)	21.5(±1.0)	9.7(±1.2)a	14.7(±0.9)b	14.5(±0.6)b	11.9(±0.4)a
Value Creation	p<0.05	39.4(±0.5)a	39.2(±0.2)a	p<0.05	40.3(±0.4)	42.5(±0.4)	35.2(±0.3)	p<0.05	40.3(±0.8)b	42.8(±0.9)c	35.2(±0.9)a	40.3(±0.5)b	42.4(±0.4)c	35.2(±0.3)a
Local Procurement	ns	41.2(±1.0)a	40.7(±0.4)a	p<0.05	32.4(±0.7)	49.5(±0.7)	40.4(±0.7)	p<0.05	34.5(±1.4)a	49.6(±2.0)c	39.3(±1.9)b	31.7(±0.7)a	49.4(±0.7)c	40.7(±0.8)b

Note: margins sharing a letter in the group label are not significantly different at the 5% level

Social Well-being

	System			County				System and County						
Sub-theme	**P**	**Org**	**Con**	**P**	**Ki**	**Mu**	**Ma**	**P**	**Org_Ki**	**Org_Mu**	**Org_Ma**	**Con_Ki**	**Con_Mu**	**Con_Ma**
Quality of Life	ns	57.8(±0.6)a	57.9(±0.3)a	ns	58.1(±0.4)b	57.9(±0.5)ab	56.6.(±0.5)a	p<0.05	60.4(±0.6)c	59.2(±0.8)abc	54.0(±1.3)	58.7(±0.4)b	57.5(±0.6)ab	57.5(±0.5)a
Capacity Development	ns	23.5(±1.2)a	23.5(±0.7)a	ns	25.3(±0.9)a	27.6(±1.0)a	18.0(±1.1)a	ns	27.3(±1.5)b	28.7(±2.0)b	15.0(±2.4)a	24.7(±1.1)b	27.2(±1.2)b	19.0(±1.2)a
Fair Access to Means of Production	ns	59.6(±0.9)a	58.5(±0.5)a	p<0.05	57.0(±0.6)a	58.2(±0.6)a	61.1(±0.8)	ns	63.6(±1.3)d	58.6(±1.6)bc	57.1(±1.8)ab	54.9(±0.7)a	61.9(±0.8)cd	58.5(±0.9)b
Responsible Buyers	<0.05	34.2(±0.5)	31.7(±0.3)	p<0.05	34.3(±0.5)	32.7(±0.4)	30.2(±0.4)	p<0.05	39.8(±0.9)	33.7(±0.7)b	29.6(±0.9)a	32.5(±0.6)b	32.4(±0.5)b	30.4(±0.4)a
Rights of Suppliers	<0.05	21.9(±0.6)	20.5(±0.4)	p<0.05	26.6(±0.7)	24.2(±0.5)	12.3(±0.4)	p<0.05	29.5(±1.2)	24.5(±0.8)b	12.4(±0.8)a	25.6(±0.8)b	24.2(±0.6)b	12.3(±0.4)a
Employment Relations	<0.05	52.5(±0.5)	53.7(±0.3)	p<0.05	54.4(±0.4)b	52.6(±0.4)a	53.3(±0.5)ab	ns	53.2(±0.7)ab	52.5(±0.7)a	51.6(±1.3)a	54.7(±0.4)b	52.6(±0.5)a	54.7(±0.4)ab
Forced labour	ns	27.7(±1.2)a	28.2(±0.6)a	p<0.05	35.8(±0.7)	21.1(±1.0)	27.8(±1.0)	p<0.05	36.8(±1.1)c	22.3(±2.0)a	24.4(±2.7)ab	35.4(±0.9)c	20.7(±1.2)a	28.9(±0.9)b
Child labour	ns	43.1(±0.5)a	43.9(±0.2)a	ns	43.6(±0.4)a	43.7(±0.2)a	43.9(±0.4)a	ns	42.8(±0.7)a	42.9(±1.3)a	43.7(±0.4)a	43.9(±0.5)a	43.7(±0.3)a	44.2(±0.3)a
Freedom of Association and Right to Bargaining	ns	26.5(±1.2)a	27.5(±0.6)a	p<0.05	36.7(±0.7)	19.8(±1.0)	25.8(±1.0)	ns	35.8(±1.1)c	21.7(±1.9)a	22.5(±2.8)ab	36.9(±0.8)c	19.2(±1.2)a	26.8(±1.0)b
Non Discrimination	ns	48.1(±1.4)a	49.6(±0.6)a	p<0.05	58.2(±0.7)	43.8(±1.3)a	46.2(±1.0)a	p<0.05	61.6(±1.2)	42.7(±2.4)a	40.9(±3.2)a	57.2(±0.8)	44.2(±1.5)a	47.9(±0.9)
Gender Equality	ns	49.8(±1.7)a	51.2(±0.8)a	p<0.05	61.9(±0.9)	45.4(±1.4)a	45.8(±1.3)a	p<0.05	67.0(±1.4)	40.4(±3.8)a	43.1(±2.6)a	60.3(±1.1)	46.1(±1.7)a	47.6(±1.3)a
Support to Vulnerable People	<0.05	23.7(±1.0)a	23.1(±0.6)a	p<0.05	32.2(±0.8)	20.1(±1.0)a	18.1(±0.8)a	p<0.05	35.7(±1.3)	21.4(±1.9)a	14.4(±2.0)	31.1(±0.9)	19.7(±1.2)a	19.1(±0.8)a
Workplace Safety and Health Provisions	<0.05	61.3(±0.8)	58.8(±0.3)	p<0.05	59.0(±0.5)	64.9(±0.6)	54.5(±0.6)	p<0.05	58.7(±0.9)bc	70.4(±0.9)	55.0(±2.0)ab	59.1(±0.6)c	63.2(±0.7)	54.4(±0.5)a
Public Health	<0.05	66.1(±0.7)	59.8(±0.3)	p<0.05	56.3(±0.5)a	71.3(±0.5)	56.0(±0.6)a	p<0.05	63.9(±0.8)	76.1(±0.8)	58.5(±1.8)b	53.9(±0.6)a	70.2(±0.6)	55.2(±0.5)ab
Indigenous Knowledge	<0.05	80.7(±0.9)	74.7(±0.6)	p<0.05	68.2(±0.8)	79.2(±1.0)a	80.6(±0.7)a	ns	84.1(±1.4)b	80.1(±1.5)ab	78.2(±1.8)a	63.2(±1.0)	78.9(±1.2)a	81.3(±0.8)ab
Food Sovereignty	ns	57.6(±0.7)a	57.3(±0.3)a	p<0.05	57.5(±0.5)a	57.3(±0.5)a	57.4(±0.5)a	p<0.05	57.4(±1.0)a	58.8(±1.0)a	56.6(±1.3)a	57.5(±0.6)a	56.8(±0.6)a	57.7(±0.5)a

Note: margins sharing a letter in the group label are not significantly different at the 5% level

Good Governance

	System			County				System and County						
Sub-theme	**P**	**Org**	**Con**	**P**	**Ki**	**Mu**	**Ma**	**P**	**Org_Ki**	**Org_Mu**	**Org_Ma**	**Con_Ki**	**Con_Mu**	**Con_Ma**

Mission Statement	ns	30.5(±1.6)a	30.0(±1)a	p<0.05	35.4(±1.3)a	35.8(±1.7)a	19.7(±1.3)	p<0.05	44.3(±2)	33.4(±3.2)b	15.0(±2.9)a	32.6(±1.6)b	36.6(±2)b	21.2(±1.4)a
Due Diligence	p<0.05	53.7(± 0.8)	48.6(± 0.4)	p<0.05	50.2(±0.6)	54.8(±0.6)	44.7(±0.6)	p<0.05	57.9(±1.2)c	57.8(±1.1)c	45.9(±1.8)ab	47.8(±0.6)b	53.8(±0.6)	44.3(±0.5)a
Holistic Audits	p<0.05	17.1(±0.8)	13.2(±0.4)	p<0.05	20.1(±0.7)	12.9(±0.5)	9.9(±0.6)	p<0.05	33.1(±1.5)	12.1(±1.1)ab	7.0(±1.4)	16.0(±0.7)	13.1(±0.6)b	10.8(±0.6)a
Responsibility	p<0.05	41.3(±0.7)	37.2(±0.4)	p<0.05	39.5(±0.6)	41.3(±0.6)	34.0(±0.5)	p<0.05	47.4(±1.3)a	45.1(±1.1)a	31.9(±1.3)	37.0(±0.7)	40.0(±0.7)	34.7(±0.5)
Transparency	p<0.05	25.3(±0.9)	21.9(±0.4)	p<0.05	27.4(±0.7)	21.8(±0.7)	19.2(±0.7)	p<0.05	35.0(±1.4)	25.1(±1.2)c	16.5(±1.9)a	25.1(±0.8)c	20.7(±0.9)b	20.1(±0.7)ab
Stakeholder Dialogue	p<0.05	72.0(±1.0)	68.3(±0.4)	ns	68.5(±0.6)a	69.1(±0.7)a	69.7(±0.8)a	p<0.05	72.0(±1.2)bc	74.6(±1.1)c	69.4(±2.3)ab	67.4(±0.7)a	67.4(±0.8)a	69.8(±0.8)b
Grievance Procedures	p<0.05	61.6(±0.8)	58.0(±0.5)	p<0.05	56.8(±0.5)a	58.2(±0.8)a	61.4(±0.8)	p<0.05	53.5(±1.0)c	59.6(±1.3)ab	61.7(±1.9)abc	54.7(±0.6)	57.8(±1.0)a	61.4(±0.8)bc
Conflict Resolution	p<0.05	83.5(±0.9)	80.4(±0.4)	ns	80.7(±0.5)a	81.0(±0.5)a	81.7(±0.9)a	p<0.05	84.5(±1.0)c	81.4(±0.8)c	81.9(±2.3)abc	79.4(±0.6)a	80.0(±0.7)ab	81.6(±0.9)b
Legitimacy	p<0.05	62.7(±0.6)	58.5(±0.4)	p<0.05	55.8(±0.4)a	67.9(±0.7)	55.0(±0.4)a	p<0.05	63.2(±0.7)	71.2(±1.2)	54.1(±1.0)ab	53.5(±0.5)a	66.8(±0.9)	55.2(±0.4)b
Remedy, Restoration & Prevention	p<0.05	78.9(±1.0)	75.5(±0.5)	p<0.05	74.9(±0.7)	76.9(±0.8)a	77.1(±0.8)a	p<0.05	85.9(±1.1)	75.9(±1.4)b	75.5(±2.2)ab	71.4(±0.8)a	77.3(±0.9)b	77.6(±0.8)b
Civic Responsibility	p<0.05	24.5(±1.2)	17.5(±0.6)	p<0.05	19.7(±1.0)	25.6(±1.1)	12.6(±0.8)	p<0.05	29.1(±2.0)b	34.6(±2.3)b	10.6(±2.1)a	16.7(±1.1)	22.7(±1.2)	13.2(±0.8)a
Resource Appropriation	p<0.05	61.1(±0.6)	59.5(±0.3)	p<0.05	58.6(±0.4)	60.5(±0.4)a	60.6(±0.5)a	p<0.05	62.9(±0.9)c	60.8(±0.7)bc	59.8(±1.5)abc	57.2(±0.5)a	60.4(±0.4)b	60.9(±0.5)bc
Sustainability Management Plan	ns	35.6(±1.2)a	35.0(±0.6)a	p<0.05	33.6(±0.8)	42.9(±0.9)	29.1(±1.0)	p<0.05	42.3(±1.6)b	41.4(±1.9)b	24.0(±2.7)	30.9(±0.9)a	43.4(±1.1)b	30.7(±1.0)a
Full-Cost Accounting	ns	30.3(±1.6)a	29.6(±1.0)a	p<0.05	35.2(±1.3)a	35.4(±1.7)a	19.4(±1.2)	p<0.05	44.0(±2.1)	32.8(±3.2)b	15.2(±2.9)a	32.5(±1.6)b	36.3(±2.0)b	20.7(±1.4)a

Note: margins sharing a letter in the group label are not significantly different at the 5% level

Annex 7: Indicators system, county, significant level of indicator scores for the system and interaction effects

Environmental Integrity

Sub-theme	Indicator	P	Org	Con	P	Machakos	Kirinyaga	Murang'a
Ecosystem Diversity	00202_AgroForestrySystems_Calculated	ns	5.67(±1.2)a	5.27(±0.6)a	P<0.05	3.41(±0.8)	12.61(±1.4)	0.34(±0.1)
	00204_WoodlandsDeforestation	ns	6.32(±0.1)a	6.44(±0.1)a	P<0.05	5.94(±0.1)	6.74(±0.1)	6.58(±0.1)
	00208_WoodlandsShareAgriculturalLand_Calculated	ns	8.53(±1.1)a	6.5(±0.6)a	P<0.05	2.53(±0.5)	6.83(±0.9)	11.82(±1.1)
	00215_ArableLandShareTemporaryGrassland_Calculated	ns	6.99(±0.7)a	5.91(±0.4)a	P<0.05	0.48(±0.2)	7.57(±0.8)	10.76(±0.8)
	00222_PermanentGrasslandsShareOfAgriculturalArea_Calculated	ns	2.7(±0.7)a	3.7(±0.3)a	P<0.05	7.49(±0.7)	1.08(±0.3)	1.56(±0.4)
	00233_NoUseSynthChemFungicides	ns	31.58(±0.7)a	31.22(±0.4)a	P<0.05	28.28(±0.7)	24.25(±0.8)	41.38(±0.2)
	00234_NoUseSynthChemInsecticides	P<0.05	33.89(±0.7)	28.16(±0.4)	P<0.05	27.13(±0.6)	21.78(±0.9)	39.65(±0.3)
	00253_PermanentGrasslandsExtensivelyManaged	ns	16.92(±2.4)a	13.94(±0.9)a	P<0.05	37.17(±2.4)	2.44(±0.7)	2.98(±0.9)
	00257_1_PesticidesToxicityBees	P<0.05	18.38(±1.2)	12.52(±0.6)	P<0.05	6.05(±0.9)	8.78(±0.9)	27.23(±1.2)
	00257_2_PesticidesToxicityAquaticOrganisms	P<0.05	17.75(±1.2)	10.01(±0.6)	P<0.05	4.92(±0.8)a	3.44(±0.6)a	27.42(±1.1)
	00257_ArableLandAveragePlotSize_Calculated	ns	38.83(±0.7)a	39.4(±0.4)a	P<0.05	39.58(±0.4)	36.22(±0.9)	41.92(±0.3)

	00323_MineralNFertilizers	P<0.05	3.82(±0.1)	3.03(±0.1)	P<0.05	4.39(±0.1)	3.33(±0.1)	1.9(±0.1)
	00324_MineralPFertilizers	P<0.05	3.29(±0.1)	2.72(±0.0)	P<0.05	3.38(±0.1)	2.88(±0.1)	2.28(±0.1)
	00371_AccessToPasture	ns	6.24(±0.5)a	6.42(±0.2)a	P<0.05	17.7(±0.5)	0.22(±0.1)	0.52(±0.2)
	00605_ManagementRiparianStripes	P<0.05	28.95(±1.9)	18.62(±1.1)	P<0.05	12.45(±1.5)	29.1(±1.7)	22.34(±1.7)
	00620_PermanentGrasslandMowingFrequency	ns	14.69(±1.8)a	13.07(±0.8)a	P<0.05	27.98(±1.8)	5.06(±0.8)	6.43(±0.8)
	00711_EcolComensationValuableLandscapeElements	ns	2.46(±0.7)a	1.1(±0.3)a	ns	2.02(±0.6)a	1.13(±0.4)a	1.1(±0.4)a
	00740_GrowthRegulation	P<0.05	3.11(±0.1)	2.6(±0.1)	P<0.05	2.54(±0.1)a	2.57(±0.1)a	3.07(±0.1)
	00743_SealedAreas_Calculated	ns	3.45(±0.0)a	3.39(±0.0)a	P<0.05	3.46(±0.0)a	3.31(±0.0)	3.44(±0.0)a
	00758_NumberPerennialcrops	ns	1.57(±0.5)a	2.5(±0.2)a	P<0.05	1.87(±0.4)a	3.53(±0.4)	1.48(±0.2)a
	00764_ShareLegumesOnPerennialCropArea	ns	5.08(±1.0)a	3.8(±0.4)a	P<0.05	10.49(±1.0)	1.3(±0.4)	0.15(±0.2)

Note: margins sharing a letter in the group label are not significantly different at the 5% level

Sub-theme	Indicator	P	Org	Con	P	Machakos	Kirinyaga	Murang'a
Genetic Diversity	00198_1_DualPurposeBreedsPoultry	ns	16.16(±1.4)a	a17.06(±0.8)	P<0.05	18.38(±1.1)a	21.13(±1.3)a	11.03(±1.1)
	00198_DualPurposeBreedsRuminants	ns	9.13(±1.2)a	9.52(±0.6)a	P<0.05	17.57(±1.2)	3.64(±0.7)	6.54(±0.8)
	00202_AgroForestrySystems_Calculated	ns	2.88(±0.6)a	2.68(±0.3)a	P<0.05	1.73(±0.4)	6.4(±0.7)	0.17(±0.1)
	00208_WoodlandsShareAgriculturalLand_Calculated	ns	5.7(±0.7)a	4.35(±0.4)a	P<0.05	1.7(±0.4)	4.57(±0.6)	7.9(±0.7)
	00222_PermanentGrasslandsShareOfAgriculturalArea_Calculated	ns	1.72(±0.4)a	2.35(±0.2)a	P<0.05	4.76(±0.5)	0.68(±0.2)	0.99(±0.2)
	00223_RareEndangeredCrops	ns	5.71(±0.8)a	4.78(±0.4)a	ns	4.84(±0.6)ab	3.32(±0.5)a	6.83(±0.9)b
	00233_NoUseSynthChemFungicides	ns	40.57(±0.9)a	40.1(±0.5)a	P<0.05	36.33(±0.8)	31.15(±1.0)	53.15(±0.3)
	00234_NoUseSynthChemInsecticides	P<0.05	43.29(±0.9)	35.97(±0.6)	P<0.05	34.66(±0.8)	27.82(±1.1)	50.65(±0.4)
	00247_HybridCultivars	P<0.05	26.61(±2.3)	13.44(±0.9)	P<0.05	25.41(±1.9)	10.29(±1.2)	13.53(±1.4)
	00249_HybridLivestock	ns	36.72(±2.0)a	40.5(±1.1)a	P<0.05	50.42(±1.4)	43.67(±1.7)	24.25(±1.8)
	00253_PermanentGrasslandsExtensivelyManaged	ns	9.79(±1.4)a	8.07(±0.5)a	P<0.05	21.52(±1.4)	1.41(±0.4)	1.72(±0.5)
	00257_1_PesticidesToxicityBees	P<0.05	25.95(±1.7)	17.68(±0.9)	P<0.05	8.54(±1.3)	12.4(±1.2)	38.45(±1.6)
	00377_1_PesticidesNumberActiveSubstances	P<0.05	39.02(±0.8)	32.9(±0.4)	P<0.05	29.5(±0.7)a	29(±0.7)a	44.74(±0.7)
	00620_PermanentGrasslandMowingFrequency	ns	7.12(±0.9)a	6.33(±0.4)a	P<0.05	13.56(±0.9)	2.45(±0.4)	3.12(±0.4)
	00711_EcolComensationValuableLandscapeElements	ns	2.06(±0.6)a	0.93(±0.2)a	ns	1.69(±0.5)a	0.95(±0.3)a	0.92(±0.3)a
	00743_SealedAreas_Calculated	ns	21.8(±0.3)a	21.4(±0.1)a	P<0.05	21.84(±0.2)a	20.89(±0.2)	21.72(±0.2)a

Note: margins sharing a letter in the group label are not significantly different at the 5% level

Sub-theme	Indicator	P	Org	Con	P	Machakos	Kirinyaga	Murang'a

Soil Quality	00202_AgroForestrySystems_Calculated	ns	3.62(±0.8)a	3.35(±0.4)a	P<0.05	2.16(±0.5)	8.02(±0.9)	0.22(±0.1)
	00206_ShareLegumesArableLand	ns	30.28(±1.4)a	30.57(±0.9)a	P<0.05	51.52(±0.9)	28.39(±1.7)	10.49(±1.3)
	00207_ArableLandShareDirectSeeding	P<0.05	1.92(±0.8)	3.98(±0.5)	P<0.05	1.49(±0.6)	8.99(±1.2)	0.18(±0.1)
	00215_ArableLandShareTemporaryGrassland_Calculated	ns	7.93(±1.0)a	7.1(±0.6)a	P<0.05	0.66(±0.2)	9.61(±1.1)	12.01(±1.1)
	00222_PermanentGrasslandsShareOfAgriculturalArea_Calculated	ns	2.88(±0.7)a	3.93(±0.3)a	P<0.05	7.95(±0.8)	1.15(±0.3)	1.67(±0.4)
	00233_NoUseSynthChemFungicides	P<0.05	40.1(±1.6)	45.36(±0.9)	P<0.05	44.23(±1.1)	35.89(±1.3)	52(±1.5)
	00234_NoUseSynthChemInsecticides	ns	45.12(±1.6)a	42.18(±0.9)a	P<0.05	42.9(±1.1)	34.48(±1.4)	51.09(±1.5)
	00286_SoilDegradationCounterMeasures	ns	50.61(±2.6)a	50.75(±1.5)a	P<0.05	45.57(±2.4)a	64.99(±1.9)	42.14(±2.4)a
	00295_AntibioticsLivestockFertilizer	P<0.05	25.28(±1.6)	19.25(±0.9)	P<0.05	20.74(±1.5)	29.41(±1.4)	12.11(±1.3)
	00298_SoilImprovement	P<0.05	59.33(±2.0)	64.91(±1.0)	P<0.05	67.36(±1.4)a	66.61(±1.5)a	56.63(±1.8)
	00300_ArableLandGradientsGreater15Percent	P<0.05	41.81(±1.4)	47.27(±0.7)	P<0.05	51.33(±0.9)a	50.16(±1.0)a	36.21(±1.4)
	00323_MineralNFertilizers	P<0.05	42.43(±1.2)	34.19(±0.8)	P<0.05	52.61(±1.0)	37.46(±1.2)	17.65(±1.3)
	00324_MineralPFertilizers	P<0.05	43.04(±1.1)	38.24(±0.7)	P<0.05	51.24(±0.9)	41.18(±1.0)	25.2(±1.2)
	00327_WasteDisposalPesticidesVeterinaryMedicines	ns	11.66(±1.5)a	11.07(±0.9)a	P<0.05	1.08(±0.5)	8.34(±1.3)	24.64(±1.8)
	00377_1_PesticidesNumberActiveSubstances	ns	27.1(±1.0)a	25.65(±0.5)a	P<0.05	25.1(±0.6)a	23.4(±0.7)a	29.5(±1.0)
	00474_2_PesticidesPersistenceSoil	ns	38.34(±1.9)a	41.04(±1.2)a	P<0.05	54.92(±1.6)	20.3(±1.9)	44.8(±1.9)
	00708_PreciseFertilisation	ns	13.03(±1.3)a	11.61(±0.7)a	P<0.05	5.26(±1.0)	29.87(±1.6)	1.44(±0.5)
	00710_HarmfulSubstancesPFertilizer	ns	32.66(±2.0)a	31.31(±1.0)a	P<0.05	37.41(±1.8)a	40.73(±1.2)a	16.67(±1.5)
	00740_GrowthRegulation	ns	34.59(±1.3)a	31.96(±0.8)a	ns	32.95(±1.2)a	33.29(±1.2)a	31.54(±1.2)a
	00743_SealedAreas_Calculated	P<0.05	30.38(±0.8)	33.37(±0.4)	P<0.05	36.79(±0.5)	33.31(±0.6)	27.67(±0.8)
	00748_HumusFormationHumusBalance	P<0.05	55.93(±0)	59.33(±0.0)	P<0.05	63.52(±0.0)	59.87(±0.0)	51.92(±0.0)
	00758_NumberPerennialcrops	P<0.05	1.43(±0.5)	2.48(±0.2)	P<0.05	1.78(±0.4)a	3.64(±0.4)	1.32(±0.2)a
	00764_ShareLegumesOnPerennialCropArea	ns	6.5(±1.3)a	4.64(±0.5)a	P<0.05	13.13(±1.3)	1.46(±0.5)	0.19(±0.2)
	00202_AgroForestrySystems_Calculated	ns	4.1(±0.9)a	3.81(±0.4)a	P<0.05	2.46(±0.6)	9.1(±1.0)	0.25(±0.1)

Note: margins sharing a letter in the group label are not significantly different at the 5% level

Sub-theme	Indicator	P	Org	Con	P	Machakos	Kirinyaga	Murang'a
Species Diversity	00204_WoodlandsDeforestation	ns	42.6(±1.0)a	43.45(±0.4)a	P<0.05	40.07(±1.0)	45.47(±0.4)	44.41(±0.6)
	00208_WoodlandsShareAgriculturalLand_Calculated	ns	9.18(±1.1)a	7.0(±0.6)a	P<0.05	2.73(±0.6)	7.36(±0.9)	12.73(±1.2)
	00215_ArableLandShareTemporaryGrassland_Calculated	ns	8.17(±0.9)a	6.91(±0.5)a	P<0.05	0.56(±0.2)	8.85(±0.9)	12.58(±0.9)
	00222_PermanentGrasslandsShareOfAgriculturalArea_Calculated	ns	2.85(±0.7)a	3.91(±0.3)a	P<0.05	7.91(±0.8)	1.14(±0.3)	1.65(±0.4)
	00233_NoUseSynthetic Chemical Fungicides	ns	49.95(±1.1)a	49.37(±0.6)a	P<0.05	44.73(±1.0)	38.36(±1.2)	65.44(±0.4)
	00234_NoUseSynthetic Chemical Insecticides	P<0.05	57.24(±1.2)	47.55(±0.8)	P<0.05	45.82(±1.1)	36.77(±1.5)	66.97(±0.5)

	00257_1_PesticidesToxicityBees	P<0.05	29.5(±1.9)	20.09(±1.0)	P<0.05	9.71(±1.4)	14.09(±1.4)	43.7(±1.8)
	00257_2_PesticidesToxicityAquaticOrganisms	P<0.05	25.4(±1.7)	14.33(±0.8)	P<0.05	7.04(±1.2)a	4.92(±0.9)a	39.23(±1.6)
	00257_ArableLandAveragePlotSize_Calculated	ns	50.87(±0.9)a	51.63(±0.5)a	P<0.05	51.86(±0.6)	47.45(±1.1)	54.93(±0.4)
	00295_AntibioticsLivestockFertilizer	P<0.05	15.63(±1.0)	11.99(±0.6)	P<0.05	12.91(±0.9)	18.31(±0.8)	7.49(±0.8)
	00323_MineralNFertilizers	P<0.05	39.48(±1.0)	31.32(±0.6)	P<0.05	45.27(±0.8)	34.38(±1.0)	19.62(±1.0)
	00324_MineralPFertilizers	P<0.05	36.25(±0.7)	29.97(±0.4)	P<0.05	37.28(±0.6)	31.78(±0.6)	25.09(±0.7)
	00377_1_PesticidesNumberActiveSubstances	P<0.05	36.16(±0.8)	30.5(±0.4)	P<0.05	27.34(±0.6)a	26.88(±0.6)a	41.47(±0.6)
	00474_1_PesticidesPersistenceWater	P<0.05	29.95(±1.8)	17.87(±1.0)	P<0.05	8.9(±1.3)a	17.66(±1.6)	36.27(±1.6)a
	00474_2_PesticidesPersistenceSoil	ns	38.41(±1.2)a	36.25(±0.9)a	P<0.05	44.35(±1.2)	18.47(±1.6)	46.7(±1.2)
	00605_ManagementRiparianStripes	P<0.05	28.99(±1.9)	18.64(±1.1)	P<0.05	12.47(±1.5)	29.14(±1.7)	22.37(±1.7)
	00620_PermanentGrasslandMowingFrequency	ns	14.6(±1.8)a	12.99(±0.8)a	P<0.05	27.81(±1.8)	5.03(±0.8)	6.39(±0.8)
	00708_PreciseFertilisation	ns	9.91(±1.0)a	9.07(±0.5)a	P<0.05	3.87(±0.7)	23.23(±1.1)	1.29(±0.4)
	00710_HarmfulSubstancesPFertilizer	ns	18.1(±1.1)a	17.93(±0.5)a	P<0.05	20.94(±1.0)	23.52(±0.6)	9.43(±0.8)
	00711_EcolComensationValuableLandscapeElements	ns	3.31(±1.0)a	1.49(±0.4)a	ns	2.72(±0.8)a	1.53(±0.5)a	1.48(±0.6)a
	00743_SealedAreas_Calculated	ns	27.46(±0.3)a	26.97(±0.2)a	P<0.05	27.48(±0.3)a	26.35(±0.3)	27.38(±0.3)a
	00748_HumusFormationHumusBalance	ns	16.37(±1.1)a	15.74(±0.6)a	P<0.05	12.81(±0.9)a	14.32(±0.7)a	20.66(±1.0)
	00757_ShareGreenCoverPerennialCropLand	P<0.05	2.82(±0.5)	5.75(±0.5)	P<0.05	1.63(±0.4)	8.57(±0.9)	5.19(±0.6)
	00758_NumberPerennialcrops	ns	2.05(±0.6)a	3.24(±0.3)a	P<0.05	2.44(±0.5)a	4.57(±0.5)	1.91(±0.3)a

Note: margins sharing a letter in the group label are not significantly different at the 5% level

Sub-theme	Indicator	P	Org	Con	P	Machakos	Kirinyaga	Murang'a
Water withdrawal	00376_1_InformationWaterAvailability	ns	30.64(±1.9)a	29.59(±1.1)a	P<0.05	11.55(±1.5)	48.22(±1.6)	31.04(±1.9)
	00377_05_WastewaterDisposal	ns	6.33(±1.3)a	9.23(±0.8)a	P<0.05	11.56(±1.3)a	3.03(±0.8)	10.73(±1.4)a
	00389_IrrigationWaterConsumption_Calculated	P<0.05	64.14(±2.8)	54.83(±1.6)	ns	55.21(±2.5)a	58.86(±2.4)a	57.27(±2.4)a
	00400_YieldDecreaseLackOfWater	ns	16.66(±1.4)a	17.72(±0.8)a	P<0.05	2.42(±0.7)	8.94(±1.3)	41.62(±1.6)
	00404_IrrigationPrecipitationMeasurement	P<0.05	52.64(±2.2)	46.23(±1.3)	ns	45.29(±2.0)a	48.17(±1.9)a	49.97(±1.9)a
	00405_WaterStorageCapacity	ns	13.09(±1.6)a	14.07(±0.9)a	P<0.05	8.01(±1.4)	4.43(±1.0)	29.14(±1.8)
	00739_ReusablePackagingMaterials	ns	14.53(±0.5)a	14.31(±0.3)a	P<0.05	12.25(±0.4)	16.94(±0.3)	14.06(±0.4)

Note: margins sharing a letter in the group label are not significantly different at the 5% level

Economic Resilience

Sub-theme	Indicator	P	Org	Con	P	Machakos	Kirinyaga	Murang'a
Community Investment	00074_CostsEnvironmentalInvolvementOutsideFarm	ns	6.15(±1.1)a	4.38(±0.6)a	P<0.05	4.51(±0.9)	8.27(±1.1)	1.71(±0.5)
	00075_CostsSocialInvolvementOutsideFarm	P<0.05	24(±2.2)	20.7(±1.2)	P<0.05	16.21(±1.8)a	23.59(±1.8)a	24.99(±2.0)
	00202_AgroForestrySystems_Calculated	ns	3.05(±0.6)a	2.83(±0.3)a	P<0.05	1.83(±0.5)	6.77(±0.7)	0.18(±0.1)
	00204_WoodlandsDeforestation	P<0.05	39.97(±1.4)	43.55(±0.7)	P<0.05	44.06(±1.1)a	46.55(±0.9)a	37.47(±1.3)
	00208_WoodlandsShareAgriculturalLand_Calculated	ns	4.99(±0.7)a	4.16(±0.4)a	P<0.05	1.84(±0.4)	4.35(±0.6)	7.01(±0.8)
	00335_1_RecyclingPaper	P<0.05	20.19(±1.3)	16.89(±0.7)	P<0.05	12.58(±1.2)a	12.69(±0.8)a	27.93(±1.2)
	00502_PublicHealthMeasures	ns	1.49(±0.7)a	2.93(±0.5)a	ns	1.97(±0.6)a	2.31(±0.7)a	3.49(±0.9)a
	00506_FoodSecurityMeasuresLocCommunities	ns	16.32(±1.8)a	13.78(±1.0)a	P<0.05	5.54(±1.1)	19.55(±1.7)	18.63(±1.7)
	00512_NumberJobsCreatedRemoved	P<0.05	32.02(±1.5)	35.32(±0.7)	P<0.05	38.02(±0.9)a	35.25(±1.4)a	30.15(±1.1)
	00605_ManagementRiparianStripes	P<0.05	21.98(±1.8)	16.21(±1.0)	P<0.05	12.18(±1.4)a	26.87(±1.7)	14.19(±1.5)a
	00711_EcolComensationValuableLandscapeElements	ns	2.76(±0.8)a	1.24(±0.3)a	ns	2.26(±0.6)a	1.27(±0.4)a	1.23(±0.5)a
	00793_LocalProcurementProducerLevel_Calculated	P<0.05	7.48(±0.7)	9.4(±0.3)	P<0.05	9.47(±0.5)	3.33(±0.3)	1.04(±0.5)
	00794_LocalProcurementAwareness	ns	4.13(±0.4)a	3.6(±0.2)a	P<0.05	4.44(±0.3)	3.2(±0.3)	3.5(±0.4)

Note: margins sharing a letter in the group label are not significantly different at the 5% level

Sub-theme	Indicator	P	Org	Con	P	Machakos	Kirinyaga	Murang'a
Food Safety	00034_2_UseageChemSynthSeedDressings	P<0.05	13.95(±1.4)	6.14(±0.6)	P<0.05	10.35(±1.1)	6.73(±0.8)	6.83(±0.9)
	00167_No ContaminatedProducts	P<0.05	83.13(±0.5)	84.36(±0.1)	P<0.05	84.11(±0.3)a	83.84(±0.3)a	84.24(±0.2)a
	00169_ContaminationCasesMeasures	ns	57.52(±3.0)a	52.25(±1.6)a	P<0.05	41.92(±2.7)	54.61(±2.5)	64.6(±2.3)
	00175_TrasparencyProduction	P<0.05	14.09(±1.3)	3.59(±0.5)	P<0.05	0.6(±0.4)	12.09(±1.2)	6.04(±0.9)
	00233_NoUseSynthChemFungicides	ns	33.47(±0.7)a	33.08(±0.4)a	P<0.05	29.97(±0.7)	25.7(±0.8)	43.85(±0.3)
	00234_NoUseSynthChemInsecticides	P<0.05	37.33(±0.8)	31.02(±0.5)	P<0.05	29.88(±0.7)	23.99(±1.0)	43.68(±0.4)
	00295_AntibioticsLivestockFertilizer	P<0.05	24.48(±1.6)	18.78(±0.9)	P<0.05	20.22(±1.4)	28.67(±1.3)	11.73(±1.2)
	00323_MineralNFertilizers	P<0.05	22.79(±0.6)	18.08(±0.4)	P<0.05	26.14(±0.5)	19.85(±0.6)	11.32(±0.6)
	00353_LivestockHealthProphylacticTreatments	ns	42.34(±1.6)a	40.99(±0.9)a	P<0.05	40.43(±1.4)a	39.28(±1.4)a	44.24(±1.3)
	00369_NumberQualityDrinkingPoints	P<0.05	23.07(±1.4)	26.33(±0.8)	P<0.05	16.22(±1.1)	25.35(±1.3)	35.53(±1.2)
	00376_2_InformationWaterQuality	ns	9.32(±1.5)a	7.23(±0.7)a	P<0.05	7.84(±1.2)	2.73(±0.7)	12.52(±1.4)
	00377_05_WastewaterDisposal	P<0.05	5.54(±1.2)	8.22(±0.7)	P<0.05	10.44(±1.2)a	2.65(±0.7)	9.4(±1.2)a
	00377_1_PesticidesNumberActiveSubstances	P<0.05	38.48(±0.8)	32.45(±0.4)	P<0.05	29.09(±0.8)a	28.6(±0.7)a	44.13(±0.7)
	00377_5_PesticidesChronicToxicity	P<0.05	49.37(±2.1)	30.47(±1.3)	P<0.05	16.08(±1.8)	36.74(±2.0)	53.17(±1.8)
	00377_7_PesticidesAcuteToxicity	P<0.05	38.22(±1.8)	26.33(±0.9)	P<0.05	19.74(±1.3)a	17.76(±1.0)a	50.28(±1.7)
	00377_75_PesticidesAcuteToxicityInhalation	P<0.05	37.45(±1.8)	24.51(±0.9)	P<0.05	17.54(±1.4)	13.44(±1.1)	52.07(±1.6)

	00470_CertifiationUsagePlantProtectionAnimalTreatmentProducts	ns	20.53(±2.0)a	23.36(±1.1)a	P<0.05	15.18(±1.6)a	34.63(±1.6)	18.87(±1.8)a
	00474_1_PesticidesPersistenceWater	P<0.05	33.23(±2.0)	19.82(±1.1)	P<0.05	9.87(±1.4)	19.59(±1.7)	40.24(±1.7)
	00474_2_PesticidesPersistenceSoil	ns	43.38(±1.4)a	40.94(±1.0)a	P<0.05	50.09(±1.4)a	20.86(±1.8)	52.75(±1.3)a
	00474_3_PesticidesKnowledge	P<0.05	36.29(±1.8)	28.88(±1.1)	P<0.05	8.79(±1.3)	31.11(±2.0)	53.16(±1.7)
	00608_UseageAntibioticDryingAgents	ns	37.15(±1.8)a	35.07(±0.9)a	P<0.05	26.36(±1.6)	40.93(±1.3)	39.98(±1.3)
	00609_MilkWaitingPeriodAntibiotics	ns	18.04(±1.0)a	17.55(±0.5)a	P<0.05	12.61(±0.9)	21.1(±0.7)	19.62(±0.8)
	00708_PreciseFertilisation	ns	9.94(±1.0)a	9.09(±0.5)a	P<0.05	3.88(±0.7)	23.28(±1.1)	1.29(±0.4)
	00710_HarmfulSubstancesPFertilizer	ns	28.99(±1.8)a	28.72(±0.9)a	P<0.05	33.54(±1.6)	37.67(±0.9)	15.11(±1.3)
	00720_SilageStorage	ns	16.68(±2.0)a	14.91(±1.1)a	P<0.05	7.54(±1.3)	21.32(±1.8)	17.66(±1.7)
	00721_FeedConcentrateStorage	ns	37.62(±2.3)a	39.53(±1.2)a	P<0.05	27.7(±1.9)	35.98(±1.8)	54.05(±1.6)
	00740_GrowthRegulation	P<0.05	43.94(±1.1)	36.74(±0.8)	P<0.05	35.88(±1.2)a	36.25(±1.3)a	43.35(±0.9)

Note: margins sharing a letter in the group label are not significantly different at the 5% level

Sub-theme	Indicator	P	Org	Con	P	Machakos	Kirinyaga	Murang'a
Stability of market	0083_SalesDiversification	ns	38.67(±1.6)a	36.88(±0.8)a	P<0.05	30.36(±1.5)a	52.09(±1.3)	30.14(±1.2)a
	00084_AvailabilityAlternativeMarkets	ns	47.93(±3.0)a	41.41(±1.6)a	P<0.05	62.99(±2.4)	44.66(±2.6)	20.31(±2.2)
	00141_DirectSales	P<0.05	17.36(±1.7)	25.95(±0.9)	P<0.05	40.86(±1.6)	12.85(±1.3)	16.87(±1.2)
	00146_No ProductReturns	P<0.05	54.42(±1.9)	60.17(±1.0)	P<0.05	63.61(±1.3)a	62.2(±1.4)a	50.4(±1.8)
	00149_LengthCustomerRelationshios	P<0.05	43.41(±2.1)	51.89(±1.3)	P<0.05	30.29(±1.9)	67.95(±1.7)	52.7(±2.1)
	00202_AgroForestrySystems_Calculated	ns	1.75(±0.4)a	1.62(±0.2)a	P<0.05	1.05(±0.3)	3.87(±0.4)	0.11(±0.0)
	00208_WoodlandsShareAgriculturalLand_Calculated	ns	2.94(±0.4)a	2.45(±0.2)a	P<0.05	1.08(±0.2)	2.56(±0.4)	4.13(±0.5)
	00223_RareEndangeredCrops	ns	1.74(±0.3)a	1.37(±0.1)a	P<0.05	1.52(±0.2)a	1.02(±0.2)	1.84(±0.3)a
	00707_CustomerRelationship	ns	28.32(±2.7)a	29.53(±1.5)a	P<0.05	21.35(±2.2)a	45.57(±2.5)	21.54(±2.2)a
	00751_DependencyMainCustomer	ns	40.72(±2.2)a	41.14(±1.0)a	P<0.05	46.33(±2.0)	40.34(±1.3)	36.17(±1.5)
	00768_CollectiveMarketing	ns	9.02(±0.5)a	9.75(±0.5)a	P<0.05	1.53(±0.3)	27.93(±1.1)	0.05(±0.0)

Note: margins sharing a letter in the group label are not significantly different at the 5% level

Sub-theme	Indicator	P	Org	Con	P	Machakos	Kirinyaga	Murang'a
Stability of supply	00088_FarmInputsSecureSupply	P<0.05	68.67(±2.2)	75.25(±1.2)	P<0.05	80.52(±1.4)	75.96(±1.8)	64.24(±2.2)
	00093_CooperationSuppliersQuality	ns	30.71(±1.8)a	29.32(±1.2)a	P<0.05	7.27(±1.1)	47.23(±2.2)	35.95(±1.8)
	00199_BoughtConcentratedFeed	ns	4.91(±1.3)a	7.18(±0.7)a	P<0.05	13.76(±1.5)	2.93(±0.8)	2.8(±0.7)
	00233_NoUseSynthChemFungicides	P<0.05	28.1(±1.2)	31.86(±0.6)	P<0.05	31.99(±0.7)	25.5(±1.0)	35.22(±1.2)
	00234_NoUseSynthChemInsecticides	ns	31.67(±1.2)a	29.59(±0.6)a	P<0.05	31.04(±0.7)	24.5(±1.0)	34.57(±1.2)

	00247_HybridCultivars	P<0.05	11.9(±1.4)	7.66(±0.6)	P<0.05	17.45(±1.3)	7.07(±0.8)	1.04(±0.4)
	00323_MineralNFertilizers	P<0.05	32.22(±0.9)	26.2(±0.6)	P<0.05	40.77(±0.7)	28.62(±0.9)	12.91(±1.0)
	00324_MineralPFertilizers	P<0.05	33.76(±0.9)	30.13(±0.6)	P<0.05	41.17(±0.7)	32.64(±0.8)	18.73(±1.0)
	00626_BoughtInRoughage	ns	47.15(±2.1)a	50.13(±1.2)a	P<0.05	58.05(±1.6)	52.08(±1.8)	37.73(±2.0)
	00708_PreciseFertilisation	ns	6.18(±0.6)a	5.5(±0.3)a	P<0.05	2.49(±0.5)	14.16(±0.7)	0.68(±0.2)
	00712_BoughtOrgFert	P<0.05	38.37(±2.0)	50.34(±0.9)	P<0.05	55.71(±1.3)	48.46(±1.5)	37.84(±1.6)
	00740_GrowthRegulation	ns	30.99(±1.2)a	28.64(±0.7)a	P<0.05	30.33(±1.1)a	30.16(±1.1)a	27.09(±1.1)

Note: margins sharing a letter in the group label are not significantly different at the 5% level

Social Well Being

Sub-theme	Indicator	P	Org	Con	P	Machakos	Kirinyaga	Murang'a
Capacity Development	00072_FarmStaffTraining	P<0.05	45.11(±2.6)	32.64(±1.4)	P<0.05	31.48(±2.2)a	32.29(±2.0)a	43.27(±2.2)
	00703_AccessAdvisoryServices	ns	23.41(±2.0)a	25.61(±1.2)a	P<0.05	21.31(±1.9)a	23.87(±1.9)a	30.23(±1.5)

Note: margins sharing a letter in the group label are not significantly different at the 5% level

Sub-theme	Indicator	P	Org	Con	P	Machakos	Kirinyaga	Murang'a
Indigenous Knowledge	00067_PreventionResourceConflicts	P<0.05	52.98(±2.8)	42.61(±1.3)	P<0.05	67.78(±1.9)	21.39(±1.8)	44.49(±2.4)
	00075_CostsSocialInvolvementOutsideFarm	P<0.05	25.18(±1.7)	18.1(±0.9)	P<0.05	12.17(±1.3)	18.2(±1.3)	29.37(±1.5)

Note: margins sharing a letter in the group label are not significantly different at the 5% level

Sub-theme	Indicator	P	Org	Con	P	Machakos	Kirinyaga	Murang'a
Public Health	00034_2_UseageChemSynthSeedDressings	P<0.05	14.3(±1.9)	6.52(±0.8)	P<0.05	9.22(±1.4)a	11.2(±1.4)a	4.76(±1.0)
	00167_No ContaminatedProducts	ns	53.1(±2.7)a	54.67(±1.5)a	P<0.05	33.25(±2.5)	68.44(±2.0)	62.53(±2.2)
	00169_ContaminationCasesMeasures	P<0.05	38.84(±2.3)	31.65(±1.4)	P<0.05	9.81(±1.6)	44.13(±2.3)	47.58(±2.4)
	00200_SlurryStoresCovered	ns	17.3(±2.2)a	16.46(±1.1)a	P<0.05	23.99(±2.0)	13.14(±1.6)	12.4(±1.5)
	00208_WoodlandsShareAgriculturalLand_Calculated	ns	3.05(±0.5)a	2.46(±0.2)a	P<0.05	0.33(±0.1)	3.05(±0.4)	4.54(±0.5)
	00233_NoUseSynthChemFungicides	ns	34.05(±2.3)a	37.46(±1.2)a	P<0.05	21.27(±1.8)	35.77(±1.7)	53.62(±1.9)
	00234_NoUseSynthChemInsecticides	P<0.05	40.65(±2.4)	35.34(±1.2)	P<0.05	20.83(±1.8)	35.65(±1.7)	54.12(±2.0)
	00257_1_PesticidesToxicityBees	ns	21.4(±2.3)a	17.84(±1.2)a	P<0.05	4.79(±1.2)	14.02(±1.6)	37.87(±2.6)
	00257_2_PesticidesToxicityAquaticOrganisms	P<0.05	19.8(±2.3)	14.7(±1.1)	P<0.05	3.37(±1.1)a	6.43(±1.3)a	38.4(±2.5)
	00295_AntibioticsLivestockFertilizer	P<0.05	20.48(±1.3)	15.05(±0.9)	P<0.05	10.2(±1.2)a	27.75(±1.4)	11.65(±1.3)a

	00320_CropResistance	P<0.05	16.83(±)1.8	21.31(±1.0)	P<0.05	6.64(±1.1)	13.07(±1.5)	41.52(±1.9)
	00327_WasteDisposalPesticidesVeterinaryMedicines	ns	13.9(±1.8)a	12.54(±1.0)a	P<0.05	0.88(±0.5)	9.28(±1.5)	28.96(±2.2)
	00331_WasteDisposalCadaver	ns	36.44(±2.0)a	33.48(±1.4)a	P<0.05	17.4(±1.8)	44.89(±2.1)	41.35(±2.2)
	00334_3_RecyclingPlastic	P<0.05	6.33(±0.0)	8.81(±0.0)	P<0.05	0.81(±0.0)	2.98(±0.0)	21.12(±0.0)
	00334_RecyclingWasteOil	ns	29.86(±1.7)a	32.09(±1.1)a	P<0.05	19.47(±1.6)	44.56(±1.4)	31.51(±1.6)
	00352_LivestockHealthCurativeTreatments	P<0.05	28.19(±1.6)	22.19(±1.0)	P<0.05	12.42(±1.3)	29.44(±1.5)	29.7(±1.6)
	00353_LivestockHealthProphylacticTreatments	ns	23.73(±1.6)a	22.83(±0.9)a	P<0.05	16.43(±1.4)	25.95(±1.3)	27.15(±1.3)
	00357_MutilationAnaestheticsAnalgesics	P<0.05	4.97(±0.7)	7.45(±0.5)	P<0.05	1.97(±0.5)	11.96(±0.9)	6.98(±0.7)
	00376_2_InformationWaterQuality	ns	11.06(±1.9)a	7.71(±0.9)a	P<0.05	8.51(±1.4)	3.21(±0.9)	13.71(±1.7)
	00377_05_WastewaterDisposal	P<0.05	7.72(±1.8)	12.19(±1.1)	P<0.05	16.43(±1.9)a	3.68(±1.0)	12.83(±1.9)a
	00377_1_PesticidesNumberActiveSubstances	ns	31.07(±1.8)a	28.05(±0.9)a	P<0.05	15.16(±1.3)	31.02(±1.2)	40.86(±1.6)
	00377_5_PesticidesChronicToxicity	P<0.05	41.8(±2.4)	27.93(±1.5)	P<0.05	9.2(±1.6)	41.67(±2.4)	44.23(±2.6)
	00377_7_PesticidesAcuteToxicity	P<0.05	27.16(±2.2)	21.95(±1.1)	P<0.05	9.49(±1.3)	18.87(±1.3)	41.82(±2.4)
	00377_75_PesticidesAcuteToxicityInhalation	P<0.05	25.66(±2.2)	19.96(±1.1)	P<0.05	7.98(±1.2)	14.01(±1.3)	42.49(±2.3)
	00380_NutrientsPollutantsSourcesOnFarm	ns	19.22(±2.2)a	16.24(±1.2)a	P<0.05	17.32(±1.8)a	11.74(±1.5)	21.68(±2.0)a
	00474_1_PesticidesPersistenceWater	P<0.05	30.33(±2.8)	20.67(±1.4)	P<0.05	6.17(±1.5)	25.03(±2.4)	38.65(±2.7)
	00474_2_PesticidesPersistenceSoil	ns	32.74(±3.2)a	35.39(±1.6)a	P<0.05	29.09(±2.6)	21.49(±2.4)	53.69(±2.7)
	00474_3_PesticidesKnowledge	ns	26.44(±1.9)a	22.46(±1.1)a	P<0.05	3.75(±0.8)	28.17(±2.0)	39.42(±2.0)
	00502_PublicHealthMeasures	ns	1.34(±0.6)a	2.27(±0.4)a	ns	0.97(±0.5)	1.87(±0.6)ab	3.35(±0.8)b
	00506_FoodSecurityMeasuresLocCommunities	P<0.05	13.78(±1.4)	9.97(±0.8)	P<0.05	1.39(±0.5)	14.65(±1.4)	17.16(±1.5)
	00606_LandslidesMudslides	ns	31.45(±1.7)a	32.27(±0.9)a	P<0.05	20.01(±1.5)	40.92(±1.3)	36.07(±1.4)
	00609_MilkWaitingPeriodAntibiotics	ns	14.78(±1.1)a	14.38(±0.7)a	P<0.05	5.13(±0.8)	20.74(±1.1)	18.15(±1.1)
	00710_HarmfulSubstancesPFertilizer	ns	25.68(±2.0)a	23.23(±1.1)a	P<0.05	12.34(±1.6)	41.87(±1.7)	18.21(±1.7)
	00740_GrowthRegulation	P<0.05	39.38(±2.1)	32.43(±1.2)	P<0.05	17.74(±1.8)	43.43(±1.8)	42.15(±1.8)
	00788_OpenBurning	ns	34.22(±2.1)a	32.64(±1.2)a	P<0.05	17.18(±1.7)	45.4(±1.7)	37.53(±1.9)
	00790_EmplyeesProtectiveGear	ns	21.37(±1.8)a	21.46(±1.2)a	P<0.05	8.33(±1.2)	29.9(±1.9)	26.91(±1.9)

Note: margins sharing a letter in the group label are not significantly different at the 5% level

Governance

Sub-theme	Indicator	P	Org	Con	P	Machakos	Kirinyaga	Murang'a
	00057_InvolvementImprovingLawsRegulations	P<0.05	16.84(±2.0)	9.44(±1.0)	P<0.05	2.75(±0.9)	13.36(±1.8)	18.01(±1.8)

Civic Responsibility	00070_CooperationEthicalFinancialInstitutions	ns	16.15(±1.7)a	18.59(±0.9)a	P<0.05	25.75(±1.4)	12.27(±1.2)	15.49(±1.3)
	00074_CostsEnvironmentalInvolvementOutsideFarm	P<0.05	11.59(±1.4)	6.37(±0.7)	P<0.05	4.99(±1.0)	9.3(±1.2)	8.75(±1.0)
	00075_CostsSocialInvolvementOutsideFarm	P<0.05	34.07(±2.3)	24.14(±1.2)	P<0.05	15.91(±1.8)	24.41(±1.8)	39.74(±2.0)
	00506_FoodSecurityMeasuresLocCommunities	P<0.05	24.33(±1.9)	17.54(±1.1)	P<0.05	5.82(±1.1)	21.24(±1.9)	31.17(±2.0)

Note: margins sharing a letter in the group label are not significantly different at the 5% level

Sub-theme	Indicator	P	Org	Con	P	Machakos	Kirinyaga	Murang'a
Full-Cost Accounting	00750_OralInformationSustainabilityImprovements	ns	11.73(±0.9)a	12.84(±0.4)a	P<0.05	9.24(±0.7)	16.6(±0.7)	12.13(±0.8)

Note: margins sharing a letter in the group label are not significantly different at the 5% level

Sub-theme	Indicator	P	Org	Con	P	Machakos	Kirinyaga	Murang'a
Holistic Audit	00748_HumusFormationHumusBalance	ns	33.09(±2.2)a	31.55(±1.1)a	P<0.05	25.87(±1.8)a	28.7(±1.4)a	41.42(±2.0)a
	00750_OralInformationSustainabilityImprovements	ns	19.34(±1.0)a	18.05(±0.6)a	P<0.05	12.87(±0.9)	25.55(±0.9)	17.1(±0.9)

Note: margins sharing a letter in the group label are not significantly different at the 5% level

Sub-theme	Indicator	P	Org	Con	P	Machakos	Kirinyaga	Murang'a
Sustainability Management Plan	00008_VerbalCommitmentSustainability	ns	17.58(±1.4)a	17.6(±0.8)a	P<0.05	11.11(±1.0)	17.18(±1.1)	24.81(±1.6)
	00100_MarketChallenges	P<0.05	30.85(±1.8)	26.11(±1.0)	P<0.05	20.71(±1.5)a	19.09(±1.4)a	42.1(±1.6)a
	00124_GuaranteedStaffReplacemetFarmSuccession	P<0.05	28.19(±1.7)	37.93(±0.8)	P<0.05	39.61(±1.3)a	40.42(±1.1)a	26.65(±1.5)a
	00134_KnowledgeClimateChangeProblems	ns	36.33(±1.5)a	36.68(±0.8)a	P<0.05	32.04(±1.2)a	29.19(±1.3)a	48.62(±1.1)a
	00136_ClimateChangeAdaptationMeasures	ns	31.72(±2.5)a	33.28(±1.3)a	P<0.05	39.99(±2.0)	29.41(±2.0)	28.9(±2.0)
	00750_OralInformationSustainabilityImprovements	ns	20.39(±1.1)a	18.91(±0.7)a	P<0.05	13.83(±1.0)	27.46(±0.9)	16.96(1.0±)

Note: margins sharing a letter in the group label are not significantly different at the 5% level

Annex 8: Indicator system and county significant level of indicator scores for the system and interaction effects

Indicators comparison between the farming system and county with the least value from left to right (highest value) with the p value indicating if there is significant differences for each indicator

Environmental integrity dimension

	Indicator	P	System and county					
Ecosystem Diversity	00202_AgroForestrySystems_Calculated		Organic#Murang'a	Conventional#Murang'a	Conventional#Machakos	Organic#Machakos	Organic#Kirinyaga	Conventional#Kirinyaga
		ns	0.31(±0.22)a	0.35(±0.15)a	2.03(±0.57)b	7.78(±3.0)bcd	8.89(±1.8)c	13.78(±1.7)d
	00204_WoodlandsDeforestation		Conventional#Machakos	Organic#Machakos	Organic#Murang'a	Organic#Kirinyaga	Conventional#Murang'a	Conventional#Kirinyaga
		ns	5.91(±0.15)a	6.02(±0.36)ab	6.29(±0.22)ab	6.66(±0.13)	6.68(±0.08)bc	6.77(±0.06)c
	00208_WoodlandsShareAgriculturalLand_Calculated		Organic#Machakos	Conventional#Machakos	Conventional#Kirinyaga	Organic#Kirinyaga	Conventional#Murang'a	Organic#Murang'a
		ns	1.87(±0.95)a	2.75(±0.65)a	6.23(±0.94)b	8.72(±1.96)bc	10.71(±1.27)cd	15.32(±2.34)d
	00215_ArableLandShareTemporaryGrassland_Calculated		Organic#Machakos	Conventional#Machakos	Conventional#Kirinyaga	Organic#Kirinyaga	Conventional#Murang'a	Organic#Murang'a
		ns	0.25(±0.25)a	0.55(±0.18)a	6.84(±0.85)b	9.87(±1.77)bc	10.61(±0.92)c	11.23(±1.39)c
	00222_PermanentGraslandsShareOfAgriculturalArea_Calculated		Organic#Murang'a	Organic#Kirinyaga	Conventional#Kirinyaga	Conventional#Murang'a	Organic#Machakos	Conventional#Machakos
		ns	0.91(±0.4)a	1.06(±0.49)a	1.08(±0.32)a	1.77(±0.46)a	5.93(±.188)b	7.99(±0.76)b
	00233_NoUseSynthChemFungicides		Organic#Kirinyaga	Conventional#Kirinyaga	Conventional#Machakos	Organic#Machakos	Conventional#Murang'a	Organic#Murang'a
			21.76(±1.39)a	25.04(±0.94)a	27.55(±0.72)b	30.6(±1.51)b	41.1(±0.33)	42.24(±0.08)
	00234_NoUseSynthChemInsecticides		Conventional#Kirinyaga	Conventional#Machakos	Organic#Machakos	Organic#Kirinyaga	Conventional#Murang'a	Organic#Murang'a
		P<0.05	18.72(±1.07)	26.23(±0.71)	29.99(±1.45)a	31.45(±1.43)a	39.43(±0.41)b	40.38(±0.37)b
	00253_PermanentGraslandsExtensivelyManaged		Conventional#Kirinyaga	Conventional#Murang'a	Organic#Murang'a	Organic#Kirinyaga	Conventional#Machakos	Organic#Machakos
		ns	1.23(±0.71)a	2.08(±0.86)ab	5.83(±2.3)ab	6.28(±2.16)b	37.09(±2.45)c	37.4(±6.24)c
	00257_1_PesticidesToxicityBees		Conventional#Machakos	Organic#Kirinyaga	Conventional#Kirinyaga	Organic#Machakos	Conventional#Murang'a	Organic#Murang'a
			4.74(±0.76)a	8.47(±1.6)b	8.88(±1.01)b	10.2(±2.81)ab	24.25(±1.44)	36.67(±1.49)
	00257_2_PesticidesToxicityAquaticOrganisms		Conventional#Kirinyaga	Conventional#Machakos	Organic#Kirinyaga	Organic#Machakos	Conventional#Murang'a	Organic#Murang'a
			2.53(±0.68)a	3.1(±0.65)ab	6.33(±1.63)bc	10.69(±2.81)c	24.6(±1.41)	36.32(±1.54)
	00257_ArableLandAveragePlotSize_Calculated		Organic#Kirinyaga	Conventional#Kirinyaga	Organic#Machakos	Conventional#Machakos	Organic#Murang'a	Conventional#Murang'a
		ns	35.18(±1.73)a	36.54(±0.99)ab	39.33(±1.2)bcd	39.66(±0.4)c	41.87(±0.54)de	41.94(±0.32)e
	00323_MineralNFertilizers		Conventional#Murang'a	Organic#Murang'a	Conventional#Kirinyaga	Conventional#Machakos	Organic#Kirinyaga	Organic#Machakos

	Indicator	P	System and county					
		P<0.05	1.79(±0.12)	2.24(±0.19)	3.04(±0.11)	4.21(±0.09)a	4.25(±0.18)a	4.94(±)0.11
	00324_MineralPFertilizers		Conventional#Murang'a	Organic#Murang'a	Conventional#Kirinyaga	Conventional#Machakos	Organic#Kirinyaga	Organic#Machakos
			2.13(±0.08)	2.75(±0.12)	2.75(±0.06)a	3.25(±0.07)b	3.29(±0.12)b	3.8(±0.07)
	00371_AccessToPasture		Conventional#Kirinyaga	Organic#Kirinyaga	Conventional#Murang'a	Organic#Murang'a	Organic#Machakos	Conventional#Machakos
		ns	0.19(±0.14)a	0.32(±0.26)a	0.47(±0.22)a	0.65(±0.38)a	17.09(±1.31)b	17.9(±0.46)b
	00605_ManagementRiparianStripes		Organic#Machakos	Conventional#Machakos	Conventional#Murang'a	Conventional#Kirinyaga	Organic#Murang'a	Organic#Kirinyaga
			11.79(±3.74)ab	12.66(±1.52)a	19.06(±1.95)bc	24.55(±2.1)c	32.74(±3.27)	43.5(±2.84)
	00620_PermanentGrasslandMowingFrequency		Conventional#Kirinyaga	Organic#Murang'a	Conventional#Murang'a	Organic#Kirinyaga	Conventional#Machakos	Organic#Machakos
		ns	3.41(±0.84)a	4.78(±1.6)ab	6.96(±0.99)bc	10.27(±1.91)c	27.9(±1.86)d	28.27(±4.72)d
	00711_EcolComensationValuableLandscapeElements		Conventional#Kirinyaga	Conventional#Murang'a	Organic#Machakos	Conventional#Machakos	Organic#Murang'a	Organic#Kirinyaga
		ns	0.25(±0.25)a	0.71(±0.41)a	1.18(±1.17)ab	2.28(±0.65)b	2.34(±1.14)ab	3.94(±1.43)b
	00740_GrowthRegulation		Conventional#Kirinyaga	Conventional#Machakos	Organic#Machakos	Conventional#Murang'a	Organic#Murang'a	Organic#Kirinyaga
			2.34(±0.11)a	2.45(±0.1)ab	2.82(±0.21)bcd	3.02(±0.08)c	3.25(±0.08)de	3.29(±0.07)e
	00743_SealedAreas_Calculated		Conventional#Kirinyaga	Organic#Kirinyaga	Organic#Machakos	Conventional#Murang'a	Conventional#Machakos	Organic#Murang'a
		ns	3.29(±0.04)a	3.36(±0.05)a	3.37(±0.1)ab	3.38(±0.04)ab	3.49(±0.04)bc	3.64(±0.07)c
	00758_NumberPerennialcrops	ns	Organic#Kirinyaga	Conventional#Murang'a	Organic#Murang'a	Organic#Machakos	Conventional#Machakos	Conventional#Kirinyaga
			1.35(±0.45)a	1.46(±0.28)a	1.53(±0.45)a	1.81(±1.15)ab	1.9(±0.4)a	4.22(±0.48)b
	00764_ShareLegumesOnPerennialCropArea		Organic#Murang'a	Conventional#Murang'a	Organic#Kirinyaga	Conventional#Kirinyaga	Conventional#Machakos	Organic#Machakos
		ns	0(±0.0)a	0.2(±0.2)a	0.95(±0.58)ab	1.41(±0.48)b	9.46(±0.98)c	13.76(±2.86)c
Genetic Diversity	00198_1_DualPurposeBreedsPoultry		Organic#Murang'a	Conventional#Murang'a	Organic#Machakos	Conventional#Machakos	Conventional#Kirinyaga	Organic#Kirinyaga
		ns	9.68(±1.8)a	11.46(±1.31)a	15.25(±2.88)ab	19.37(±1.19)bc	20.3(±1.54)bc	23.74(±2.33)c
	00198_DualPurposeBreedsRuminants		Organic#Kirinyaga	Conventional#Kirinyaga	Conventional#Murang'a	Organic#Murang'a	Organic#Machakos	Conventional#Machakos
			2.1(±0.97)a	4.13(±0.88)ab	4.77(±0.88)b	12.13(±1.83)c	12.84(±2.81)c	19.07(±1.26)
	00202_AgroForestrySystems_Calculated		Organic#Murang'a	Conventional#Murang'a	Conventional#Machakos	Organic#Machakos	Organic#Kirinyaga	Conventional#Kirinyaga
		ns	0.16(±0.11)a	0.18(±0.08)a	1.03(±0.29)b	3.95(±1.53)bcd	4.52(±0.91)c	6.99(±0.86)d
	00208_WoodlandsShareAgriculturalLand_Calculated		Organic#Machakos	Conventional#Machakos	Conventional#Kirinyaga	Organic#Kirinyaga	Conventional#Murang'a	Organic#Murang'a
		ns	1.25(±0.63)a	1.84(±0.43)a	4.17(±0.63)b	5.83(±1.31)bc	7.16(±0.85)cd	10.25(±1.57)d
	00222_PermanentGrasslandsShareOfAgriculturalArea_Calculated		Organic#Murang'a	Organic#Kirinyaga	Conventional#Kirinyaga	Conventional#Murang'a	Organic#Machakos	Conventional#Machakos
		ns	0.58(±0.25)a	0.67(±0.31)a	0.69(±0.2)a	1.12(±0.29)a	3.77(±1.2)b	5.08(±0.48)b

	Indicator	P	System and county					
	00223_RareEndangeredCrops		Conventional#Kirinyaga	Organic#Machakos	Organic#Kirinyaga	Conventional#Machakos	Conventional#Murang'a	Organic#Murang'a
		ns	2.89(±0.64)a	4.63(±1.36)ab	4.66(±0.94)ab	4.9(±0.64)b	6.5(±0.99)b	7.88(±1.89)b
	00233_NoUseSynthChemFungicides		Organic#Kirinyaga	Conventional#Kirinyaga	Conventional#Machakos	Organic#Machakos	Conventional#Murang'a	Organic#Murang'a
			27.95(±1.79)a	32.17(±1.2)a	35.39(±0.92)b	39.3(±1.93)b	52.8(±0.42)	54.25(±0.1)
	00234_NoUseSynthChemInsecticides		Conventional#Kirinyaga	Conventional#Machakos	Organic#Machakos	Organic#Kirinyaga	Conventional#Murang'a	Organic#Murang'a
		P<0.05	23.91(±1.37)	33.5(±0.91)	38.31(±1.85)a	40.17(±1.83)a	50.36(±0.52)b	51.58(±0.47)b
	_00247_HybridCultivars		Conventional#Kirinyaga	Conventional#Murang'a	Organic#Kirinyaga	Organic#Machakos	Conventional#Machakos	Organic#Murang'a
			5.93(±1.21)a	8.18(±1.5)a	24.1(±3.36)b	25.3(±4.92)b	25.45(±1.95)b	30.46(±3.48)b
	00249_HybridLivestock		Conventional#Murang'a	Organic#Murang'a	Organic#Kirinyaga	Conventional#Kirinyaga	Organic#Machakos	Conventional#Machakos
		P<0.05	24.04(±2.11)a	24.92(±3.35)a	35.68(±3.3)	46.19(±1.9)b	48.93(±3.88)bc	50.89(±1.43)c
	00253_PermanentGrasslandsExtensivelyManaged		Conventional#Kirinyaga	Conventional#Murang'a	Organic#Murang'a	Organic#Kirinyaga	Conventional#Machakos	Organic#Machakos
		ns	0.71(±0.41)a	1.2(±0.5)ab	3.38(±1.33)ab	3.64(±1.25)b	21.47(±1.42)c	21.65(±3.61)c
	00257_1_PesticidesToxicityBees		Conventional#Machakos	Organic#Kirinyaga	Conventional#Kirinyaga	Organic#Machakos	Conventional#Murang'a	Organic#Murang'a
			6.69(±1.08)a	11.95(±2.25)b	12.54(±1.43)b	14.4(±3.97)ab	34.24(±2.03)	51.78(±2.1)
	00377_1_PesticidesNumberActiveSubstances		Conventional#Kirinyaga	Conventional#Machakos	Organic#Machakos	Organic#Kirinyaga	Conventional#Murang'a	Organic#Murang'a
			27.34(±0.77)a	28.33(±0.63)a	33.18(±1.86)b	34.26(±)1.29b	43.14(±0.84)	49.8(±0.82)
	_00620_PermanentGrasslandMowingFrequency		Conventional#Kirinyaga	Organic#Murang'a	Conventional#Murang'a	Organic#Kirinyaga	Conventional#Machakos	Organic#Machakos
		ns	1.65(±0.41)a	2.31(±0.78)ab	3.37(±0.48)bc	4.98(±0.93)c	13.52(±0.9)d	13.7(±2.28)d
	00711_EcolComensationValuableLandscapeElements		Conventional#Kirinyaga	Conventional#Murang'a	Organic#Machakos	Conventional#Machakos	Organic#Murang'a	Organic#Kirinyaga
		ns	0.21(±0.21)a	0.59(±0.34)a	0.99(±0.99)ab	1.92(±0.54)b	1.96(±0.96)ab	3.31(±1.2)b
	00743_SealedAreas_Calculated		Conventional#Kirinyaga	Organic#Kirinyaga	Organic#Machakos	Conventional#Murang'a	Conventional#Machakos	Organic#Murang'a
		ns	20.79(±0.24)a	21.2(±0.33)a	21.24(±0.61)ab	21.32(±0.27)ab	22.02(±0.26)bc	22.98(±0.45)c
Soil Quality	00202_AgroForestrySystems_Calculated		Organic#Murang'a	Conventional#Murang'a	Conventional#Machakos	Organic#Machakos	Organic#Kirinyaga	Conventional#Kirinyaga
		ns	0.2(±0.14)a	0.22(±0.1)a	1.28(±0.37)b	4.96(±1.91)bc	5.67(±1.15)c	8.76(±1.08)c
	00206_ShareLegumesArableLand		Organic#Murang'a	Conventional#Murang'a	Organic#Kirinyaga	Conventional#Kirinyaga	Conventional#Machakos	Organic#Machakos
		ns	7.42(±2.11)a	11.46(±1.57)a	28.29(±2.95)b	28.42(±2.0)b	50.77(±1.09)c	53.91(±1.9)c
	00207_ArableLandShareDirectSeeding		Organic#Murang'a	Conventional#Murang'a	Conventional#Machakos	Organic#Kirinyaga	Organic#Machakos	Conventional#Kirinyaga
			0.04(±0.04)a	0.23(±0.1)a	0.77(±0.37)a	1.86(±1.1)a	3.77(±2.19)a	11.25(±1.56)

	Indicator	P	System and county					
	00215_ArableLandShareTemporaryGrassland_Calculated		Organic#Machakos	Conventional#Machakos	Conventional#Kirinyaga	Organic#Murang'a	Conventional#Murang'a	Organic#Kirinyaga
		ns	0.37(±0.37)a	0.75(±0.26)a	8.09(±1.15)b	9.5(±1.87)bc	12.81(±1.32)c	14.44(±2.58)c
	00222_PermanentGrasslandsShareOfAgriculturalArea_Calculated		Organic#Murang'a	Organic#Kirinyaga	Conventional#Kirinyaga	Conventional#Murang'a	Organic#Machakos	Conventional#Machakos
		ns	0.98(±0.42)a	1.13(±0.52)a	1.15(±0.34)a	1.89(±0.49)a	6.33(±2.01)b	8.47(±0.81)c
	00233_NoUseSynthChemFungicides		Organic#Kirinyaga	Conventional#Kirinyaga	Organic#Murang'a	Conventional#Machakos	Organic#Machakos	Conventional#Murang'a
			34.63(±2.22)a	36.28(±1.62)a	36.43(±3.73)ab	42.82(±1.19)b	48.7(±2.4)	56.92(±1.62)
	00234_NoUseSynthChemInsecticides		Conventional#Kirinyaga	Organic#Murang'a	Conventional#Machakos	Organic#Machakos	Organic#Kirinyaga	Conventional#Murang'a
		ns	29.38(±1.76)a	36.39(±3.72)ab	41.19(±1.19)b	48.3(±2.33)c	50.64(±2.3)cd	55.73(±1.64)d
	00286_SoilDegradationCounterMeasures		Organic#Murang'a	Conventional#Machakos	Conventional#Murang'a	Organic#Machakos	Conventional#Kirinyaga	Organic#Kirinyaga
			26.74(±4.22)a	44.66(±2.48)a	47.01(±2.79)a	48.43(±6.18)ab	61.09(±2.4)b	77.34(±1.63)
	00295_AntibioticsLivestockFertilizer		Organic#Murang'a	Conventional#Murang'a	Conventional#Machakos	Organic#Machakos	Conventional#Kirinyaga	Organic#Kirinyaga
			11.86(±2.31)a	12.19(±1.48)a	20.46(±1.49)b	21.62(±3.79)bc	25.15(±1.73)c	42.9(±1.63)
	00298_SoilImprovement		Organic#Murang'a	Conventional#Murang'a	Conventional#Kirinyaga	Organic#Machakos	Conventional#Machakos	Organic#Kirinyaga
			39.08(±4.19)	62.17(±2.0)a	64.03(±1.92)ab	64.21(±4.2)ab	68.35(±1.36)b	74.79(±0.46)
	00300_ArableLandGradientsGreater15Percent		Organic#Murang'a	Conventional#Murang'a	Organic#Machakos	Conventional#Kirinyaga	Organic#Kirinyaga	Conventional#Machakos
		P<0.05	24.12(±2.94)	40.03(±1.54)	49.47(±2.74)a	49.68(±1.21)a	51.67(±1.4)a	51.92(±0.77)a
	00323_MineralNFertilizers		Organic#Murang'a	Conventional#Murang'a	Conventional#Kirinyaga	Conventional#Machakos	Organic#Kirinyaga	Organic#Machakos
		P<0.05	14.83(±2.57)a	18.54(±1.46)a	32.95(±1.48)	50.26(±1.22)b	51.71(±2.14)b	60.06(±1.38)
	00324_MineralPFertilizers		Organic#Murang'a	Conventional#Murang'a	Conventional#Kirinyaga	Conventional#Machakos	Organic#Kirinyaga	Organic#Machakos
		P<0.05	19.55(±2.53)	26.98(±1.39)	38.21(±1.2)	48.99(±1.13)a	50.57(±1.84)a	58.39(±1.11)
	00327_WasteDisposalPesticidesVeterinaryMedicines		Conventional#Machakos	Organic#Machakos	Conventional#Kirinyaga	Organic#Kirinyaga	Organic#Murang'a	Conventional#Murang'a
		ns	0.94(±0.47)a	1.51(±1.5)a	7.56(±1.45)b	10.8(±2.54)b	23.14(±3.28)c	25.12(±2.1)c
	00377_1_PesticidesNumberActiveSubstances		Conventional#Kirinyaga	Organic#Murang'a	Conventional#Machakos	Organic#Machakos	Organic#Kirinyaga	Conventional#Murang'a
		ns	21.42(±0.81)a	22.89(±2.42)ab	23.95(±0.58)a	28.73(±1.61)c	29.66(±1.12)c	31.58(±1.11)c
	00474_2_PesticidesPersistenceSoil		Organic#Kirinyaga	Conventional#Kirinyaga	Organic#Murang'a	Conventional#Murang'a	Conventional#Machakos	Organic#Machakos
		P<0.05	14.75(±3.09)a	22.05(±2.32)a	34.84(±3.84)	47.94(±2.24)b	52.16(±1.85)b	63.67(±2.88)
	00708_PreciseFertilisation		Conventional#Murang'a	Organic#Murang'a	Organic#Machakos	Conventional#Machakos	Conventional#Kirinyaga	Organic#Kirinyaga

	Indicator	P	System and county					
		ns	1.29(±0.57)a	1.92(±1.09)a	5.19(±2.47)ab	5.28(±0.98)b	28.95(±1.87)c	32.78(±2.74)c
	_00710_HarmfulSubstancesPFertilizer		Organic#Murang'a	Conventional#Murang'a	Conventional#Machakos	Organic#Machakos	Conventional#Kirinyaga	Organic#Kirinyaga
		ns	15.59(±2.91)a	17.01(±1.77)a	36.58(±1.9)b	40.05(±4.66)bc	40.27(±1.48)bc	42.17(±1.93)c
	_00740_GrowthRegulation		Organic#Murang'a	Conventional#Kirinyaga	Conventional#Machakos	Conventional#Murang'a	Organic#Machakos	Organic#Kirinyaga
			23.33(±2.51)	30.11(±1.53)a	31.63(±1.29)ab	34.13(±1.36)b	37.11(±2.71)b	43.38(±0.91)
	00743_SealedAreas_Calculated		Organic#Murang'a	Conventional#Murang'a	Conventional#Kirinyaga	Organic#Kirinyaga	Organic#Machakos	Conventional#Machakos
			18.49(±1.93)	30.58(±0.92)a	32.4(±0.84)a	36.2(±0.56)b	36.29(±1.05)b	36.94(±0.55)b
	00748_HumusFormationHumusBalance		Organic#Murang'a	Conventional#Murang'a	Conventional#Kirinyaga	Conventional#Machakos	Organic#Kirinyaga	Organic#Machakos
		P<0.05	35.78(±0.0)	57.02(±0.0)	57.98(±0.0)	62.78(±0.0)	65.87(±0.0)	65.87(±0.0)
	00758_NumberPerennialcrops		Organic#Murang'a	Organic#Kirinyaga	Conventional#Murang'a	Conventional#Machakos	Organic#Machakos	Conventional#Kirinyaga
			0.94(±0.34)a	1.43(±0.48)a	1.43(±0.29)a	1.74(±0.38)a	1.9(±1.21)ab	4.34(±0.51)b
	00764_ShareLegumesOnPerennialCropArea		Organic#Murang'a	Conventional#Murang'a	Organic#Kirinyaga	Conventional#Kirinyaga	Conventional#Machakos	Organic#Machakos
			0.0(±0.0)a	0.26(±0.26)a	1.22(±0.74)ab	1.54(±0.56)b	11.72(±1.24)c	17.62(±3.66)c
Species Diversity	00202_AgroForestrySystems_Calculated		Organic#Murang'a	Conventional#Murang'a	Conventional#Machakos	Organic#Machakos	Organic#Kirinyaga	Conventional#Kirinyaga
		ns	0.22(±0.16)a	0.25(±0.11)a	1.46(±0.14)b	5.62(±2.17)bcd	6.42(±1.3)c	9.95(±1.22)d
	00204_WoodlandsDeforestation		Conventional#Machakos	Organic#Machakos	Organic#Murang'a	Organic#Kirinyaga	Conventional#Murang'a	Conventional#Kirinyaga
		ns	39.9(±1.01)a	40.63(±2.44)ab	42.42(±1.45)ab	44.91(±0.87)bc	45.04(±0.56)bc	45.64(±0.42)c
	00208_WoodlandsShareAgriculturalLand_Calculated		Organic#Machakos	Conventional#Machakos	Conventional#Kirinyaga	Organic#Kirinyaga	Conventional#Murang'a	Organic#Murang'a
		ns	2.01(±1.02)a	2.96(±0.7)a	6.71(±1.01)b	9.4(±2.11)bc	11.54(±1.37)cd	16.5(±2.52)d
	00215_ArableLandShareTemporaryGrassland_Calculated		Organic#Machakos	Conventional#Machakos	Conventional#Kirinyaga	Organic#Kirinyaga	Conventional#Murang'a	Organic#Murang'a
		ns	0.3(±0.29)a	0.65(±0.21)a	8.0(±1.0)b	11.54(±2.07)bc	12.41(±1.08)c	13.13(±1.63)c
	00222_PermanentGrasslandsShareOfAgriculturalArea_Calculated		Organic#Murang'a	Organic#Kirinyaga	Conventional#Kirinyaga	Conventional#Murang'a	Organic#Machakos	Conventional#Machakos
		ns	0.97(±0.42)a	1.12(±0.51)a	1.14(±0.34)a	1.87(±0.49)a	6.26(±1.99)b	8.43(±0.8)b
	00233_NoUseSynthChemFungicides		Organic#Kirinyaga	Conventional#Kirinyaga	Conventional#Machakos	Organic#Machakos	Conventional#Murang'a	Organic#Murang'a
			34.41(±2.2)a	39.6(±1.48)a	43.57(±1.13)b	48.39(±2.38)b	65.01(±0.51)	66.8(±0.12)
	00234_NoUseSynthChemInsecticides		Conventional#Kirinyaga	Conventional#Machakos	Organic#Machakos	Organic#Kirinyaga	Conventional#Murang'a	Organic#Murang'a
		P<0.05	31.62(±1.81)	44.29(±1.2)	50.65(±2.44)a	53.11(±2.41)a	66.58(±0.69)b	68.19(±0.62)b
	00257_1_PesticidesToxicityBees		Conventional#Machakos	Organic#Kirinyaga	Conventional#Kirinyaga	Organic#Machakos	Conventional#Murang'a	Organic#Murang'a

	Indicator	P	System and county					
			7.61(±1.22)a	13.59(±2.56)b	14.25(±1.62)b	16.37(±4.52)ab	38.92(±2.31)	58.85(±2.39)
	00257_2_PesticidesToxicityAquaticOrganisms		Conventional#Kirinyaga	Conventional#Machakos	Organic#Kirinyaga	Organic#Machakos	Conventional#Murang'a	Organic#Murang'a
			3.62(±0.98)a	4.43(±0.93)ab	9.06(±2.33)bc	15.3(±4.02)c	35.2(±2.02)	51.97(±2.21)
	00257_ArableLandAveragePlotSize_Calculated		Organic#Kirinyaga	Conventional#Kirinyaga	Organic#Machakos	Conventional#Machakos	Organic#Murang'a	Conventional#Murang'a
		ns	46.1(±2.27)a	47.88(±1.3)ab	51.54(±1.58)bcd	51.96(±0.52)c	54.85(±0.71)de	54.95(±0.42)e
	00295_AntibioticsLivestockFertilizer		Organic#Murang'a	Conventional#Murang'a	Conventional#Machakos	Organic#Machakos	Conventional#Kirinyaga	Organic#Kirinyaga
			7.34(±1.43)a	7.54(±0.92)a	12.77(±0.92)b	13.37(±2.35)bc	15.71(±1.07)	26.53(±1.01)
	00323_MineralNFertilizers		Conventional#Murang'a	Organic#Murang'a	Conventional#Kirinyaga	Conventional#Machakos	Organic#Kirinyaga	Organic#Machakos
		P<0.05	18.51(±1.22)	23.1(±1.94)	31.38(±1.12)	43.47(±0.97)a	43.89(±1.81)a	50.97(±1.17)
	00324_MineralPFertilizers		Conventional#Murang'a	Organic#Murang'a	Conventional#Kirinyaga	Conventional#Machakos	Organic#Kirinyaga	Organic#Machakos
			23.45(±0.89)a	30.28(±1.29)a	30.35(±0.63)a	35.82(±0.75)b	36.29(±1.32)b	41.91(±0.8)
	00377_1_PesticidesNumberActiveSubstances		Conventional#Kirinyaga	Conventional#Machakos	Organic#Machakos	Organic#Kirinyaga	Conventional#Murang'a	Organic#Murang'a
			25.34(±0.71)a	26.26(±0.58)a	30.75(±1.73)b	31.75(±1.2)b	39.99(±0.78)	46.16(±0.76)
	00474_1_PesticidesPersistenceWater		Conventional#Machakos	Conventional#Kirinyaga	Organic#Machakos	Organic#Kirinyaga	Conventional#Murang'a	Organic#Murang'a
		P<0.05	6.38(±1.12)	15.83(±1.83)a	16.89(±4.09)ab	23.45(±3.04)b	31.92(±1.97)	50.03(±1.97)
	00474_2_PesticidesPersistenceSoil		Organic#Kirinyaga	Conventional#Kirinyaga	Conventional#Machakos	Conventional#Murang'a	Organic#Machakos	Organic#Murang'a
		P<0.05	11.69(±2.45)	20.61(±1.91)	42.42(±1.42)a	45.07(±1.46)a	50.48(±2.28)b	51.88(±1.32)b
	00605_ManagementRiparianStripes		Organic#Machakos	Conventional#Machakos	Conventional#Murang'a	Conventional#Kirinyaga	Organic#Murang'a	Organic#Kirinyaga
			11.8(±3.74)ab	12.68(±1.52)a	19.08(±1.95)bc	24.58(±2.11)c	32.78(±3.27)	43.55(±2.84)
	00620_PermanentGrasslandMowingFrequency		Conventional#Kirinyaga	Organic#Murang'a	Conventional#Murang'a	Organic#Kirinyaga	Conventional#Machakos	Organic#Machakos
		ns	3.39(±0.84)a	4.75(±1.59)ab	6.91(±0.98)bc	10.21(±1.9)c	27.72(±1.84)d	28.09(±4.69)d
	SpeciesDiversity_00708_PreciseFertilisation		Conventional#Murang'a	Organic#Murang'a	Organic#Machakos	Conventional#Machakos	Conventional#Kirinyaga	Organic#Kirinyaga
		ns	0.95(±0.42)a	2.36(±1.03)ab	3.83(±1.82)ab	3.89(±0.73)b	22.93(±1.36)c	24.16(±2.02)c
	00710_HarmfulSubstancesPFertilizer		Organic#Murang'a	Conventional#Murang'a	Conventional#Machakos	Organic#Machakos	Organic#Kirinyaga	Conventional#Kirinyaga
		ns	8.64(±1.61)a	9.68(±0.98)a	20.54(±1.05)b	22.19(±2.58)bc	23.37(±1.07)bc	23.56(±0.7)c
	00711_EcolComensationValuableLandscapeElements		Conventional#Kirinyaga	Conventional#Murang'a	Organic#Machakos	Conventional#Machakos	Organic#Murang'a	Organic#Kirinyaga
		ns	0.33(±0.33)a	0.95(±.055)a	1.59(±1.58)ab	3.07(±0.87)b	3.15(±1.54)ab	5.31(±1.93)b
	00743_SealedAreas_Calculated		Conventional#Kirinyaga	Organic#Machakos	Organic#Kirinyaga	Conventional#Murang'a	Conventional#Machakos	Organic#Murang'a

	Indicator	P	System and county					
		ns	26.21(±0.3)a	26.62(±0.75)ab	26.82(±0.42)ab	26.87(±0.34)ab	27.76(±0.33)bc	28.96(±0.57)c
	00748_HumusFormationHumusBalance		Organic#Machakos	Conventional#Kirinyaga	Conventional#Machakos	Organic#Murang'a	Conventional#Murang'a	Organic#Kirinyaga
		ns	9.1(±2.13)a	11.3(±0.82)a	13.98(±0.95)a	16.65(±1.93)b	21.93(±1.1c7)	23.87(±1.27)c
	00757_ShareGreenCoverPerennialCropLand		Organic#Machakos	Conventional#Machakos	Organic#Kirinyaga	Conventional#Murang'a	Organic#Murang'a	Conventional#Kirinyaga
			0.09(±0.09)	2.12(±0.54)a	3.29(±0.98)ab	5.18(±0.76)b	5.23(±1.13)b	10.24(±1.18)
	00758_NumberPerennialcrops		Organic#Kirinyaga	Conventional#Murang'a	Organic#Murang'a	Organic#Machakos	Conventional#Machakos	Conventional#Kirinyaga
		ns	1.75(±0.59)a	1.89(±0.37)a	1.98(±0.58)a	2.39(±1.49)ab	2.45(±0.5a1)	5.46(±0.63)b
Water withdrawal	00376_1_InformationWaterAvailability		Organic#Machakos	Conventional#Machakos	Conventional#Murang'a	Organic#Murang'a	Conventional#Kirinyaga	Organic#Kirinyaga
		ns	10.96(±3.77)a	11.74(±1.53)a	30.84(±2.22)b	31.69(±3.49)b	47.45(±1.94)	50.68(±2.69)c
	00377_05_WastewaterDisposal		Conventional#Kirinyaga	Organic#Machakos	Organic#Kirinyaga	Organic#Murang'a	Conventional#Murang'a	Conventional#Machakos
		ns	2.18(±0.81)a	4.49(±2.5)ab	5.7(±1.92)ab	8.87(±2.37)bc	11.32(±1.66)c	13.8(±1.58)c
	00389_IrrigationWaterConsumption_Calculated		Conventional#Machakos	Conventional#Kirinyaga	Conventional#Murang'a	Organic#Murang'a	Organic#Machakos	Organic#Kirinyaga
			53.08(±2.6)a	54.31(±2.98)a	57.19(±2.83)a	57.5(±4.44)a	61.96(±6.06)ab	73.26(±3.27)b
	00400_YieldDecreaseLackOfWater		Organic#Machakos	Conventional#Machakos	Conventional#Kirinyaga	Organic#Kirinyaga	Organic#Murang'a	Conventional#Murang'a
		ns	1.45(±1.44)a	2.73(±0.77)a	8.48(±1.49)b	10.38(±2.44)b	38.76(±3.06)c	42.52(±1.82)c
	00404_IrrigationPrecipitationMeasurement		Conventional#Machakos	Conventional#Kirinyaga	Organic#Murang'a	Conventional#Murang'a	Organic#Machakos	Organic#Kirinyaga
			43.22(±2.1)a	44.66(±2.4)ab	46.95(±3.6)ab	50.92(±2.16)b	51.86(±4.75)abc	59.27(±2.65)c
	00405_WaterStorageCapacity		Organic#Kirinyaga	Conventional#Kirinyaga	Conventional#Machakos	Organic#Machakos	Conventional#Murang'a	Organic#Murang'a
			0.71(±0.71)	5.61(±1.26)a	7.71(±1.26)a	8.97(±3.39)a	29.01(±2.11)b	29.54(±3.33)b
	00739_ReusablePackagingMaterials		Conventional#Machakos	Organic#Murang'a	Organic#Machakos	Conventional#Murang'a	Conventional#Kirinyaga	Organic#Kirinyaga
			11.75(±0.46)a	12.07(±0.75)a	13.84(±1.09)	14.68(±0.47)b	16.67(±0.36)	17.79(±0.37)

Note: margins sharing a letter in the group label are not significantly different at the 5% level

Economic Resilience

	Indicator	P	System and county					
Community	00074_CostsEnvironmentalInvolvementOutsideFarm		Conventional#Murang'a	Organic#Machakos	Organic#Murang'a	Conventional#Machakos	Conventional#Kirinyaga	Organic#Kirinyaga
			1.02(±0.46)a	1.58(±1.57)a	3.9(±1.63)ab	5.43(±107)b	6.67(±1.21)b	13.36(±2.58)
	00075_CostsSocialInvolvementOutsideFarm		Organic#Machakos	Organic#Murang'a	Conventional#Kirinyaga	Conventional#Machakos	Conventional#Murang'a	Organic#Kirinyaga
		P<0.05	12.8(±4.41)a	15.57(±3.32)a	16.95(±2.04)	17.28(±1.88)	27.97(±2.36)	44.62(±3.65)

	Indicator	P	System and county					
	00202_AgroForestrySystems_Calculated		Organic#Murang'a	Conventional#Murang'a	Conventional#Machakos	Organic#Machakos	Organic#Kirinyaga	Conventional#Kirinyaga
		ns	0.17(±0.21)a	0.19(±0.08)a	1.09(±0.31)b	4.19(±1.62)bc	4.78(±0.97)c	7.39(±0.91)c
	00204_WoodlandsDeforestation		Organic#Murang'a	Conventional#Murang'a	Conventional#Machakos	Organic#Machakos	Conventional#Kirinyaga	Organic#Kirinyaga
			25.84(±2.85)	41.14(±1.43)a	43.87(±1.11)ab	44.66(±2.68)abc	45.66(±1.13)b	49.37(±0.96)c
	00208_WoodlandsShareAgriculturalLand_Calculated		Organic#Machakos	Conventional#Machakos	Conventional#Kirinyaga	Organic#Kirinyaga	Conventional#Murang'a	Organic#Murang'a
		ns	1.36(±0.69)a	1.99(±0.47)a	3.73(±0.65)b	6.33(±1.42)bc	6.85(±0.88)c	7.5(±1.57)c
	00335_1_RecyclingPaper		Conventional#Kirinyaga	Organic#Machakos	Conventional#Machakos	Organic#Murang'a	Conventional#Murang'a	Organic#Kirinyaga
		P<0.05	5.81(±0.95)a	6.61(±2.5)a	14.47(±1.3)	20.47(±2.38)	30.29(±1.37)	34.46(±1.5)
	00502_PublicHealthMeasures		Organic#Kirinyaga	Organic#Machakos	Conventional#Machakos	Organic#Murang'a	Conventional#Kirinyaga	Conventional#Murang'a
		ns	0.72(±0.71)a	1.5(±1.49)ab	2.11(±0.69)ab	2.23(±1.27)ab	2.82(±0.92)ab	3.89(±1.05)b
	00506_FoodSecurityMeasuresLocCommunities		Organic#Machakos	Conventional#Machakos	Conventional#Kirinyaga	Conventional#Murang'a	Organic#Murang'a	Organic#Kirinyaga
		ns	4.66(±2.59)a	5.82(±1.14)a	17.79(±2.03)b	18.22(±2.0)b	19.93(±3.23)b	25.13(±3.34)b
	00512_NumberJobsCreatedRemoved		Organic#Murang'a	Conventional#Murang'a	Conventional#Kirinyaga	Organic#Machakos	Organic#Kirinyaga	Conventional#Machakos
			21.38(±2.43)a	32.93(±1.29)a	34.37(±1.58)a	36.55(±2.34)ab	38.02(±2.87)ab	38.48(±0.85)b
	00605_ManagementRiparianStripes		Organic#Machakos	Conventional#Machakos	Organic#Murang'a	Conventional#Murang'a	Conventional#Kirinyaga	Organic#Kirinyaga
			11.53(±3.66)a	12.39(±1.49)a	12.81(±2.67)a	14.63(±1.78)a	21.92(±2.03)	42.55(±2.78)
	00711_EcolComensationValuableLandscapeElements		Conventional#Kirinyaga	Conventional#Murang'a	Organic#Machakos	Conventional#Machakos	Organic#Murang'a	Organic#Kirinyaga
		ns	0.28(±2.8)a	0.79(±0.46)a	1.33(±1.32)ab	2.56(±0.73)b	2.62(±1.28)ab	4.42(±1.61)b
	00793_LocalProcurementProducerLevel_Calculated		Conventional#Kirinyaga	Organic#Kirinyaga	Organic#Machakos	Conventional#Machakos	Organic#Murang'a	Conventional#Murang'a
			3.3(±0.39)a	3.43(±0.6)a	8.76(±1.39)b	9.7(±0.49)b	10.09(±1.21)b	15.04(±0.6)
	00794_LocalProcurementAwareness		Conventional#Kirinyaga	Organic#Murang'a	Conventional#Murang'a	Organic#Machakos	Conventional#Machakos	Organic#Kirinyaga
		ns	2.65(±0.35)a	3.5(±0.77)abc	3.5(±0.41)ab	3.96(±0.66)abc	4.59(±0.34)c	4.96(±0.87)bc
Food Safety	00034_2_UseageChemSynthSeedDressings		Conventional#Kirinyaga	Conventional#Murang'a	Conventional#Machakos	Organic#Machakos	Organic#Murang'a	Organic#Kirinyaga
			4(±0.87)a	4.42(±0.89)a	9.79(±1.09)b	12.12(±2.94)bc	14.47(±2.16)bc	15.39(±2.15)c
	00167_No ContaminatedProducts		Organic#Kirinyaga	Organic#Machakos	Organic#Murang'a	Conventional#Kirinyaga	Conventional#Machakos	Conventional#Murang'a
			82.48(±0.99)a	83.43(±1.05)ab	83.45(±0.73)ab	84.27(±0.22)ab	84.32(±0.17ab)	84.49(±0.0)b
	00169_ContaminationCasesMeasures		Organic#Machakos	Conventional#Machakos	Conventional#Kirinyaga	Organic#Murang'a	Conventional#Murang'a	Organic#Kirinyaga
			41.3(±6.89)a	42.11(±2.73)a	48(±3.13)ab	56.89(±4.61)bc	67.04(±2.59)c	75.55(±3.21)
	00175_TrasparencyProduction		Conventional#Machakos	Organic#Machakos	Conventional#Murang'a	Conventional#Kirinyaga	Organic#Murang'a	Organic#Kirinyaga
		P<0.05	0.26(±0.26)a	1.66(±1.65)ab	3.48(±0.9)b	7.28(±1.28)	14.17(±2.51)	27.33(±2.72)
	00233_NoUseSynthChemFungicides		Organic#Kirinyaga	Conventional#Kirinyaga	Conventional#Machakos	Organic#Machakos	Conventional#Murang'a	Organic#Murang'a
			23.06(±1.48)a	26.54(±0.99)a	29.2(±0.76)b	32.43(±1.6)b	43.56(±0.34)	44.76(±0.08)
	00234_NoUseSynthChemInsecticides		Conventional#Kirinyaga	Conventional#Machakos	Organic#Machakos	Organic#Kirinyaga	Conventional#Murang'a	Organic#Murang'a

	Indicator	P	System and county					
		P<0.05	20.62(±1.18)a	28.89(±0.78)	33.04(±1.59)a	34.64(±1.58)a	43.43(±0.45)	44.47(±0.4)b
	00295_AntibioticsLivestockFertilizer		Organic#Murang'a	Conventional#Murang'a	Conventional#Machakos	Organic#Machakos	Conventional#Kirinyaga	Organic#Kirinyaga
			11.49(±2.24)a	11.81(±1.43)a	19.99(±1.44)b	20.94(±3.67)bc	24.6(±1.68)c	41.55(±1.58)
	00323_MineralNFertilizers		Conventional#Murang'a	Organic#Murang'a	Conventional#Kirinyaga	Conventional#Machakos	Organic#Kirinyaga	Organic#Machakos
		P<0.05	10.69(±0.7)	13.34(±1.12)	18.12(±0.64)	25.1(±0.56)a	25.34(±1.05)a	29.42(±0.67)
	00353_LivestockHealthProphylacticTreatments		Organic#Machakos	Conventional#Kirinyaga	Conventional#Machakos	Organic#Kirinyaga	Conventional#Murang'a	Organic#Murang'a
		ns	37.66(±3.54)a	38.58(±1.69)a	41.31(±1.41)a	41.5(±2.13)a	43.02(±1.55)ab	48.08(±2.08)b
	00369_NumberQualityDrinkingPoints		Organic#Machakos	Conventional#Machakos	Organic#Kirinyaga	Conventional#Kirinyaga	Conventional#Murang'a	Organic#Murang'a
			11.36(±2.49)	17.75(±1.24)a	19.41(±2.36)a	27.22(±1.47)	34.45(±1.47)b	38.95(±2.3)b
	00376_2_InformationWaterQuality		Conventional#Kirinyaga	Organic#Kirinyaga	Organic#Machakos	Conventional#Machakos	Conventional#Murang'a	Organic#Murang'a
		ns	1.83(±0.74)a	5.58(±1.88)ab	5.86(±2.79)abc	8.47(±1.29)bc	11.22(±1.62)cd	16.63(±2.94)d
	00377_05_WastewaterDisposal		Conventional#Kirinyaga	Organic#Machakos	Organic#Kirinyaga	Organic#Murang'a	Conventional#Murang'a	Conventional#Machakos
			1.91(±0.71)a	3.93(±2.19)ab	5.0(±1.69)ab	7.77(±2.08)bc	9.92(±1.45)c	12.5(±1.4)c
	00377_1_PesticidesNumberActiveSubstances		Conventional#Kirinyaga	Conventional#Machakos	Organic#Machakos	Organic#Kirinyaga	Conventional#Murang'a	Organic#Murang'a
			26.96(±0.76)a	27.94(±0.62)a	32.72(±1.84)b	33.79(±1.28)b	42.55(±0.83)	49.12(±0.81)
	00377_5_PesticidesChronicToxicity		Conventional#Machakos	Organic#Machakos	Conventional#Kirinyaga	Conventional#Murang'a	Organic#Kirinyaga	Organic#Murang'a
			13.87(±1.77)a	23.08(±5.28)ab	28.85(±2.53)b	49.47(±2.31)	61.72(±2.62)c	64.88(±2.23)c
	00377_7_PesticidesAcuteToxicity		Conventional#Kirinyaga	Conventional#Machakos	Organic#Kirinyaga	Organic#Machakos	Conventional#Murang'a	Organic#Murang'a
			15.58(±1.17)a	17.51(±1.1)a	24.66(±2.13)b	26.79(±4.15)b	46.11(±2.08)	63.49(±2.28)
	00377_75_PesticidesAcuteToxicityInhalation		Conventional#Kirinyaga	Conventional#Machakos	Organic#Kirinyaga	Organic#Machakos	Conventional#Murang'a	Organic#Murang'a
		P<0.05	10.96(±1.3)	14.96(±1.28)	21.29(±2.43)a	25.74(±4.29)a	47.8(±2.04)	65.56(±2.06)
	00470_CertifiationUsagePlantProtectionAnimalTreatmentProducts		Organic#Machakos	Conventional#Machakos	Organic#Murang'a	Conventional#Murang'a	Organic#Kirinyaga	Conventional#Kirinyaga
			14.37(±4.19)a	15.43(±1.63)a	18.62(±3.4)a	18.94(±2.05)a	29.08(±2.23)	36.39(±1.99)
	00474_1_PesticidesPersistenceWater		Conventional#Machakos	Conventional#Kirinyaga	Organic#Machakos	Organic#Kirinyaga	Conventional#Murang'a	Organic#Murang'a
		P<0.05	7.07(±1.24)	17.56(±2.03)	18.73(±4.54)ab	26.02(±3.37)b	35.42(±2.19)	55.51(±2.19)
	00474_2_PesticidesPersistenceSoil		Organic#Kirinyaga	Conventional#Kirinyaga	Conventional#Machakos	Conventional#Murang'a	Organic#Machakos	Organic#Murang'a
		P<0.05	13.21(±2.77)	23.27(±2.16)	47.91(±1.61)a	50.9(±1.65)a	57.01(±2.58)b	58.59(±1.49)b
	00474_3_PesticidesKnowledge		Organic#Machakos	Conventional#Machakos	Conventional#Kirinyaga	Organic#Kirinyaga	Conventional#Murang'a	Organic#Murang'a
		P<0.05	6.16(±3.03)a	9.63(±1.36)a	26.77(±2.39)	44.84(±3.68)b	51.14(±2.11)b	59.54(±2.44)
			Conventional#Machakos	Organic#Machakos	Organic#Murang'a	Conventional#Kirinyaga	Conventional#Murang'a	Organic#Kirinyaga

	Indicator	P	System and county					
	00608_UseageAntibioticDryingAgents	ns	25.23(±1.63)a	29.95(±4.09)ab	38.58(±2.54)bc	40.15(±1.59)c	40.42(±1.54)c	43.4(±2.13)c
	00609_MilkWaitingPeriodAntibiotics		Conventional#Machakos	Organic#Machakos	Organic#Murang'a	Conventional#Murang'a	Conventional#Kirinyaga	Organic#Kirinyaga
		ns	12.39(±0.87)a	13.33(±2.22)a	19.4(±1.53)b	19.68(±0.91)b	20.9(±0.89)b	21.71(±1.37)
	00708_PreciseFertilisation		Conventional#Murang'a	Organic#Murang'a	Organic#Machakos	Conventional#Machakos	Conventional#Kirinyaga	Organic#Kirinyaga
		ns	0.95(±0.42)a	2.37(±1.03)ab	3.84(±1.83)ab	3.9(±0.73)b	22.98(±1.36)c	24.21(±2.03)c
	00710_HarmfulSubstancesPFertilizer		Organic#Murang'a	Conventional#Murang'a	Conventional#Machakos	Organic#Machakos	Organic#Kirinyaga	Conventional#Kirinyaga
		ns	13.84(±2.59)a	15.51(±1.58)a	32.9(±1.68)b	35.55(±4.14)bc	37.44(±1.72)bc	37.74(±1.12)c
	00720_SilageStorage		Conventional#Machakos	Organic#Machakos	Organic#Murang'a	Conventional#Murang'a	Conventional#Kirinyaga	Organic#Kirinyaga
		ns	7.22(±1.32)a	8.56(±3.59)ab	14.79(±3.11)bc	18.57(±2.06)c	19.44(±2.08)cd	27.31(±3.56)d
	00721_FeedConcentrateStorage		Organic#Machakos	Conventional#Machakos	Conventional#Kirinyaga	Organic#Kirinyaga	Organic#Murang'a	Conventional#Murang'a
		ns	20.54(±4.83)a	29.96(±2.04)	34.86(±2.16)bc	39.53(±3.54)c	53.68(±3.05)d	54.16(±1.86)d
	00740_GrowthRegulation		Conventional#Kirinyaga	Conventional#Machakos	Organic#Machakos	Conventional#Murang'a	Organic#Murang'a	Organic#Kirinyaga
			33.01(±1.62)a	34.65(±1.36)ab	39.77(±2.91)bcd	42.57(±1.09)c	45.82(±1.16)de	46.48(±0.98)e
Stability of market	00083_SalesDiversification		Organic#Murang'a	Conventional#Machakos	Organic#Machakos	Conventional#Murang'a	Conventional#Kirinyaga	Organic#Kirinyaga
		P<0.05	20.33(±2.52)	29.94(±1.47)a	31.7(±3.88)a	33.24(±1.3)a	48.05(±1.62)	64.89(±1.17)
	00084_AvailabilityAlternativeMarkets		Conventional#Murang'a	Organic#Murang'a	Conventional#Kirinyaga	Organic#Machakos	Organic#Kirinyaga	Conventional#Machakos
		ns	19.94(±2.59)a	21.51(±4.19)a	38.79(±3.13)	58.8(±6.47)b	63.26(±4.24)b	64.31(±2.4)b
	00141_DirectSales		Organic#Kirinyaga	Organic#Murang'a	Conventional#Kirinyaga	Conventional#Murang'a	Organic#Machakos	Conventional#Machakos
			3.6(±1.12)	11.66(±2.03)a	15.77(±1.71)ab	18.52(±1.43)b	35.63(±4.42)c	42.51(±1.61)c
	00146_No ProductReturns		Organic#Murang'a	Conventional#Murang'a	Conventional#Kirinyaga	Organic#Machakos	Conventional#Machakos	Organic#Kirinyaga
			33.85(±3.92)	55.62(±2.02)a	60.42(±1.77)ab	61.52(±3.69)abc	64.27(±1.24)bc	67.8(±1.43)c
	00149_LengthCustomerRelationshios		Organic#Machakos	Conventional#Machakos	Organic#Murang'a	Conventional#Murang'a	Conventional#Kirinyaga	Organic#Kirinyaga
		P<0.05	17.93(±4.4)	34.19(±2.02)a	36.46(±4.29)a	57.82(±2.37)	64.82(±2.16)	77.85(±1.63)
	00202_AgroForestrySystems_Calculated		Organic#Murang'a	Conventional#Murang'a	Conventional#Machakos	Organic#Machakos	Organic#Kirinyaga	Conventional#Kirinyaga
		ns	0.09(±0.07)a	0.11(±0.05)a	0.62(±0.18)b	2.39(±0.92)bc	2.74(±0.55)c	4.23(±0.52)c
	00208_WoodlandsShareAgriculturalLand_Calculated		Organic#Machakos	Conventional#Machakos	Conventional#Kirinyaga	Organic#Kirinyaga	Conventional#Murang'a	Organic#Murang'a
		ns	0.8(±0.4)a	1.17(±0.28)a	2.2(±0.38)b	3.73(±0.84)bc	4.04(±0.52)c	4.42(±0.93)c
	00223_RareEndangeredCrops		Conventional#Kirinyaga	Organic#Machakos	Organic#Kirinyaga	Conventional#Machakos	Conventional#Murang'a	Organic#Murang'a
		ns	0.88(±0.2)a	1.45(±0.43)ab	1.46(±0.3)ab	1.54(±0.2)b	1.69(±0.28)b	2.31(±0.59)b
	00707_CustomerRelationship		Organic#Murang'a	Organic#Machakos	Conventional#Machakos	Conventional#Murang'a	Conventional#Kirinyaga	Organic#Kirinyaga
		ns	16.3(±3.66)a	18.56(±5.47)a	22.24(±2.3)a	23.19(±2.62)a	43.83(±2.98)b	51.07(±4.39)b
	00751_DependencyMainCustomer		Organic#Murang'a	Conventional#Murang'a	Organic#Kirinyaga	Conventional#Kirinyaga	Conventional#Machakos	Organic#Machakos
			25.78(±3.19)	39.46(±1.72)a	39.8(±2.01)a	40.52(±1,53)a	43.33(±2.06)a	55.82(±5.15)

	Indicator	P	System and county					
	00768_CollectiveMarketing		Conventional#Murang'a	Organic#Murang'a	Organic#Machakos	Conventional#Machakos	Organic#Kirinyaga	Conventional#Kirinyaga
			0.04(±0.04)a	0.09(±0.09)a	0.19(±0.19)a	1.95(±0.43)	27.62(±1.5)b	28.03(±1.42)b
Stability of supply	00088_FarmInputsSecureSupply		Organic#Murang'a	Conventional#Murang'a	Conventional#Kirinyaga	Organic#Machakos	Organic#Kirinyaga	Conventional#Machakos
			44.96(±4.83)	70.32(±2.4)a	74.52(±2.18)ab	80.21(±3.62)bc	80.52(±2.45)bc	80.62(±1.39)c
	00093_CooperationSuppliersQuality		Organic#Machakos	Conventional#Machakos	Organic#Murang'a	Conventional#Murang'a	Conventional#Kirinyaga	Organic#Kirinyaga
		P<0.05	6.74(±2.61)a	7.43(±1.2)a	23.86(±3.33)	39.77(±2.06)b	42.13(±2.66)b	63.41(±3.56)
	00199_BoughtConcentratedFeed		Organic#Kirinyaga	Conventional#Murang'a	Organic#Murang'a	Conventional#Kirinyaga	Organic#Machakos	Conventional#Machakos
		ns	1.53(±1.07)a	2.65(±0.82)a	3.28(±1.35)ab	3.37(±0.97)ab	9.62(±3.45)bc	15.06(±1.6)c
	00233_NoUseSynthChemFungicides		Organic#Kirinyaga	Organic#Murang'a	Conventional#Kirinyaga	Conventional#Machakos	Organic#Machakos	Conventional#Murang'a
			24.61(±1.57)a	24.7(±2.66)a	25.78(±1.15)a	31.16(±0.81)b	34.6(±1.7)bc	38.54(±1.28)c
	00234_NoUseSynthChemInsecticides		Conventional#Kirinyaga	Organic#Murang'a	Conventional#Machakos	Organic#Machakos	Organic#Kirinyaga	Conventional#Murang'a
		ns	20.87(±1.25)a	24.67(±2.65)ab	30.01(±0.81)b	34.32(±1.65)c	35.98(±1.64)c	37.69(±1.28)c
	00247_HybridCultivars		Conventional#Murang'a	Organic#Murang'a	Conventional#Kirinyaga	Organic#Kirinyaga	Organic#Machakos	Conventional#Machakos
		P<0.05	0.86(±0.43)a	1.61(±0.83)a	4.07(±0.83)	16.55(±2.31)b	17.37(±3.38)b	17.47(±1.34)b
	00323_MineralNFertilizers		Organic#Murang'a	Conventional#Murang'a	Conventional#Kirinyaga	Conventional#Machakos	Organic#Kirinyaga	Organic#Machakos
		P<0.05	10.71(±1.91)a	13.61(±1.13)a	25.18(±1.13)	39.15(±0.87)b	39.52(±1.63)b	45.9(±1.05)
	00324_MineralPFertilizers		Organic#Murang'a	Conventional#Murang'a	Conventional#Kirinyaga	Conventional#Machakos	Organic#Kirinyaga	Organic#Machakos
		P<0.05	14.42(±1.95)	20.09(±1.12)	30.29(±0.95)	39.56(±0.83)a	40.09(±1.46)a	46.28(±0.88)
	00626_BoughtInRoughage		Organic#Murang'a	Conventional#Murang'a	Conventional#Kirinyaga	Organic#Kirinyaga	Organic#Machakos	Conventional#Machakos
		P<0.05	28.03(±3.82)	40.8(±2.34)	51.05(±2.26)a	55.35(±2.75)ab	57.72(± 4.16)ab	58.15(±1.7)b
	00708_PreciseFertilisation		Conventional#Murang'a	Organic#Murang'a	Organic#Machakos	Conventional#Machakos	Conventional#Kirinyaga	Organic#Kirinyaga
		ns	0.61(±0.27)a	0.91(±0.52)a	2.46(±1.17)ab	2.5(±0.47)b	13.72(±0.89)c	15.54(±1.3)c
	00712_BoughtOrgFert		Organic#Murang'a	Organic#Kirinyaga	Conventional#Murang'a	Conventional#Kirinyaga	Organic#Machakos	Conventional#Machakos
			25.09(±3.19)	37.01(±3.11)a	41.87(±1.83)a	52.07(±1.77)b	52.29(±3.86)bc	56.79(±1.24)c
	00740_GrowthRegulation		Organic#Murang'a	Conventional#Kirinyaga	Conventional#Machakos	Conventional#Murang'a	Organic#Machakos	Organic#Kirinyaga
			20.12(±2.27)	27.27(±1.38)a	29.29(±1.15)ab	29.29(±1.29)ab	33.62(±2.46)b	39.29(±0.83)

Note: margins sharing a letter in the group label are not significantly different at the 5% level

Social well-being

	Indicator	P	System and county					
Capacity	00072_FarmStaffTraining		Conventional#Kirinyaga	Organic#Machakos	Conventional#Machakos	Organic#Murang'a	Conventional#Murang'a	Organic#Kirinyaga
			20.64(±2.37)a	26.11(±5.5)ab	33.17(±2.39)bc	41.49(±3.95)cd	43.83(±2.54)d	69.2(±3.45)
			Organic#Machakos	Conventional#Kirinyaga	Conventional#Machakos	Organic#Kirinyaga	Conventional#Murang'a	Organic#Murang'a

	Indicator	P	System and county					
	00703_AccessAdvisoryServices	ns	14.2(±4.14)a	23.44(±2.26)ab	23.56(±2.06)b	25.23(±3.23)bc	29.89(±1.79)c	31.29(±2.79)c
Indigenous	00067_PreventionResourceConflicts		Conventional#Kirinyaga	Organic#Murang'a	Conventional#Murang'a	Organic#Kirinyaga	Organic#Machakos	Conventional#Machakos
			11.02(±2.02)	41.18(±4.54)a	45.54(±2.85)ab	54.24(±4.2)bc	63.05(±5.39)cd	69.28(±1.81)d
	00075_CostsSocialInvolvementOutsideFarm		Organic#Machakos	Conventional#Machakos	Conventional#Kirinyaga	Conventional#Murang'a	Organic#Murang'a	Organic#Kirinyaga
			9.61(±3.31)a	12.98(±1.41)a	13.37(±1.55)a	28.11(±1.8)b	33.39(±2.7)b	33.5(±2.74)b
Public Health	00034_2_UseageChemSynthSeedDressings		Conventional#Murang'a	Conventional#Kirinyaga	Organic#Murang'a	Conventional#Machakos	Organic#Machakos	Organic#Kirinyaga
			4.11(±1.15)a	6.45(±1.45)ab	6.8(±2.29)ab	8.87(±1.45)b	10.33(±3.9)ab	26.22(±3.66)
	00167_No ContaminatedProducts		Organic#Machakos	Conventional#Machakos	Organic#Murang'a	Conventional#Kirinyaga	Conventional#Murang'a	Organic#Kirinyaga
		P<0.05	30.92(±6.42)a	33.99(±2.62)a	46.86(±4.7)	63.75(±2.68)b	67.48(±2.45)b	83.27(±0.99)
	00169_ContaminationCasesMeasures		Conventional#Machakos	Organic#Machakos	Conventional#Kirinyaga	Organic#Murang'a	Conventional#Murang'a	Organic#Kirinyaga
			9.73(±1.64)a	10.05(±4.22)a	36(±2.89)b	38.7(±4.48)b	50.38(±2.75)	69.85(±2.97)
	00200_SlurryStoresCovered		Conventional#Murang'a	Conventional#Kirinyaga	Organic#Murang'a	Organic#Kirinyaga	Organic#Machakos	Conventional#Machakos
		ns	11.68(±1.78)a	12.05(±1.86)a	14.7(±2.98)a	16.61(±3.01)a	20.41(±4.95)ab	25.12(±2.06)b
	00208_WoodlandsShareAgriculturalLand_Calculated		Organic#Machakos	Conventional#Machakos	Conventional#Kirinyaga	Organic#Kirinyaga	Conventional#Murang'a	Organic#Murang'a
		ns	0.18(±0.18)a	0.37(±0.17)a	2.67(±0.45)b	4.27(±0.96)bc	4.44(±0.59)c	4.87(±1.01)c
	00233_NoUseSynthChemFungicides		Conventional#Machakos	Organic#Machakos	Conventional#Kirinyaga	Organic#Kirinyaga	Organic#Murang'a	Conventional#Murang'a
			20.77(±1.81)a	22.86(±4.8)a	34.91(±2.04)b	38.5(±2.46)b	41.42(±4.13)b	57.48(±2.15)
	00234_NoUseSynthChemInsecticides		Conventional#Machakos	Organic#Machakos	Conventional#Kirinyaga	Organic#Murang'a	Organic#Kirinyaga	Conventional#Murang'a
			20.01(±1.77)a	23.41(±4.91)ab	28.71(±2.06)b	42.09(±4.2)	57.65(±2.62)c	57.92(±2.21)c
	00257_1_PesticidesToxicityBees		Conventional#Machakos	Organic#Machakos	Conventional#Kirinyaga	Organic#Kirinyaga	Conventional#Murang'a	Organic#Murang'a
		ns	4.24(±1.09)a	6.52(±3.63)ab	12.9(±1.89)bc	17.58(±3.31)c	36.96(±3.0)d	40.76(±4.77)d
	00257_2_PesticidesToxicityAquaticOrganisms		Conventional#Machakos	Conventional#Kirinyaga	Organic#Machakos	Organic#Kirinyaga	Conventional#Murang'a	Organic#Murang'a
			2.38(±0.89)a	4.3(±1.34)a	6.52(±3.63)ab	13.19(±3.38)b	37.82(±2.96)c	40.22(±4.8)c
	00295_AntibioticsLivestockFertilizer		Organic#Machakos	Conventional#Machakos	Organic#Murang'a	Conventional#Murang'a	Conventional#Kirinyaga	Organic#Kirinyaga
			7.35(±2.78)a	11.1(±1.29)a	11.49(±2.31)a	11.7(±1.48)a	22.71(±1.77)	43.74(±1.66)
	00320_CropResistance		Organic#Machakos	Conventional#Machakos	Organic#Kirinyaga	Conventional#Kirinyaga	Organic#Murang'a	Conventional#Murang'a
			6.01(±2.95)a	6.84(±1.16)a	11.44(±2.74)ab	13.59(±1.85)b	33.48(±3.71)	44.06(±2.21)
	00327_WasteDisposalPesticidesVeterinaryMedicines		Conventional#Machakos	Organic#Machakos	Conventional#Kirinyaga	Organic#Kirinyaga	Organic#Murang'a	Conventional#Murang'a
		ns	0.58(±0.41)a	1.84(±1.82)a	8.06(±1.66)b	13.15(±3.09)b	27.28(±3.97)c	29.5(±2.55)c
	00331_WasteDisposalCadaver		Organic#Machakos	Conventional#Machakos	Organic#Murang'a	Conventional#Kirinyaga	Conventional#Murang'a	Organic#Kirinyaga
		P<0.05	9.14(±3.84)	20(±2.05)	33.42(±4.06)a	37.34(±2.65)ab	43.86(±2.53)b	68.8(±1.9)
	00334_3_RecyclingPlastic		Organic#Machakos	Conventional#Machakos	Conventional#Kirinyaga	Organic#Kirinyaga	Organic#Murang'a	Conventional#Murang'a
		P<0.05	0.0(±0.0)	1.06(±0.0)	2.56(±0.0)	4.32(±0.0)	14.94(±0.0)	23.07(±0.0)
	00334_RecyclingWasteOil		Organic#Murang'a	Organic#Machakos	Conventional#Machakos	Conventional#Murang'a	Conventional#Kirinyaga	Organic#Kirinyaga
			16.86(±2.9)a	17.08(±4.14)a	20.23(±1.71)a	36.13(±1.93)b	40.67(±1.83)b	56.85(±0.07)

	Indicator	P	System and county					
	00352_LivestockHealthCurativeTreatments		Organic#Machakos	Conventional#Machakos	Conventional#Kirinyaga	Organic#Murang'a	Conventional#Murang'a	Organic#Kirinyaga
			11.7(±3.17)a	12.65(±1.36)a	22.69(±1.86)b	23.35(±3.01)b	31.7(±1.86)	50.83(±1.52)
	00353_LivestockHealthProphylacticTreatments		Organic#Machakos	Conventional#Machakos	Organic#Murang'a	Conventional#Kirinyaga	Conventional#Murang'a	Organic#Kirinyaga
			14.72(±3.44)a	16.97(±1.41)a	21.97(±2.58)ab	23.03(±1.6)b	28.79(±1.57)	35.19(±1.81)
	00357_MutilationAnaestheticsAnalgesics		Conventional#Machakos	Organic#Machakos	Organic#Murang'a	Conventional#Murang'a	Organic#Kirinyaga	Conventional#Kirinyaga
			1.88(±0.45)a	2.26(±1.26)ab	4.46(±1.16)b	7.78(±0.91)c	8.41(±1.42)c	13.08(±1.08)
	00376_2_Information WaterQuality		Conventional#Kirinyaga	Organic#Kirinyaga	Organic#Machakos	Conventional#Machakos	Conventional#Murang'a	Organic#Murang'a
		ns	1.96(±0.87)a	7.17(±2.42)b	7.53(±3.58)ab	8.82(±1.52)b	12.17(±1.95)bc	18.58(±3.62)c
	00377_05_Wastewater Disposal		Conventional#Kirinyaga	Organic#Machakos	Organic#Kirinyaga	Organic#Murang'a	Conventional#Murang'a	Conventional#Machakos
			2.25(±1.0)a	6.48(±3.61)ab	8.23(±2.78)b	8.53(±2.87)b	14.18(±2.27)bc	19.57(±2.27)c
	00377_1_PesticidesNumberActiveSubstances		Conventional#Machakos	Organic#Machakos	Conventional#Kirinyaga	Organic#Murang'a	Conventional#Murang'a	Organic#Kirinyaga
		P<0.05	15.04(±1.27)a	15.55(±3.5)a	26.97(±1.42)	34.87(±3.58)b	42.75(±1.83)bc	43.84(±1.66)c
	00377_5_PesticidesChronicToxicity		Conventional#Machakos	Organic#Machakos	Conventional#Kirinyaga	Organic#Murang'a	Conventional#Murang'a	Organic#Kirinyaga
		P<0.05	8.71(±1.63)a	10.72(±4.5)a	31.28(±2.99)	42.37(±4.78)b	44.82(±3.03)b	74.56(±3.17)
	00377_7_PesticidesAcuteToxicity		Conventional#Machakos	Organic#Machakos	Conventional#Kirinyaga	Organic#Kirinyaga	Organic#Murang'a	Conventional#Murang'a
			8.9(±1.11)a	11.39(±3.92)ab	15.36(±1.45)b	29.96(±2.59)	40.97(±4.73)c	42.09(±2.71)c
	00377_75_PesticidesAcuteToxicityInhalation		Conventional#Machakos	Conventional#Kirinyaga	Organic#Machakos	Organic#Kirinyaga	Organic#Murang'a	Conventional#Murang'a
			7.14(±1.11)a	10.52(±1.49)a	10.63(±3.62)a	25.07(±2.86)	42.01(±4.61)b	42.64(±2.62)b
	00380_NutrientsPollutantsSourcesOnFarm		Organic#Machakos	Conventional#Kirinyaga	Conventional#Murang'a	Conventional#Machakos	Organic#Kirinyaga	Organic#Murang'a
		ns	7.38(±3.51)a	7.68(±1.63)a	20.18(±2.33)b	20.46(±2.07)b	24.59(±3.81)b	26.41(±3.94)b
	00474_1_PesticidesPersistenceWater		Conventional#Machakos	Organic#Machakos	Conventional#Kirinyaga	Conventional#Murang'a	Organic#Kirinyaga	Organic#Murang'a
			4.57(±1.24)a	11.25(±4.72)ab	21.09(±2.76)b	37.16(±3.14)c	37.5(±4.86)c	43.33(±5.01)c
	00474_2_PesticidesPersistenceSoil		Organic#Kirinyaga	Conventional#Kirinyaga	Conventional#Machakos	Organic#Machakos	Organic#Murang'a	Conventional#Murang'a
		ns	19.39(±4.07)a	22.15(±2.82)a	28.28(±2.63)a	31.67(±6.85)ab	46.92(±5.04)bc	55.82(±3.11)c
	00474_3_PesticidesKnowledge		Organic#Machakos	Conventional#Machakos	Conventional#Kirinyaga	Organic#Murang'a	Conventional#Murang'a	Organic#Kirinyaga
		P<0.05	1.75(±1.74)a	4.38(±0.95)a	22.98(±2.31)	34.59(±3.9)b	40.94(±2.39)b	44.61(±3.66)b
	00502_PublicHealthMeasures		Organic#Kirinyaga	Conventional#Machakos	Organic#Machakos	Organic#Murang'a	Conventional#Kirinyaga	Conventional#Murang'a
		ns	0.64(±0.64)a	0.85(±0.42)a	1.35(±1.34)ab	2.01(±1.14)ab	2.26(±0.78)ab	3.77(±0.98)
	00506_FoodSecurityMeasuresLocCommunities		Conventional#Machakos	Organic#Machakos	Conventional#Kirinyaga	Conventional#Murang'a	Organic#Murang'a	Organic#Kirinyaga
			1.01(±0.45)a	2.59(±1.79)a	12.66(±1.61)b	16.73(±1.71)bc	18.52(±2.77)bc	20.94(±2.78)
	00606_LandslidesMudslides		Organic#Machakos	Conventional#Machakos	Organic#Murang'a	Conventional#Kirinyaga	Conventional#Murang'a	Organic#Kirinyaga
			19.24(±3.94)a	20.25(±1.57)a	26.61(±2.86)a	38.22(±1.62)b	39.06(±1.55)b	49.48(±1.04)
	00609_MilkWaitingPeriodAntibiotics		Organic#Machakos	Conventional#Machakos	Organic#Murang'a	Conventional#Kirinyaga	Conventional#Murang'a	Organic#Kirinyaga
		P<0.05	4.49(±1.88)a	5.33(±0.8)a	12.85(±2.02)	18.51(±1.3)b	19.83(±1.26)b	27.78(±1.75)
	00710_HarmfulSubstancesPFertilizer		Conventional#Machakos	Organic#Machakos	Organic#Murang'a	Conventional#Murang'a	Conventional#Kirinyaga	Organic#Kirinyaga
			12.28(±1.69)a	12.51(±4.31)ab	16.76(±3.32)ab	18.67(±2.04)b	39.64(±2.07)	48.92(±2.24)

	Indicator	P	System and county					
	00740_GrowthRegulation		Conventional#Machakos	Organic#Machakos	Organic#Murang'a	Conventional#Kirinyaga	Conventional#Murang'a	Organic#Kirinyaga
			16.18(±1.76)a	22.66(±4.9)ab	34.37(±3.6)bc	37.43(±2.32)c	44.61(±2.11)	62.42(±1.32)
	00788_OpenBurning		Conventional#Machakos	Organic#Machakos	Organic#Murang'a	Conventional#Murang'a	Conventional#Kirinyaga	Organic#Kirinyaga
		P<0.05	16.79(±1.76)a	18.44(±4.39)a	30.09(±3.57)	39.89(±2.17)b	42.26(±2.13)b	55.35(±2.38)
	00790_EmplyeesProtectiveGear		Organic#Machakos	Conventional#Machakos	Organic#Murang'a	Conventional#Kirinyaga	Conventional#Murang'a	Organic#Kirinyaga
		ns	5.19(±2.31)a	9.32(±1.33)a	22.2(±3.55)b	27.38(±2.27)b	28.39(±2.3)b	37.88(±3.58)

Note: margins sharing a letter in the group label are not significantly different at the 5% level

Governance

	Indicator	P	System and county					
Civic Responsibility	00057_InvolvementImprovingLawsRegulations		Conventional#Machakos	Organic#Machakos	Organic#Kirinyaga	Conventional#Murang'a	Conventional#Kirinyaga	Organic#Murang'a
			1.8(±0.73)a	5.76(±3.21)ab	10.06(±2.84)bc	12.61(±2.01)bc	14.4(±2.17)c	35.09(±4.27)
	00070_CooperationEthicalFinancialInstitutions		Conventional#Kirinyaga	Organic#Murang'a	Organic#Kirinyaga	Conventional#Murang'a	Organic#Machakos	Conventional#Machakos
		ns	11.99(±1.46)a	13.07(±2.31)ab	13.15(±2.28)ab	16.26(±1.56)bc	21.87(±3.65)cd	26.97(±1.42)d
	00074_CostsEnvironmentalInvolvementOutsideFarm		Organic#Machakos	Conventional#Murang'a	Conventional#Machakos	Conventional#Kirinyaga	Organic#Kirinyaga	Organic#Murang'a
			1.75(±1.73)a	5.57(±1.08)ab	6.02(±1.19)b	7.57(±1.34)b	14.79(±2.86)c	18.8(±2.67)c
	00075_CostsSocialInvolvementOutsideFarm		Organic#Machakos	Conventional#Machakos	Conventional#Kirinyaga	Conventional#Murang'a	Organic#Murang'a	Organic#Kirinyaga
			13(±4.48)a	16.83(±1.9)a	17.8(±2.09)a	38.02(±2.44)b	45.17(±3.65)b	45.32(±3.7)b
	00506_FoodSecurityMeasuresLocCommunities		Organic#Machakos	Conventional#Machakos	Conventional#Kirinyaga	Organic#Kirinyaga	Conventional#Murang'a	Organic#Murang'a
			5.06(±2.82)a	6.06(±1.21)a	19.32(±2.21)b	27.31(±3.63)bc	27.86(±2.35)c	41.64(±3.66)
Full-Cost	00750_OralInformationSustainabilityImprovements		Organic#Machakos	Conventional#Machakos	Conventional#Murang'a	Organic#Kirinyaga	Organic#Murang'a	Conventional#Kirinyaga
			6.07(±1.47)	10.24(±0.72)a	11.31(±0.81)ab	14.7(±1.2)c	14.75(±2.01)bc	17.21(±0.78)c
Holistic Audit	00748_HumusFormationHumusBalance		Organic#Machakos	Conventional#Kirinyaga	Conventional#Machakos	Organic#Murang'a	Conventional#Murang'a	Organic#Kirinyaga
		ns	19.06(±4.42)ab	22.65(±1.65)a	28.02(±1.9)bc	33.37(±3.86)c	43.97(±2.34)d	47.86(±2.55)d
	00750_OralInformationSustainabilityImprovements		Organic#Machakos	Conventional#Machakos	Conventional#Murang'a	Organic#Murang'a	Conventional#Kirinyaga	Organic#Kirinyaga
		P<0.05	9.21(±2.23)	14.03(±0.99)a	16.87(±1.1)a	17.81(±1.69)a	23.58(±1.06)	31.79(±1.21)
Sustainability	00008_VerbalCommitmentSustainability		Organic#Machakos	Conventional#Machakos	Conventional#Kirinyaga	Organic#Kirinyaga	Organic#Murang'a	Conventional#Murang'a
		ns	9.11(±2.21)a	11.74(±1.06)a	15.65(±1.35)b	22.04(±1.8)c	22.11(±3.01)bc	25.67(±1.82)c
	00100_MarketChallenges		Conventional#Kirinyaga	Organic#Machakos	Conventional#Machakos	Organic#Kirinyaga	Conventional#Murang'a	Organic#Murang'a
			14.29(±1.73)a	16.29(±3.65)ab	22.11(±1.65)b	34.3(±2.24)	41.89(±1.9)c	42.77(±3.21)c
			Organic#Murang'a	Conventional#Murang'a	Organic#Kirinyaga	Organic#Machakos	Conventional#Machakos	Conventional#Kirinyaga

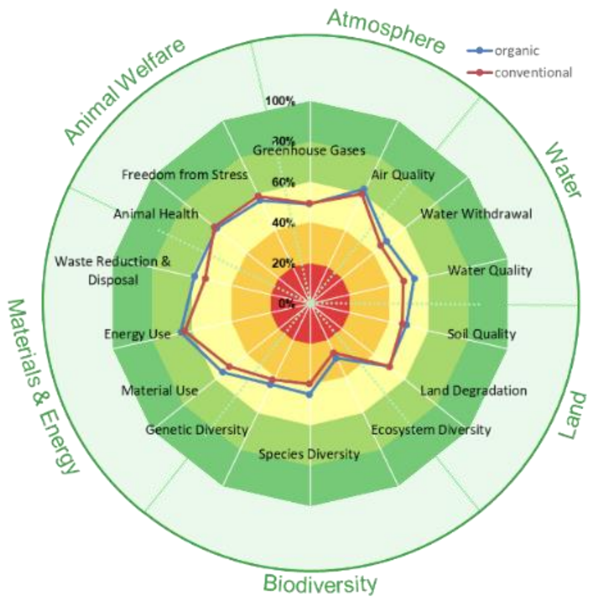
	Indicator	P	System and county					
	00124_GuaranteedStaffReplacemetFarmSuccession		17.05(±2.71)	29.68(±1.76)a	33.5(±2.27)a	33.87(±3.6)a	41.42(±1.22)b	42.61(±1.22)b
	00134_KnowledgeClimateChangeProblems		Conventional#Kirinyaga	Organic#Kirinyaga	Organic#Machakos	Conventional#Machakos	Organic#Murang'a	Conventional#Murang'a
		ns	28.92(±1.52)a	30.02(±2.11)a	31.17(±3.3)a	32.32(±1.2)a	47.92(±2.14)b	48.84(±1.31)b
	00136_ClimateChangeAdaptationMeasures		Conventional#Kirinyaga	Organic#Murang'a	Conventional#Murang'a	Organic#Machakos	Organic#Kirinyaga	Conventional#Machakos
		ns	26.7(±2.4)a	26.82(±3.7)a	29.56(±2.38)ab	30.55(±5.36)ab	37.99(±3.69)bc	42.96(±2.05)c
	00750_OralInformationSustainabilityImprovements		Organic#Machakos	Conventional#Machakos	Conventional#Murang'a	Organic#Murang'a	Conventional#Kirinyaga	Organic#Kirinyaga
		P<0.05	9.89(±2.4)a	15.07(±1.06)a	16.66(±1.19)a	17.92(±1.83)a	25.34(±1.14)	34.16(±1.3)

Note: margins sharing a letter in the group label are not significantly different at the 5% level

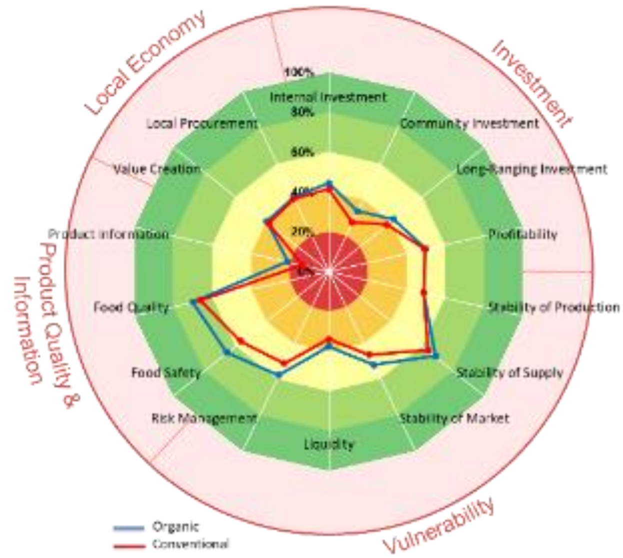
Annex 9: Comparing organic and conventional at sub-theme and county level

Comparing organic vs conventional at sub-theme level

Environmental Integrity

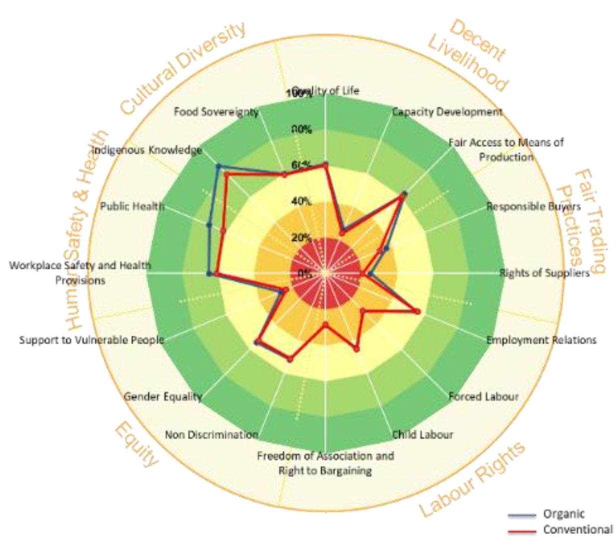


Economic Resilience

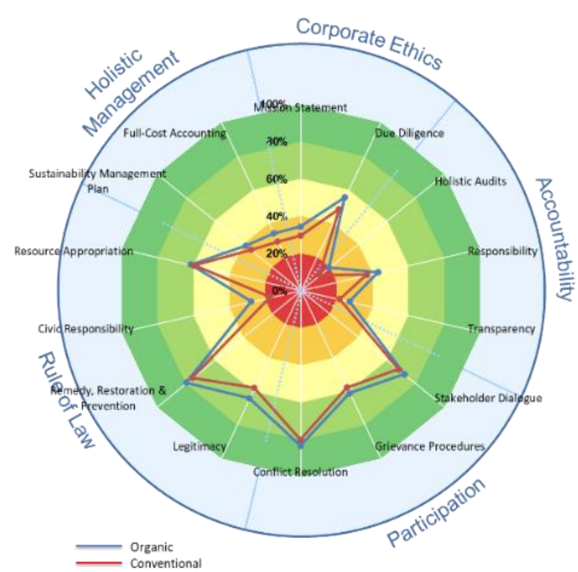


Comparing organic vs. conventional in environmental integrity and economic resilience at sub-theme level

Social Well-being



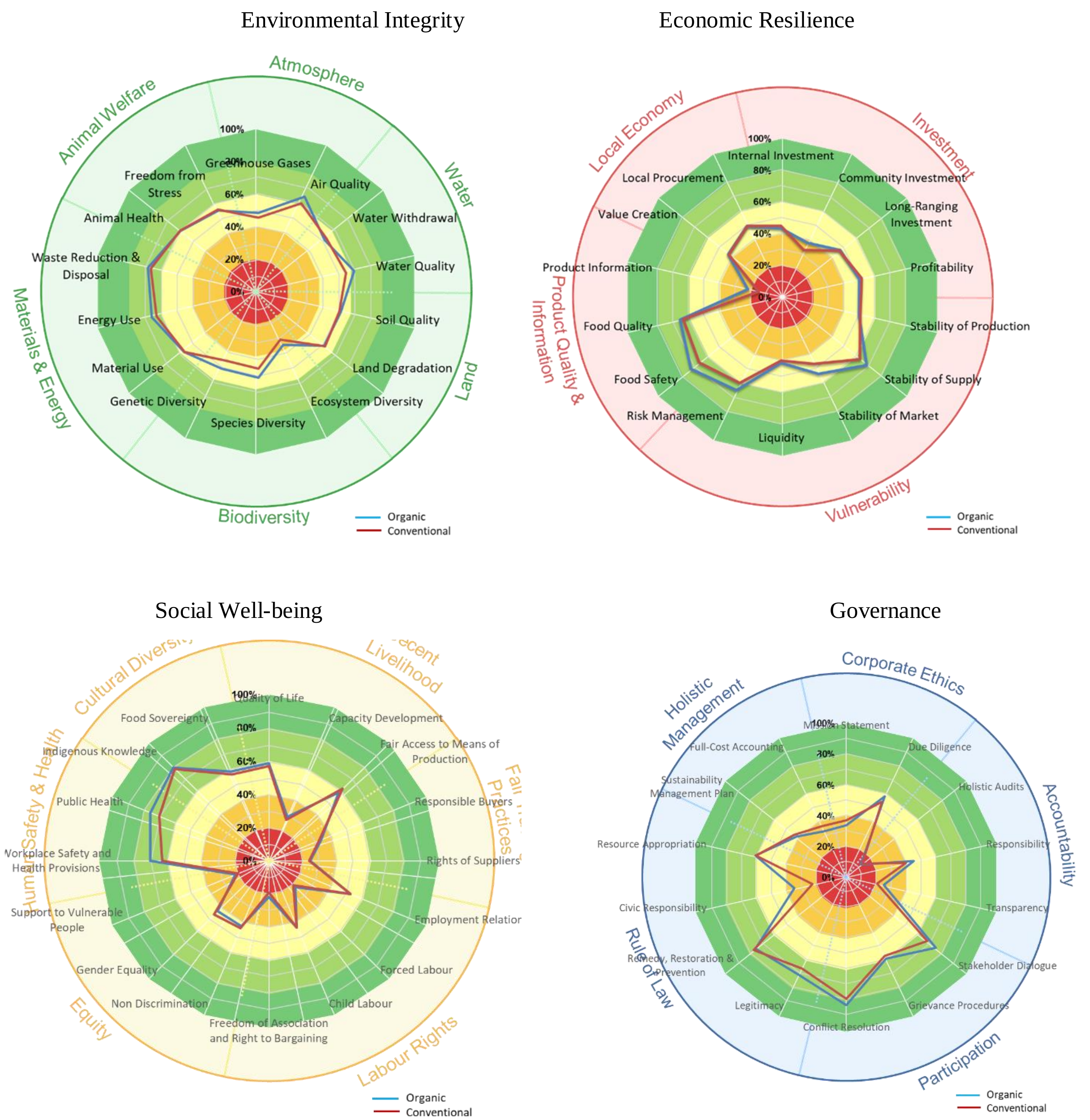
Governance



Comparing organic vs. conventional in the social well-being and governance dimensions at sub-theme level

Sustainability scores at sub-theme level comparing organic and conventional at the County *level*

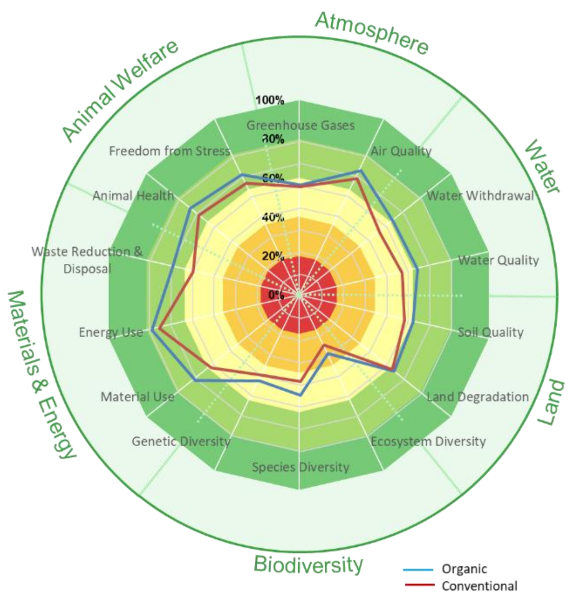
Murang'a County



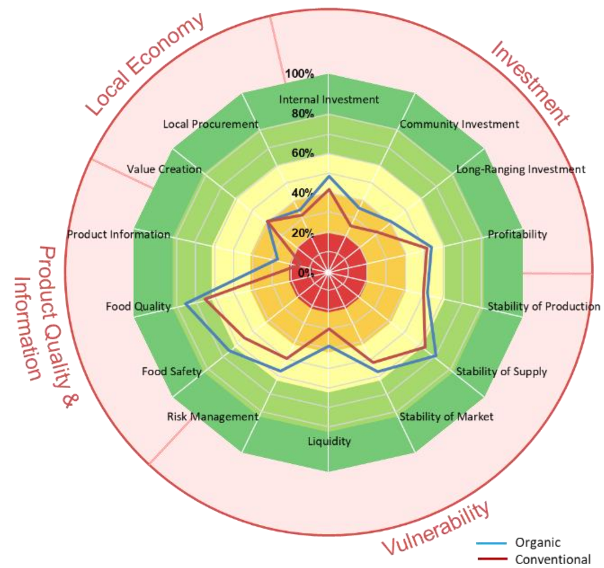
Comparing organic vs. conventional farming in the environmental, economic, social and governance dimensions at sub-theme level for Murang'a County

Kirinyaga County

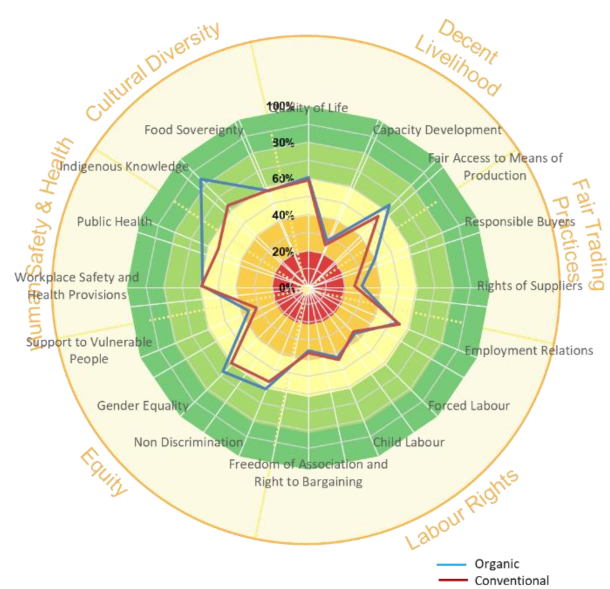
Environmental Integrity



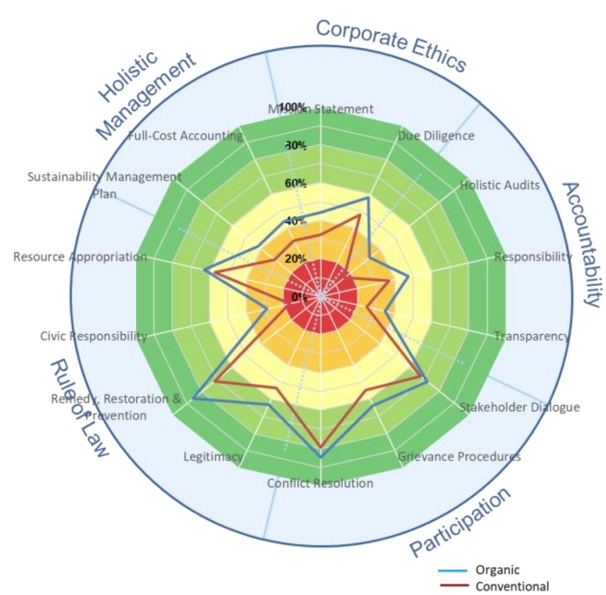
Economic Resilience



Social Well-being



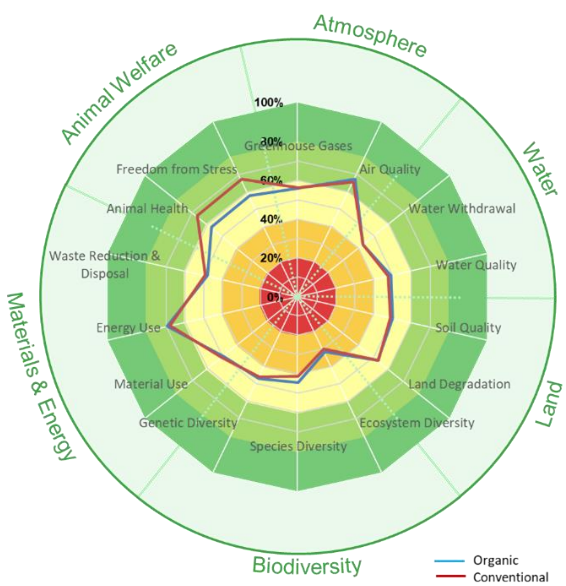
Governance



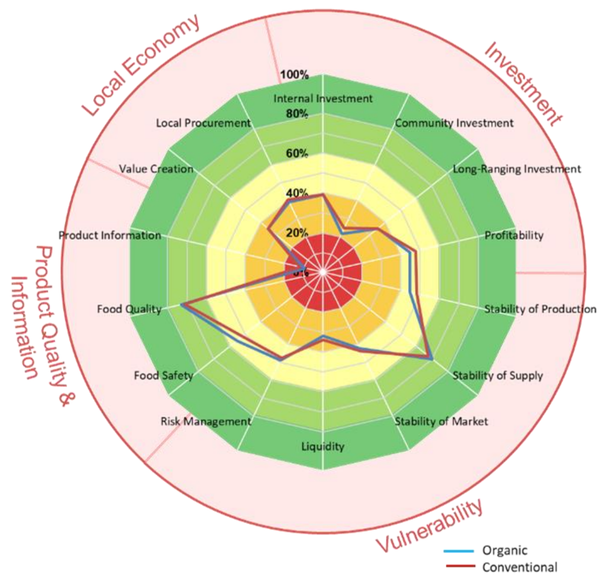
Comparing organic vs. conventional in the environmental, economic, social and governance dimensions at sub-theme level for Kirinyaga County

Machakos County

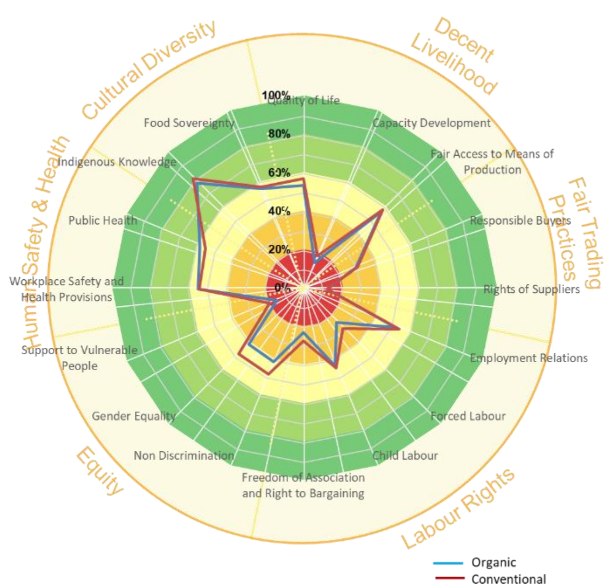
Environmental Integrity



Economic Resilience



Social Well-being

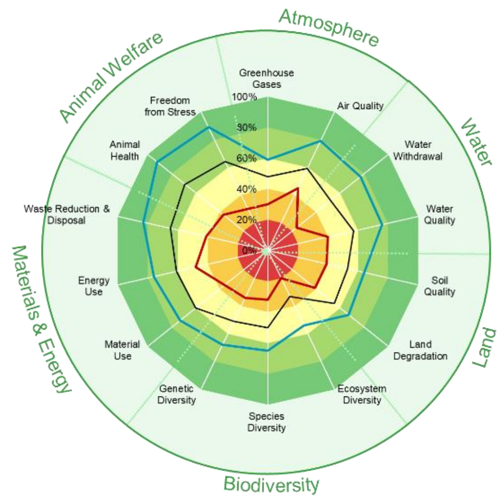


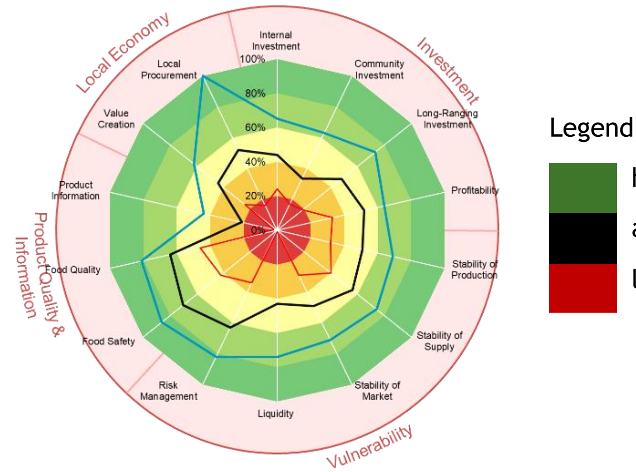
Governance

Comparing organic vs. conventional in the environmental, economic, social and governance dimensions at sub-theme level for Machakos County

Annex 10: Key message points for farmer feedback workshops

The areas that had low scores based on the sustainability assessment charts below were selected and used for farmer feedback workshops. The main question put to the farmers was: what are the areas for improvement in the following aspects?





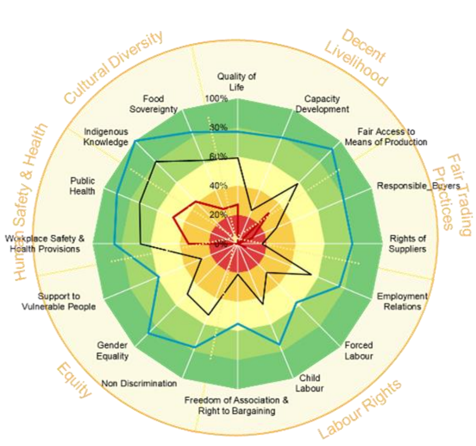
Environmental integrity *Economic resilience*

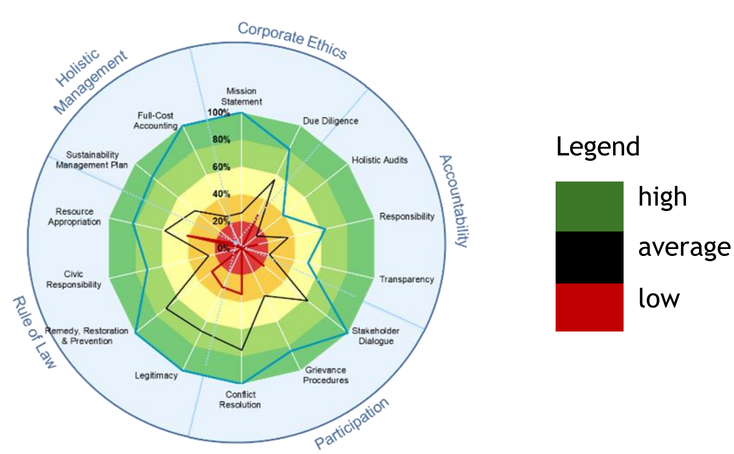
1. Environmental integrity

- Biodiversity (this covers the areas of genetic, species, and ecosystems diversity)
- water withdrawal
- Soil quality

2. Economic resilience (interconnected)

- Market-driven, or part of a market. Stability of markets
- Improve profitability keeping records emphasized
- Investments community stability
- Food safety (handling of storage, pesticide use, residual levels)





Social well-being *Governance*

1 *Social well-being*
- Capacity development (Demand-driven, look for extension services, join groups)
- Workplace safety health provisions (protective clothing etc.)
- Public health

2 *Governance*
- Civic responsibility (Involvement in community etc.)
- Record-Keeping (cover full cost accounting, holistic audits, transparency)

Annex 11: Program developed for the farmer feedback meeting

Farmer feedback meeting program for Machakos, Kirinyaga and Murang'a 15th- 23rd July 2019

Prayer

Introduction

Why we are here

- To assess the farmers' farms on productivity, profitability, and sustainability
- Training workshop on record keeping
- Enumerators visiting their farms to collect data at least twice a month
- Sensitization meetings First farmer reports

Why we are here

- Data analysis of their farms done and farmer report generated
- Five seasons data Productivity, Profitability, and Sustainability
- Here to have a feedback from farmers

Share and discuss the outcome of sustainability assessment

Key Messages for Sustainability (what are the areas for improvement on the following areas (Suggestions from farmers required)

Environmental integrity

- Biodiversity,
- water withdrawal,
- Soil quality,

Economic resilience (interconnected)

- Market-driven or part of a market. Stability of markets (alternative markets) group marketing
- Improve profitability keeping records emphasized
- Investments community stability
- Food safety (handling of storage, pesticide use, residual levels

Social Welfare

- Capacity development Demand-driven, look for extension services, join groups,
- Workplace safety health provisions (protective clothing
- Public health

Governance

- Civic responsibility (Involvement in community
- Record-Keeping cover full cost accounting, holistic audits, transparency

Final session

General Questions from farmers

Closing remarks

Prayers /End of meeting

Annex 12 : In-depth Farmer Workshop

ProEco Africa

Validation of the outcomes of the Sustainability Assessment of Smallholder farms in Murang'a, Machakos and Kirinyaga and discussion of potential improvement measures October 04-10, 2019

Checklist of questions for farmer discussions

Part 1: Feedback on the ProEco/OFSA Farm Report

1. Have you gone through the farmer report given to you on 15-23rd July 2019?

Note: the aim here is to get an idea on whether farmers had a look or not at the report after the workshop. One could address the group and say "those who have opened the report, raise your hand!"

2. What did you understand from the report?

    a. Which challenges did you face when reading through?

Note: If farmers had a look at the report, it is important to understand what (if anything at all) they could understand from the report. If they could not understand something, why not?

As a facilitator, probe the farmers.

3. Was there anything interesting for you from the report?

    a. If so, what were the most interesting parts of the report?

    b. Do you have any concerns regarding the data reported?

4. Did you show your report to any of your family members? Or your friends/neighbour's?

Part 2: 1. Participatory identification of sustainability improvement measures

Aim: The aim here is to jointly identify sustainability improvement measures and understand why they are currently not implemented and what the requirements for implementation are.

Note: as a facilitator, you should have in mind which are potential sustainability improvement measures. Nevertheless, we first want to see what the farmers consider as potential improvement measures.

1. For each of the following sustainability hotspots, farmers will be asked which measures they could/are implementing to address the given hotspot:

a. ENVIRONMENTAL INTEGRITY

i. Biodiversity,

ii. Water withdrawal,

iii. Soil quality (note: for example, applying compost could be regarded as one specific measures farmers could implement. As a facilitator you could ask who is applying compost, if the majority of the farmers says no, understand why not (not available? lack of knowledge?)

b. ECONOMIC RESILIENCE (INTERCONNECTED)

i. Market driven or part of a market. Stability of markets (alternative markets) group marketing

ii. Improve profitability keeping records emphasized

iii. Investments community stability

iv. Food safety (handling of storage, pesticide use, residual levels)

c. SOCIAL WELFARE

i. Capacity development. Demand driven, extension services, join groups,

ii. Workplace safety health provisions (protective clothing)

iii. Public health

d. GOVERNANCE

i. Civic responsibility (Involvement in community

ii. Record keeping covering full cost accounting, holistic audits, and transparency

2. Of the above improvement, measures mentioned which can be implemented at individual or community/ village or both.

a. ENVIRONMENTAL INTEGRITY

i. Biodiversity,

ii. Water withdrawal,

iii. Soil quality (note: for example, applying compost could be regarded as one specific measures farmers could implement. As a facilitator you could ask who is applying compost, if the majority of the farmers says no, understand why not (not available? lack of knowledge?)

b. ECONOMIC RESILIENCE (INTERCONNECTED)

i. Market driven or part of a market. Stability of markets (alternative markets) group marketing

ii. Improve profitability keeping records emphasized

iii. Investments community stability

iv. Food safety (handling of storage, pesticide use, residual levels)

c. SOCIAL WELFARE

i. Capacity development. Demand driven, extension services, join groups,

ii. Workplace safety health provisions (protective clothing)

iii. Public health

d. GOVERNANCE

i. Civic responsibility (Involvement in community

ii. Record keeping covering full cost accounting, holistic audits, and transparency

In-depth Farmer Workshop

Validation of the outcomes of the Sustainability Assessment of Smallholder farms in Murang'a, Machakos and Kirinyaga and discussion of potential improvement measures

October 04-10, 2019

Date:

Community: ____venue: ____

Name of minute taker:

PART 1: DISCUSSION OF THE MAIN CHALLENGES PERCEIVED BY THE FARMERS

Challenge mentioned	**Agreed upon by a low/average/high share of farms**	**Other relevant comments**

Part 2: Discussion of improvement measures and requirements for the identified hotspots

Improvement measure proposed by the farmers	Reasons for low adoption currently	Requirements to stimulate or increase the likelihood of adoption	Comments/ any other key discussion points of interest	Who proposed the measure (farmers or facilitator?)

Annex 13: The dimension, themes and subthemes with low degree of goal achievement in the three counties (frequency n)

Dimensions	Themes	Sub-themes	Murang'a Unacceptable 0%-20%	Kirinyaga Unacceptable 0%-20%	Machakos Unacceptable 0%-20%
Environmental Integrity	Water	Water Withdrawal	0	2	27
	Biodiversity	Ecosystem Diversity	2	61	17
Economic Resilience	Investment	Internal Investment	0	3	2
		Community Investment	5	56	101
		Long-Ranging Investment	2	12	19
	Vulnerability	Stability of Market	0	0	1
		Liquidity	11	44	39
	Product Quality and Information	Product Information	184	160	265
	Local Economy	Local Procurement	7	0	2
Social Well-being	Decent Livelihood	Capacity Development	113	89	169
		Fair Access to Means of Production	0	0	3
	Fair Trading Practices	Responsible Buyers	9	62	29
		Rights of Suppliers	82	82	265
	Labour Rights	Forced Labour	122	21	0
		Child Labour	1	0	2
		Freedom of Association and Right to Bargaining	148	22	108
	Equity	Non Discrimination	42	2	15
		Gender Equality	48	7	27
		Support to Vulnerable People	123	48	191
Good Governance	Corporate Ethics	Mission Statement	85	39	135
		Due Diligence	0	0	1
	Accountability	Holistic Audits	261	161	237
		Responsibility	2	2	5
		Transparency	109	92	169
	Participation	Grievance Procedures	2	0	5
	Rule of Law	Civic Responsibility	137	151	221
	Holistic Management	Sustainability Management Plan	24	30	83
		Full-Cost Accounting	88	39	137

Note: Numbers are frequency

Annex 14: List of challenges discussed with farmers

Challenge mentioned	Agreed upon by a low/average/high share of farms
Environmental Integrity	
Lack of water for irrigation	270
Planting of Eucalyptus trees along with the water bodies	45
Lack of proper knowledge on soil testing and location of the labs for the region.	90
Low soil quality leading to low yields	135
Economic resilience	
Low Group formation focusing on agriculture	180
Market-related challenges	180
Lack of a stable market	270
Fluctuating prices	180
Exploitation by brokers	180
Lack of target/alternative market	180
No control of prices	90
Food safety Lack of proper holding and storage facilities	45
social well-being	
Limited access to information and capacity building programs.	90
Lack of enough capacity development programs within the region	90
Lack of know-how on chemical storage, usage, and pre-harvest intervals	135
Governance	
Lack of proper record keeping by the majority of the farmers due to time constraints, forgetfulness, and perceived as a tedious process.	180
Small farm size	87
Poor road networks, especially when it rains, making it difficult to transport goods from the farm to the markets.	90

END