A Taxonomy of Barriers to the Adoption of Sustainable Practices in the Coffee Farming Process

1. Introduction

Over the past 40 years, the consumption of coffee has been rising at an average annual growth rate of 2.4% due to factors such as global population growth and millennials increasing consumption of coffee drinks (Yohannes, Matsuda and Sato, 2016). As demand increases, farmers must increase crop production, which is likely to reduce arable land availability and further increase pressure on the use of soil nutrients and water. The problem worsens as global warming intensifies, with rising sea levels and droughts leading to a decline in the supply of food commodities (Iscaro, 2014). These issues would have important social and economic implications for millions of smallholder farmers in developing economies in developing countries and those whose livelihoods depend on the coffee industry (Bianco, 2020; Pham et al, 2019; Berlan, 2013).

To address these potential impacts, over 40 years ago sustainable (organic) agriculture began in Kenya through the combined efforts of non-governmental organisations (NGOs), faith-based organisations and commercial entities (Chiputwa and Matin, 2016). The sector evolved without formal regulation, until recently when the African Union established the Ecological Organic Agriculture Initiative (EOA-I) to integrate sustainable practices into national agricultural systems in Africa by 2025 (Gama and Millinga, 2016). Sustainable agriculture is becoming an increasingly important aspect of government policies in African countries for various reasons. Africa's smallholder farmers form a key part of the global agroindustry (Amanor, 2019), and the global food supply chain is being shaped by sustainability efforts and other programs of multinational companies, aiming at achieving social and environmental objectives other than profit (Meneghetti and Monti, 2015).

In addition, sustainable agriculture can help farmers to cope with challenges imposed on them by climate change, increased food production, resource efficiency and profit to meet the growing global demand (Ehiakpor, Danso-Abbeam, and Mubashiru, 2021; Rodriguez et al. 2009). However, despite the benefits and opportunities that sustainable agriculture offers, adoption of these practices is still low amongst smallholder farmers in developing countries, especially Africa (Ehiakpor, Danso-Abbeam, and Mubashiru, 2021; Guo, Ola, and Benjamin, 2020; Nkomoki, Bavorová and Banout, 2018). Recent research has identified several barriers to the adoption of sustainable agriculture like climate-smart practices (Jellason, Conway and Baines, 2020; Wreford et al., 2017), no-till farming (Dang et al, 2020), and sustainable coffee (Ibnu, 2020; Bro et al., 2019). However, these studies did not consider adequately consider the distinct and separate stages of crop production in their analysis of SAPs adoption barriers. There is still limited evidence for understanding barriers distribution across the differences in stages of the farming process.

Therefore, this study seeks to examine whether barriers to SAPs adoption differ for different stages of coffee cultivation, if so, how, and why. Since it is difficult to assess whether a difference in the barriers reported in the literature on specific type of SAP is due to the differences in stages of the farming process or context-specific variables, such as institutional or socio-cultural factors of smallholders, we adopted an empirical approach (Vermunt et al, 2019) to explore variation in these factors. In the context of coffee farming, barriers were explored and compared between four different stages namely nursey, planting, growing, and harvesting. Consequently, to collect primary data, we conduct semi-structured interviews with 32 smallholder coffee farmers from Nyeri county in Kenya.

Based on our findings, we develop a taxonomy to conceptualise barriers to SAPs adoption in smallholder coffee farming context. The proposed classification system illustrates the barriers that occur in adopting specific SAP at each stage of the coffee farming process. This can guide professional, policymakers, and researchers develop interventions to mitigate the impacts of the barriers and help boost SAPs adoption rate amongst smallholder coffee farmers. In terms of theoretical contributions, the research emphasises the role of rational, institutional, attitudinal, and circumstantial factors in influencing the decision of smallholder farmers' towards adopting SAPs.

The following section provides an overview of key stages of the coffee farming process, before elaborating on barriers to the adoption of SAPs currently highlighted in the literature. We then discuss various SAPs relevant to smallholder coffee farming and a comparison of their costs and benefits.

2. Literature review

We have implemented a narrative review approach to synthesise extant evidence. Narrative reviews methodology is unlike a systematic review, which requires using pre-specified eligibility criteria or article selection process for database searches. According to Greenhalgh, Thorne and Malterud (2018), a "narrative reviewer selects evidence judiciously and purposively with an eye to what is relevant for key questions" (p4). Such is the case with our study wherein a wide range of subjects are being considered. Consequently, we searched online databases (e.g., EBSCO Information Services, Emerald Journals, Science Direct, ProQuest, and Google Scholar), using the terms relating to sustainable production or sustainable innovation, sustainable agriculture AND practices, barriers/difficulties of sustainable agriculture, and coffee farming process.

2.1. Stages of the coffee farming process: activities and impacts

The coffee farming process is usually broken down into five phases: nursery, planting, growing, harvesting and post-harvesting/processing, e.g. drying, pulping, milling, and grading (Avelino et al. 2012; Central Coffee Research Institute, 2008). Generally, smallholder farmers in Kenya do not control the coffee processing mills; these are owned and managed by cooperatives (Global Agricultural Information Network, 2016). Hence, in this section, we will briefly describe various activities associated with the first four stages and illustrate their related sustainability impact impacts. The findings are summarised in Table 1. The nursery phase is an important part of the coffee farming process in which seedlings are propagated and grown in nursery beds to a usable size, before transferring to the field. In a nursery, young coffee plants are nurtured by providing them with fertilisers and regular (irrigation) watering irrigated before transferring to the field for planting (Mitchell, 1988).

The planting phase involves a range of land preparation activities such as bush clearing, tillage, removal of stumps, harrowing, terraces, and cut-off drains for preventing erosion of soil and flooding (Avelino et al. 2012; Uganda Coffee Development Authority, 2014). These activities have important sustainability implications including irreversible changes in soil structure and drainage/infiltration of hazardous chemicals (e.g., fertilisers) into freshwater. Most importantly, the highlands and Mount Kenya, where coffee is commonly grown in Kenya, host rare and endangered species like migratory birds (Carsan et al., 2013), so land clearing and tree removal activities for growing coffee plants could reduce biodiversity.

The growth phase seems to be the most important aspect of coffee farming for two main reasons: first, it usually takes between three to four years for the trees to start bearing fruits, and second, activities associated with this stage include the frequent application of herbicides, and pesticides, which cause environmental and health problems (Milligan et al., 2016). As the coffee plant grows, irrigation is required at least once every week (between 5 to 10 litres of water per plant) to help plants retain moisture, prevent wilting, and facilitate the rooting process (Uganda Coffee Development Authority, 2014). However, there is growing pressure on water resources because coffee farmers depend on streams around Mount Kenya for irrigation, whereas this is the main water source for powering the Kenyan hydroelectric plants (Notter et al., 2007). This a potential challenge that should not be ignored to prevent impending lack of access to irrigation water, which may consequently affect the productivity and income generation potentials of coffee farmers.

Another activity relating to the growth phase of coffee farming is the application of synthetic fertilizers to supply plant nutrients essential to the growing crops (Central Coffee Research Institute, 2008). The chemical substances associated with the use of herbicides, pesticides and inorganic fertilisers can contribute to the number of greenhouse gases in the environment, such as methane, nitrogen, and carbon dioxide.

Concerning coffee harvesting, three broad methods can be used: stripping/mechanically harvesting and selective picking of only ripe coffee fruit by hand (Sanz-Uribe et al., 2017). Smallholder coffee farmers in Kenya usually use a manual harvesting process which requires farmworkers to pick the coffee cherries literally by hand. However, this approach poses health and safety risks to farmworkers such as snake (insect) bites, musculoskeletal problems, attributed to repetitive movements and back bending, in addition to skin irritation from abrasions (e.g Kanyenze, 2004; Mureithi, 2008). If these issues go unaddressed, they may seriously impact coffee farmers, particularly in Kenya where people have limited access to basic or affordable healthcare services for treating work-related injuries.

[Insert Table 1]

2.2. Sustainable production

The concept of sustainable production has been described by different authors as a process in which organisation manufacture goods and services not only to make a profit but to promote sustainable development. Historically, the concept gained more prominence in the manufacturing industry (O'Brien, 1999) because the current industrial systems are not sustainable and put excessive pressure on the world's natural resources. However, organisations must develop motions for environmental and social consciences to implement sustainable production systems (Brockhaus et al, 2017). This highlights the need for cultural change through the provision of awareness and training for employees to develop sustainability competences in every area of the company's operations.

Agarwal, Sengupta and El-Halwagi (2018) highlight the importance of integrating sustainability into product and processes accompanying concurrent engineering designs. They believe that organisations can drive efficiency in costing and decision support systems by addressing sustainability issues in their design systems. In a study that examines recycling and re-use practices in the mining sector, Matinde, Simate and Ndlovu (2018) conclude that production is unsustainable and incomplete without the incorporation of re-processed and re-manufactured mechanisms. To achieve this objective, there is a need for fundamental changes in the organisation's product design and re-processing capability (O'Brien, 1999). Furthermore, sustainable production requires a fundamental change in customers behaviour and societal culture, but incentives are needed to derive such cultural changes.

Kumar et al (2020) examine the role of economic incentives for promoting sustainable legume production in India. In addition to using policy instruments and regulations, incentives have been used as an effective way to boost the adoption of sustainable technologies in industries and supply chains (Fischer and Pascucci, 2017; Wang et al, 2021). Overall, while the concept of sustainability is fast becoming fashionable in industries, nature or dimensions implementing sustainable (production) practices will vary according to the industry sector. Given the aim of this research, the next section will focus on discussing several key sustainable farming practices.

2.3. Sustainable Agriculture Practices

As Rajović and Bulatović (2016) have observed, it is extremely difficult to arrive at a functional and generally acceptable definition of sustainable agriculture or sustainable farming practices, because the debate involves different worldviews from a variety of stakeholders (e.g., government, private sector, NGOs, Academia). For example, Dogliotti et al (2014) define sustainable agriculture as the act of ensuring a sustainable increase in food production, resource efficiency and enhancing the profit of farmers in environmentally friendly ways. This seems to agree with Ikerd's (1993) earlier definition that sustainable agriculture practices must be capable of maintaining productivity and usefulness to society over the long run, and must be resource-conserving, economically viable/competitive, socially, and environmentally sound.

According to Gold (2016), sustainable agriculture is a system of agribusiness that can produce food consistently and still offer benefits to the wider society indefinitely. It is expected to make money from food production, reduce the impact on the environment and support social development. What can be deduced from these definitions is the conventional methods of farming, which typically depend on land clearing and energy-intensive inputs such as fertilizers, pesticides, and other agro-chemicals, are inappropriate and unsustainable. Therefore, in this study, the terms sustainable agriculture and organic farming are used interchangeably and include the combination of a wide range of practices or techniques, some of the more well-known of which include crop rotation, growing cover crops, biological pest control methods, recycling coffee processing water, drip irrigation, organic manure (compost) and techniques to address health and safety risks in farming.

These SAPs would be the unit of analysis for our study and are briefly described in the list below. We then present a summary analysis of their strengths and weaknesses in Table 2, regarding smallholder coffee farming.

[Insert Table 2]

1. *Crop rotation.* In crop rotation, farmers can improve the soil texture and biological conditions of their farming systems, in addition to tackling pests and weeds (Brankatschk and Finkbeiner, 2015).
2. *Cover crop*. Involves growing different types of crops in the same area across a sequenced of farming seasons. This can help farmers promote soil fertility and to protect the soil from tillage or erosional effects (Licht, 2016).
3. *Biological pest control*. This is the use of natural (non-chemical) pest control system such as cooking oil/smearing oil to attract predators to feed on pests (Mugo et al., 2011), or using traps (made from local brews/banana juice) to capture adult coffee berry borers.
4. *Sustainable irrigation system.* This helps to provide sufficient hydration for crops even with a limited supply of water. A common example is drip irrigation that distributes water directly to a plant's roots and can reduce water use by an average of 50% (Chartzoulakis and Bertaki, 2015).
5. *Recycling wastewater from coffee processing for irrigation*. It has been suggested that wastewater from wet coffee processing contains a considerable quantity of phosphorus and potassium that can boost the soil’s organic nutrient contents (Hue et al. 2006). Thus, represents a potential complementary source of water for irrigation.
6. *Organic manures*. These are fertilizers made of naturally occurring materials such as food waste, animal dungs and vegetable wastes. For example, evidence indicates that Kenyan farmers often use chemical fertilisers to grow coffee plants (Njeru, 2015), but little is known about their low adoption of organic fertiliser.
7. *Protecting the health and safety of agricultural workers.* This relates to providing first aid kits with personal protective equipment in farms and to ensure safe working condition (Mureithi, 2008; Potts et al., 2003). For example, smallholder coffee farmers in Kenya,

typically use manual (selective) harvesting method that exposes them to musculoskeletal injuries and other hazards (Potts et al., 2003).

Using insights from the analysis in Table 1, we have demonstrated the contributory link between the different SAPs mentioned above and substantiality impacts associated with activities in each stage of the coffee farming process. This analysis can be seen in Table 3. For example, as seen in the table below, crop rotation and organic manure can serve as sustainable alternatives to chemical-based fertilisers in the planting and growth stages of coffee farming, whereas the use of personal protective gear and first aid kits are more relevant to safety and health issues in coffee farming and harvesting, which is performed manually by smallholder farmers. Table 3 therefore provides an initial starting point for the development of our proposed taxonomy for classifying SAPs adoption barriers. We subsequently adopted this as a mapping guide to link identified barriers for SAPs with distinct stages of the coffee farming process.

[Insert Table 3]

2.4. Barriers (difficulties) in adopting sustainable agriculture practices.

Our literature review draws on multiple theoretical perspectives to provide broad insights into underlying factors affecting the adoption of sustainable practices. These perspectives served as a foundation for our classification of the barriers' categories identified from the literature regarding SAP adoption. Dessart *et al* (2019) use Attribution theory to examine the behavioural factors that influence farmers' decisions to adopt environmentally sustainable practices. The findings are categorised into dispositional factors (relating to the internal characteristic of a person), social factors/societal pressures and cognitive factors that influence the adoption of sustainable practices by farmers. Attribution theory also provides explanations for why people assign the cause of behaviour to some external factors or situational circumstances, rather than internal dispositional factors. Through this theory, Su, Gong and Huang, (2020) examine how destination social responsibility strategies affect tourists' intention to visit.

Besides, Adnan *et al* (2019) utilised the Theory of Planned Behaviour (TPB) to identify the factors that influence paddy farmer's adoption decision on green fertilizer technology in Malaysia. This theory assumes that attitude, subjective norms, and perceived behavioural controls influence an individual's behavioural intentions (Ajzen, 1985). For example, previous research (e.g. Wreford et al., 2017) has acknowledged that negative attitudes towards SAPs could negatively influence a farmer's adoption intention. Glover et al (2014) adopted the Institutional Theory to investigate the role of supermarkets in the development of legitimate sustainable practices across the dairy supply chains. The findings revealed that the supermarkets exert coercive pressure on smaller organizations across the supply chain to adopt sustainable practices.

Similarly, evidence suggests that coffee farmers who engage in sustainable practices are usually influenced by social enforcement through engagement with farmer-based organisations and cooperatives (Kamau et al., 2018). From a rationality perspective, Vanclay and Lawrence (1994) examine a farmer's reasons for the adoption of environmentally sound practices. They discovered that attitudes and lack of knowledge were the main barriers to adoption. Like the rationality model for planning behaviour (de Roo and Perrone, 2020), a farmer might refuse to adopt new practices if the cost of implementation exceeds perceived benefits, as previous studies have highlighted that economic concerns are important factors in the adoption of SAPs amongst smallholders, such as lack of access to credit and excessive cost of organic certification (e.g., Wreford et al., 2017; McCarthy and Schurmann, 2014; Jouzi, et al., 2017).

The study conducted by Mousavi and Bossink (2017) shows that a firm's resources and capabilities are an important consideration for implementing sustainable innovation strategies. Firms' resources could be categorised as either tangible (equipment, building and infrastructures) or intangible (skills, experience, and knowledge) assets (Sirmon, Hitt and Ireland, 2007; Hunt and Derozier, 2004). With regards to coffee farming, research has revealed that the lack of certain tangle resources can affect the adoption of sustainable practices, such as transport links, electricity/power and effective communication networks (Pretty and Hine, 2001; Khanna et al, 1999; Rodriguez et al., 2009).

Table 4 presents a synthesis of evidence from the literature on the barriers to adoption of sustainable agriculture practices under six key themes (1) Rationality factors, (2) Knowledge and skills, (3) Attitudinal and behavioural factors, (4) Institutional factors, (5) Circumstantial factors, and (6) Infrastructural factors. These were further grouped into two broad categories namely internal and external factors, as previous authors have suggested (Vermunt et al, 2019; Mont, 2002; Sandberg and Aarikka-Stenroos, 2014). Internal factors are the pressures within smallholdings that can hinder their adoption of SAPs. Whereas external barriers are factors that are beyond the control of the smallholder coffee farmers, which hinder their adoption of SAPs. As previously mentioned, most studies mentioned barriers in general terms, but conceptual clarity is needed on how the various SAP barriers apply to the stages of the coffee farming process. In the next section, we gather and analysed empirical data from smallholders to illustrates the barriers that occur in adopting specific SAP at a different stage of the coffee farming process.

[Table 4]

3. Methodology

We employed an exploratory qualitative approach to examine whether barriers to adoption of SAPs differ for different stages of the coffee farming process and, if so, how. As Bryman and Bell (2011) have noted, it is very important to select a contextual setting for conducting research. Therefore, to investigate our research problem, a sample of smallholder coffee farmers were selected from Nyeri County in the central region of Kenya. We focussed mainly on the coffee farmers in this region for two key reasons: (1) Nyeri county is part of Kenya's rich agricultural sector, consisting mostly of smallholders that belong to cooperative organizations, and thus provides a reliable source (database) to identify potential study participants; and (2), coffee from the region is among the best quality coffee produced worldwide due to its quality and flavour (Karanja, 2012).

3.1. Sampling and recruitment

Using the purposive sampling technique (Lucas, 2014), we recruited participants from a directory belonging to Farmers' Cooperative Societies, located in Othaya, Nyeri, Githiru, Tetu and Mathrira towns in Nyeri County. To ensure our sample was representative of the population, potential participants were required to be operating or working on a small-scale coffee farm within the study area (Nyeri Country) and not have a firm size greater than 2.5 hectares, following the classification system for Kenyan smallholders (Wollverton and Neven, 2014). Initially, 27 of the 120 contacted smallholder coffee farmers agreed to participate. Data was collected through interviews structured around activities in key stages of coffee farming, to elicit respondents' views about factors inhibiting farmers' decisions to adopt more sustainable practices. We then used the snowball technique (Saunders, Lewis, and Thorntonhill 2012) to identify additional 5 participants who met the eligibility criteria. Table 5 presents a summary of the study participants and features attesting to the diversity of our sample.

Participants have different roles, work on different farm locations across Nyeri County and are middle-aged (between about 40 and 65). Coffee happens to be the only cash crop being cultivated by most participants, but they also farm other staple crops such as maize, millet, sorghum and vegetables. Participants' experience in growing coffee ranged from 10 to 35 years and most have a basic level of education (i.e. primary school). By seeking multiple perspectives from the standpoints of key actors across smallholding coffee farms, namely farm-owners, farmer's wife and farmworker/labourer, we can promote triangulation and increase the credibility and validity of research findings (McDougall, Wagner and MacBryde, 2019).

[Insert Table 5]

3.2. Data collection

Semi-structured interviews were conducted to gain an in-depth understanding of the perspectives of the participants on the barriers encountered by adopting SAPs at various stages of the coffee farming process. Interviews were more valuable for the aim of our study than secondary data because we aim for an analysis of barriers associated with different SAPs related to distinct stages of coffee farming. Furthermore, using interviews offers participants the opportunities to share experiences on the subject under investigation, and help with in-depth probing of perspectives (Gray, 2004). In total, 32 interviews were conducted with members of smallholder coffee farming households in Kenya, until saturation was reached, and no new information emerged from participants (Silverman 2013). Each of the participants is considered an expert and key informant because of their first-hand experience (McDougall, Wagner and MacBryde, 2019) and specialist knowledge about coffee farming processes.

Participants were asked three questions: (Question 1) to describe the stages of their coffee cultivation process and the farm practices involved; data collected will help us determine whether such practices are sustainable or conventional. When participants indicated that they are using conventional agricultural practices, we prompted further to know their awareness of relevant sustainable alternatives (Question 2). Hence, to provide some structure for eliciting more specific data (Vermunt et al, 2019), we showed the interviewees a predefined list of SAPs. Then, we asked them to provide reasons for not adopting those SAPs as alternatives to their current conventional farming practices (Question 3). Where a barrier may apply to more than one SAP, we clearly distinguish for which SAP the barriers were found, and to help ensure that barriers could be linked to the specific stage of the coffee farming process, in the subsequent analysis leading to taxonomy development.

Participants could express their views (and/or concerns) freely regarding the adoption of any SAPs on our predefined list that they perceive as relevant for them, but were neither forced to respond to all of them nor were they limited to those practices in their response. Hence, participants were asked to describe any other farming techniques that they have used or currently using, which have limited/no impact on the environment. The average length of the interview process was 45 minutes. All interviews were recorded (subject to participants consent) and transcribed.

3.3. Data analysis

In data analysis, we followed the key steps of thematic analysis recommended by advocates of qualitative research methods (e.g., Braun and Clarke, 2006; Miles and Huberman, 1994; Marshall and Rossman, 2006). First, there was data immersion and familiarisation, involving a thorough reading of the interview transcripts, and we consequently made extensive notes on the data to gain a holistic view. We then embarked on data reduction through the process of inductive coding and grouping of the emergent themes from the data (Creswell, 2003). At this stage, we carried out coding independently and later compared emergent themes to discuss and resolve discrepancies. The coding scheme was adjusted where necessary (based on the extent of agreement between the different coders) before we proceeded further to the full analysis. Through this process, we were able to ensure inter-coder reliability and validity (Weber, 1990), enhancing the extent to which the final coding results represent what the researchers intended to measure (Strauss and Corbin, 1990).

Eight key themes were identified through this process: 1. "lack of finance to invest in drip irrigation", 2. "shortage of raw materials for making sufficient manure", 3. "perceived ease or difficulty of implementation (e.g., compost making is arduous, time-consuming), 4. "insensitive attitude towards issues of water scarcity" 5. "risk perceptions (a subjective judgement that farmers make about the severity of farm accidents)", 6. "the land tenure system (rules guiding land use and ownership)",7. "impracticality of reusing wastewater from coffee mills" and 8. "smallholders limited ability to influence their social and economic circumstances". As seen in Table 6, these themes were then grouped into broader barrier categories, corresponding to those derived earlier from the theoretical framework (in Table 2), and to help us understand how the barriers mentioned by smallholder coffee farmers differ per type of SAPs.

The systematic process of summarising and comparing emergent themes helped us to integrate, validate and finalise data collected from the participants into findings, along with the questions explored during the interviews. We then wrote up the findings by moving the collected data from the narrative commentaries of the smallholder farmers to interpretative information that could enhance our understanding of the barriers to SAP adoption at different stages of coffee farming.

[Table 6]

4. Results

In the following sections, we discuss the barriers to the adoption of SAPs identified and as they relate to the different SAPs. The findings generated from qualitative analysis of interview data and support these with evidence in the form of direct quotations from participants. All quotes in 4 are presented anonymously using the following codes: R1, R2, R3 […] R32. Our findings show that there are internal barriers and five external barriers preventing the adoption of SAPs by smallholder coffee farmers in Kenya. The barriers are discussed below under the following factors: Rationality; Attitude and Behavioural; Institutional; and Circumstantial. As can be seen in Table 6, we did not identify barriers in the following categories: Knowledge and Skills; and Infrastructural.

4.1. Internal barriers

4.1.1. Rationality factors

Most of the respondents argue that there is a rational basis for low adoption of SAPs amongst smallholder farmers, mainly attributable to **“lack of finance”, “compost making is arduous” and “shortage of raw materials for making compost”.** Some smallholders (R1–R15, R19–R25, & R26–R31) expressed concerns about the high transition costs (Rodriguez et al., 209) for implementing biological pest control as an alternative to pesticides. This echoes the idea that individuals depend on their cognitive capabilities and the reality they experience for clear thought and reasoning (Weber. 1978). Similarly, coffee farmers seem to be making logical deductions by calculating the costs, benefits and risks associated with switching from conventional farming techniques to sustainable alternatives such as adopting a drip irrigation system to conserve water usage.

This view was shared by almost all the coffee farmers (e.g. R1–R5, R19–R24, R30 & R31); and they expressed fears about the additional cost that could be incurred in doing away with existing irrigation systems to install new ones. For example, one participant commented: '*I have seen it at Wambugu farm and am sure it uses less water, but the amount of money needed to install it on my farm is too high. The tools are expensive and difficult to set up* […] *currently, I have arrangements in place for overhead sprinkler watering; wouldn't that go to waste if I switch to this other method?' (R 5)*. This shows participants have an awareness of SAPs such as drip irrigation and their associated benefits but are discouraged by the cost and complexity of implementation. In a similar vein, they are aware that attractants (smearing oil) and ethanol traps can be feasible sustainable alternatives to conventional pesticides but considered the latter as much easier to implement and more desirable. The observed lack of enthusiasm for biological pest control techniques is largely due to its time-consuming nature.

For instance, a farmer (R13) said: *'In my farm, pests are controlled by spraying with a pesticide acquired from the coffee society and weeding is done manually, but I also spray herbicides sometimes. I saw these non-chemical techniques at the workshop organised by TechnoServe. I was told we can control by sweeping clean around the base of the tree and pouring grease around, so the pest sticks before it climbs the coffee tree. See, these alternative approaches are very time consuming and would need a lot of effort from labourers (they need to be paid for it), compared to using chemicals.' (R 2)*.

Regarding the adoption of organic manure, many respondents suggest that their inability to obtain adequate raw material (e.g. animal manure, wasted fruit and vegetables) to make large-scale compost manure to grow their coffee was a discouraging factor. When asked how the soil is being enriched to cultivate coffee, they (e.g. R7–R10, R18–R21, R32) said that chemical-based fertilisers (e.g. NPK) are used in most cases, but they would use organic manure only if enough raw materials can be sourced to make the needed quantity of compost manure. To reinforce this point, R10 and R18 said: *'It's not possible to not use fertilizer because the amount* *of manure needed is much more than I have. My coffee farm is not too big, yet I can't produce enough manure for the farm' (R10)* […] *'I use some manure, just that it's not sufficient enough to go round the whole farm, so I must use NPK fertilizers or buy premade organic alternative to supplement.' (R18).*

This suggests that farmers' inability to obtain an adequate amount of manure for their coffee plantations presents a potential barrier to adopting SAPs. Interestingly, some participants said they have learned from training organised by local and international NGOs in Kenya that old banana trees, banana peels or animal dung can be composted and used as organic manure. However, if farmers cannot access adequate raw materials for composting, the continued use of NPK fertilisers seems to be a very well thought out or rational decision.

4.1.2. Attitude and behavioural factors

Respondents (R7, R10–R17, R20–R23, & R2–R5) exhibited some sort of implicitly "**insensitive attitude towards issues of water scarcity**" in coffee agriculture, and the need for reducing water consumption by adopting more efficient irrigation systems. Generally, they have the notion that water is always available to them in their communities and easily accessible for irrigation purposes, but acknowledged, surprisingly, that climate change is making them water their coffee plants more often than ever. Through this careless attitude, there appears to be a social norm (Passafaro, Livi and Kosic et al., 2019: Ajzen, 2015) amongst coffee farmers that promotes a lack of enthusiasm for minimising water consumption in agriculture, as R13 identified: *'Due to climate change, it is drier [...] the rains are shorter and less these days. We must wet the coffee plants more often, but water availability is not a problem. I don't experience any water shortage* […] *already, there is more than enough water piped to my farm via the homestead the community water project, and this has been a reliable source of supply.'* The above comment resonates with recent studies suggesting that climate change is increasing agricultural water demand (Wang *et al*. 2016), but contrary to our expectations, respondents are implicitly unmindful about water scarcity.

Furthermore, while most respondents (e.g. R2–R9, R10, R17–R22 & R30–R36) are cognizant of the health and safety risks associated with manual harvesting the coffee cherries, they perceive such risks as low and not worth paying attention to. The **"risk perceptions (a subjective judgement that farmers make about the severity of farm accidents)"** make them unenthusiastic about using personal protective equipment while working in the coffee plantations. For instance, a farmworker (R17) said: *'I pick coffee alone and I use no safety measures* […] *for me the working condition for picking coffee is just pleasant weather. There is not much risk apart from being pricked by the coffee tree and the rare occurrence of skin rashes from insect bites.* […] *snakes may come around, but I have not come across any.'* Another respondent R9 added; *'I provide my workers with gloves though they rarely use them. They say the gloves slow them down when picking cherries from the tree.'*

These views correspond with the idea that personal experience predicts risk perception and acceptance (van der Linden, 2014). Although it is commonly said that experience is the best teacher, people working on coffee farms should be proactive rather than reactive to prevent health and safety risks. The common belief that farmworkers will consider it unimportant to wear protective clothing or safety equipment while working on the farms reflects how the subjective norm (Ajzen, 1985) can influence decisions not to adopt sustainable practices. In contrast, previous findings recommend that social pressure, albeit from agricultural stakeholders (e.g. farmers groups, associations, or cooperatives), can influence farmers to adopt SAPs (Schneeberger et al., 2002).

4.2.External barriers

4.2.1. Institutional factor

Institutions are governance rules, signifying traditions, values, customs, and procedures for social conduct (Buchanan, 2018). By conforming to these rules, organisations gain legitimacy and have a right to continued existence. Concomitantly, the "**rules guiding land use and ownership**" i.e. agricultural land tenancy system in Kenya represents a barrier by disallowing farmers from practising crop rotation or the growing of cover crops. This view was shared by R6, R8, R12, R22–24, R29–R30. These respondents came across as very knowledgeable about the benefits associated with these SAPs, like erosion reduction, soil water retention and fertilisation, yet, as previously acknowledged by (Rodriguez et al., 2009), their views suggest that the rules guiding land use and ownership are a significant barrier to the adoption of some SAPs amongst coffee farmers. R8 & R12, for example, said: *'Cover crops are beneficial as they can help reduce water loss to the sun when it's hot. However, the community does not allow this because they felt the different crops would compete for limited soil nutrients, leading to a decline in soil fertility* […] *so they say.' (R8). 'I understand that the cover crops help reduce the rate of weed growth. I have cover crops in my other farm such as sweet potatoes but not in the coffee farm…our society does not allow any other crops being grown.' (R12).*

While stakeholders (Simpson et al., 2012) like farmers' cooperatives can play an increasingly vital role in forcing individual coffee growers to adopt sustainable practices, it is apparent from the above comments that the leasing of agricultural land for coffee cultivation comes with greater formal restrictions, which ensure the legitimacy of the operation. This also makes farmers more reluctant to use flexible cropping approaches, such as crop rotation and cover crops. Given that typical smallholders in African countries are resource-constrained in terms of finance and capability (Tittonell and Giller, 2013), they are unlikely to able to influence landowner decisions. Thus, government intervention is needed to address this issue, perhaps through reforms on the land tenancy system in the Kenyan coffee sector.

4.2.2. Circumstantial factors

Respondents held the view that it would be ***"impracticable"*** to adopt certain types of SAPs, such as reusing wastewaters from the coffee processing plant and the application of crop rotation. While some of them (R2, R7–R9, R15–18) agreed that reusing wastewater from coffee mills for irrigation would be a good idea, they showed concerns and doubt about its practicality given the geographic proximity/distance between coffee farms and the processing mills. In the words of R15: *'[…] we have more than enough water actually but if the wastewater can be channelled to our farms it would be a welcomed idea and can help with irrigating other crops, not just coffee. But this idea cannot work in Kenya because most of our processing mills are in towns - a long distance from the coffee plantation.'* In line with other evidence (Global Agricultural Information Network, 2016), respondents said that the demand for such wastewater would be much higher than supply because of the large numbers of farmers, who process their cherry from the same mill, and that individual coffee farmers in Kenya do not have their processing mills.

For example, R18 said: *'Yes, the water could be put into that use but it's not practical as my farm is far from the factory and the water is less than what can be sufficient for farmers all the way here* […]. *Also, I doubt the processing factory would allow that as it would create conflict because the water would be less than what is enough to supply all the farmers.'* In the same vein, respondents argued that crop rotation and growing cover crops would be completely unrealistic in the Kenyan coffee sector. This view was also shared by R34: *'Crop rotation is not practical here because the size of the land is small. Besides, my main farming interest is coffee; therefore, I am not interested in any rotation[…] you see, coffee is a long-term crop* *and it doesn't make any sense to be wasting time in planting new crops when all you need is to rear new trees from the original coffee trunk.'*

Furthermore, the influence of farmers' "***socio-economic status"*** as previously acknowledged by Rapsomanikis (2015), was highlighted in respondents' (R7–R8, R14–R17, R26–R30) descriptions of how coffee trees are reused when they no longer bear cherries. They mentioned that when a coffee tree reaches the life cycle of productivity, it is usually cut-off for firewood. Although these respondents claimed to be knowledgeable about the negative environmental effects of tree burning, they argued that firewood sourced from coffee logs is cheaper and more easily accessible than gas or cooking stoves. According to R17, this scenario is a trade-off between the exigent need for survival versus striving to reduce the environmental impact of farming activities: *'Cherries are plucked from the coffee tree during harvesting, so you do not need to cut the tree down at this stage […]. but after 3 years, we carry out a cycling system where one old tree is cut and a new shoot reared. This continues yearly after every harvest until all the primary trees have been cut, and the cycle is then repeated. Those we cut can be used for fencing the farm, but we usually take them home for firewood.*

The reported experiences of respondents reinforce previous research (e.g. Lambe et al., 2015) that has raised concern about the lack of access to affordable and cleaner cooking fuels for poor people in developing countries. This also alludes to the fact that organisational circumstances play a critical role in determining perceived behavioural control (Wells et al., 2018). Since most smallholder households in Kenya live in remote rural communities, it is not surprising to see firewood as their best choice for cooking.

[Insert Figure 1]

5. Discussion

The previous section reported the experiences of smallholder coffee farmers regarding barriers to the adoption of SAPs and discussed the results with previous evidence. The identified list of internal and external barriers has been classified and discussed under four categories of factors: rationality, attitude and behavioural, institutional, and circumstantial. To develop the proposed taxonomy, we mapped the barriers for adopting specific SAPs against the four stages of coffee farming as presented in figure 1. The taxonomy depicts that barriers to the adoption of SAPs could be caused by four factors, but not all are occurring in all the stages of coffee farming. Some barriers would play a more dominant role in explaining adoption barriers at one stage of the coffee farming process than another. For example, all categories of barriers exist in the growing phase, but the planting stage has only two barriers relating to the formal rationality factor (RaF_1 = lack of finance and RaF_2 = shortage of raw materials). The challenge at the harvesting stage is caused by attitude and behavioural factor (AbF_2 = risk perceptions.

Much of the earlier work (Wreford et al., 2017) assumes that improved knowledge or provision of better education on the environmental impacts of agricultural activities will make farmers take SAPs more seriously. On the contrary, our findings show that smallholder coffee farmers in Kenya are considerably knowledgeable about SAPs, but this has not been actively applied to practice. For example, although they showed an awareness of the impacts of climate change on irrigation, the need to use water more efficiently was not taken seriously. This has been implicitly interpreted as believing that current water sources are sustainable in future.

Government and NGOs can play an important role in this area by providing specially designed training and campaigns to raise awareness about sustainable water usage and its implications for coffee production in Kenya.

As Mousavi and Bossink (2017) have observed, a firm's intangible resources like knowledge and skills are important for implementing sustainable innovation strategies. Hence, training in these areas is essential and would help bridge gaps between farmers' current knowledge of sustainable agriculture and their willingness to apply it practically. Furthermore, respondents admit the likelihood of farm injuries occurring during coffee harvesting activities by manual picking, as has been evinced previously (e.g., Mureithi, 2008). However, from their point of view, the occurrence of such hazards is rare and within tolerable limits, if they ever occur. So, they do not warrant investment in personal protective equipment. The issue is exacerbated by the dissenting action of labourers/farmworkers.

General unwillingness to be proactive in preventing the occurrences of health and safety-related risks on coffee farms signifies the influence of subjective norms on the behavioural intentions (of coffee farmers towards not adopting SAPs. To address this, coffee farmers can use a performance-based incentives approach (Przewozny, Bitsch and Peters, 2016) that will tie labourers' wages to their rate of compliance with health and safety measures. It has been argued that most smallholders have a low level of education and literacy skills (Kørnøv and Thissen, 2000) and are therefore might not recognise the appropriate incentive systems to use to motivate labourers in making an ethically conscious decision. We recommend therefore that they consult different household members in determining the most appropriate incentive scheme.

Some less obvious findings emerged too, such as the institutional constraints imposed by the land tenure arrangements (Place & Otsuka, 2002), which offer legitimacy or social licence to operate (Scott, 2004) to smallholders in coffee-growing communities. This stems from the obstacles that coffee farmers are likely to face with the adoption of crop rotation and the growing of cover crops in Kenya. We would argue that it is unlikely that individual smallholder farmers can influence such institutional barriers, given their limited resources and capabilities. Nevertheless, the co-operative structure in Kenyan coffee farming can be leveraged to spark new conversations with landlords of agricultural assets, to make the current land tenure system more attractive to SAPs.

A similar idea has been suggested by Darnhofer et al. (2005) that agricultural associations can be social influencers to motivate farmers' choice. Thus, highlighting the role of societal pressures in influencing human behaviours (Su, Gong and Huang, 2020). Likewise, the evidence gathered from our respondents reveals that coffee farmers use coffee trees that have reaches the end of productive life, as firewood for cooking. This reflects a trade-off between the immediacy of concerns around meeting survival needs versus the longer-term concern around the environmental impact of wood-burning. One explanation for this behaviour is that smallholders are typically poor and less able to afford clean cooking energy alternatives (Kabyanga et al. 2018), limiting their choices.

Although using wood fuel for cooking increases the quantity of CO_2 in the atmosphere and contributes to climate change (Junior et al., 2018), most farming households live in remote areas of Kenya and use wood as their primary cooking fuel because it is cheap and easily accessible (Okoko et al., 2017). It is therefore rational for them to use coffee tree logs for cooking rather than taking the environmental impacts of their actions more seriously.

6. Conclusion

This study developed a taxonomy that depicts the barriers hindering the adoption of SAPs at different stages of coffee farming. By understanding the barriers in various stages of coffee farming, appropriated mitigation interventions can be developed. Beyond sustainable agriculture, this study contributes to knowledge of the process approach to evaluating technology and practice adoption in businesses generally. For example, by sectioning a business operation up into a chain of activities (like different phases of coffee farming), where one process feeds into the next, managers can be able to detect areas and priorities for improvement in the adoption of smart practices like blockchain systems, which often go against conventional methods. We present further theoretical and practical implications as follows.

6.1. Theoretical contributions

The results highlight the smallholders contextual, attitudinal, institutional, and situational factors affecting the adoption of sustainable farming practices. It reveals that attitudes and normative issues influence farmers' intentions to not adopt some SAPs like drip irrigation, organic manures, and biological pest control. The careless attitude that smallholders have towards water sustainability issues, affect how much value they place on adopting SAPs like drip irrigation in coffee farming. This is consistent with key assumptions of the theory of planned behaviour.

Expectedly, we discovered that coffee farmers rationally calculate the relative costs and benefits of sustainable alternatives versus existing conventional farming techniques. Particularly regarding using drip irrigation, organic manure, and reusing wastewater from coffee mills for irrigation. This has an important implication for other climate-smart practices not included in our analysis. For example, resource-poor smallholders are likely to be comfortable with their conventional practices rather than acquiring "zero tillage machines" or "installing solar-powered irrigation system" on their farms.

Consistent with key assumptions of Weber rationality theory, small-scale coffee farmers are usually concerned about the relative convenience and cost of implementing sustainable agricultural practices (McCarthy and Schurmann, 2014). In addition, our findings lend some support to the basic postulation of institutional theory by revealing how established rules and processes of coffee farming communities discourage the practising of crop rotation and growing of cover crops.

6.2. Practical implications

Based on the results, we were able to identify key factors acting as barriers to the adoption of different types of SAPs and proposed a taxonomy for understanding where these barriers exist in key stages of the coffee farming process. The analysis can be seen in Figure 1. Such distinctions can help policymakers, NGOs and researchers recommend interventions tailored to help increase the adoption of sustainable practices in coffee farming. There is also a growing demand for sustainable agricultural products in developed countries (Kamau et al., 2018). Therefore, the taxonomy developed from this study can provide insight to enable key actors in the coffee value chain (e.g., government, exporters, and manufacturers) to design and select appropriate policy interventions to help smallholder farmers overcome the challenges of implementing SAPs. Furthermore, the findings can guide future empirical studies evaluating the influence of barriers on the adoption of SAPs under a different small-scale agriculture model.

Existing evidence (Kumar et al., 2020; Antle, John and Bocar Diagana, 2003) demonstrating the importance of using incentives and subsidies for the adoption of SAPs. However, the current policy of the Kenya government still incentivises smallholder coffee farmers to use fertilisers to increase crop yields (Njeru, 2015). Yet, fertiliser use causes carbon emissions from coffee farming, accounting for 94% of the total farm footprint (Maina, 2017). The government needs to formulate an appropriate subsidies policy to help smallholder farmers afford organic manure and protective clothing or kits for farmworkers. The justification for such subsidies is that smallholders are resources constrained and might need financial help to acquire the materials for practising sustainable agriculture. Likewise, there is a need for a policy to help increase access to affordable and reliable sustainable energy for cooking. If this issue is not addressed, and the demand for firewood is increasing, smallholders might have no option but to cut their coffee trees as household cooking fuel.

6.3. Limitations and suggestions for future research

Like most qualitative exploratory studies, the goal of this research is not to generalize but rather to provide a rich, contextualized understanding of the major barriers to the adoption of SAPs amongst smallholder coffee farmers. For instance, although 80% of the world's coffee is grown by smallholders, the results from our sample do not apply to all of them. In areas of water stress, one would expect very different results. It could be interesting in future studies to examine coffee farmers' definitions of agricultural practices that would be considered sustainable. In such a study, researchers may address this question: what does sustainability mean to smallholder coffee farmers in Africa? We feel this area requires greater attention because what is sustainable in one context may not be in another.

The interpretive Structural Modelling (ISM) method can be utilised to determine the mutual interaction of these barriers and identify the barriers which influence or depend on other barriers. Researchers can adapt the proposed taxonomy for cross-country comparative analysis of SAP adoption barriers. It can guide the collection and analysis of primary data from multiple coffee-producing countries in Africa to produce a generic set of metrics for evaluating factors influencing the adoption of SAPs in coffee agriculture.

Despite its limitations, the study contributes to the literature by providing a tool to assist in the process of investigating, preventing, and mitigating barriers to the adoption of SAPs.

References

Adnan, N., Nordin, S. M., Bahruddin, M. A., & Tareq, A. H. (2019). A state-of-the-art review on facilitating sustainable agriculture through green fertilizer technology adoption: Assessing farmers behaviour. Trends in Food Science & Technology, 86, 439-452.

Agarwal, A., Sengupta, D., & El-Halwagi, M. (2018). Sustainable process design approach for on-purpose propylene production and intensification. ACS Sustainable Chemistry & Engineering, 6(2), 2407-2421.

Ajzen, I. 1985. From intentions to actions: A theory of planned behavior. In *Action control* (pp. 11-39). Springer, Berlin, Heidelberg.

Ajzen, I. 2015. The theory of planned behaviour is alive and well, and not ready to retire: a commentary on Sniehotta, Presseau, and Araújo-Soares. *Health Psychology Review*, 9(2), 131-137.

Alila, P. and Atieno, R., 2006. Agricultural Policy in Kenya: Issues and Processes, Future Agricultures Consortium Workshop Institute for Development Studies. *University of Nairobi, Nairobi, Kenya*.

Amanor, K. S. 2019. Global Value Chains and Agribusiness in Africa: Upgrading or Capturing Smallholder Production? Agrarian South: Journal of Political Economy, 8(1-2), 30-63.

Antle, J M., and Diagana, B. 2003. "Creating Incentives for the Adoption of Sustainable Agriculture Practices: The Role of Carbon Sequestration." American *Journal of Agricultural Economics* 85(5):1178-1184.

Avelino, J., Romero-Gurdián, A., Cruz-Cuellar, H.F. and Declerck, F.A., 2012. Landscape context and scale differentially impact coffee leaf rust, coffee berry borer, and coffee root-knot nematodes. *Ecological Applications*, *22*(2): 584-596.

Barrett, H.R., Browne, A.W., Harris, P.J.C. and Cadoret, K., 2001. Smallholder farmers and organic certification: Accessing the EU market from the developing world. *Biological Agriculture & Horticulture*, *19*(2):183-199.

Bennett, M. and Franzel, S., 2013. Can organic and resource-conserving agriculture improve livelihoods? A synthesis. *International Journal of Agricultural Sustainability*, *11*(3):193-215.

Berlan, A. 2013. Social sustainability in agriculture: an anthropological perspective on child labour in cocoa production in Ghana. The Journal of Development Studies, 49(8), 1088-1100.

Bianco, G. B. (2020). Climate change adaptation, coffee, and corporate social responsibility: challenges and opportunities. International Journal of Corporate Social Responsibility, 5(1), 1-13

Brandt, K. and Mølgaard, J.P., 2001. Organic agriculture: does it enhance or reduce the nutritional value of plant foods? *Journal of the Science of Food and Agriculture*, *81*(9): 924-931.

Brankatschk, G. and Finkbeiner, M., 2015. Modeling crop rotation in agricultural LCAs—challenges and potential solutions. *Agricultural Systems*, *138* (?): 66-76.

Bro, A. S., Clay, D. C., Ortega, D. L., & Lopez, M. C. (2019). Determinants of adoption of sustainable production practices among smallholder coffee producers in Nicaragua. Environment, Development and Sustainability, 21(2), 895-915.

Brockhaus, S., Fawcett, S. E., Knemeyer, A. M., & Fawcett, A. M. (2017). Motivations for environmental and social consciousness: Reevaluating the sustainability-based view. Journal of Cleaner Production, 143, 933-947.

Buchanan, A. 2018. Institutional legitimacy. *Oxford studies in political philosophy*, *4*, 53-80.

Carsan, S., Stroebel, A., Dawson, I., Kindt, R., Swanepoel, F. and Jamnadass, R., (2013). Implications of shifts in coffee production on tree species richness, composition and structure on small farms around Mount Kenya. *Biodiversity and conservation*, *22*(12): 2919-2936.

Central Coffee Research Institute 2008. Coffee Cultivation Guide for South-West Monsoon Area Growers in India (Coffee Kaipidi). *Central Coffee Research Institute, Chikmagalur*, Karnataka; India. http://vikaspedia.in/agriculture/crop-production/package-of-practices/coffee-production-guide

Chartzoulakis, K. and Bertaki, M., 2015. Sustainable water management in agriculture under climate change. *Agriculture and Agricultural Science Procedia*, *4* (?): 88-98.

Chiputwa, B. and Qaim, M., 2016. Sustainability standards, gender, and nutrition among smallholder farmers in Uganda. *The Journal of Development Studies*, *52*(9), pp.1241-1257.

Craves, J. 2008. Coffee growing in Kenya. Coffee Habitat. [Online] http://www.coffeehabitat.com/2008/03/coffee-growing-in-kenya/
Cycon, D., 2007. *Javatrekker: Dispatches from the world of fair-trade coffee*. Chelsea Green Publishing, United States.
Dang, Y. P., Page, K. L., Dalal, R. C., & Menzies, N. W. (2020). No-till Farming Systems for Sustainable Agriculture: An Overview. No-till Farming Systems for Sustainable Agriculture, 3-20.
Darnhofer, I., Schneeberger, W., & Freyer, B. 2005. Converting or not converting to organic farming in Austria: Farmer types and their rationale. *Agriculture and human values*, *22*(1), 39-52.
Dessart, F. J., Barreiro-Hurlé, J., & van Bavel, R. (2019). Behavioural factors affecting the adoption of sustainable farming practices: a policy-oriented review. Eur. Rev. Agric. Econ, 46(3), 417-471.
DiMaggio, P.J. and Powell, W.W., 1983. The iron cage revisited: Institutional isomorphism and collective rationality in organizational fields. *American Sociological Review*, pp.147-160.
Drost, D. 1996. Barriers to Adopting Sustainable Agricultural Practices. Journal of Extension, 34(6), n6. https://www.joe.org/joe/1996december/a1.php
Edwards, R. and Holland, J., 2013. *What is qualitative interviewing?* A&C Black.
Ehiakpor, D. S., Danso-Abbeam, G., & Mubashiru, Y. (2021). Adoption of interrelated sustainable agricultural practices among smallholder farmers in Ghana. Land Use Policy, 101, 105142.
Fischer, A., & Pascucci, S. (2017). Institutional incentives in circular economy transition: The case of material use in the Dutch textile industry. Journal of Cleaner Production, 155, 17-32.
Gama, J., & Millinga, M. L. 2016. Latest developments in organic Agriculture in Africa. the World of organic agriculture, 174 Gama, J., & Millinga, M. L. (2016). Latest developments in organic Agriculture in Africa. the World of organic agriculture, 174
Global Agricultural Information Network. 2016. Kenya Coffee Annual Report 2016 - USDA Foreign Agricultural Service. https://gain.fas.usda.gov/Recent%20GAIN%20Publications/Coffee%20Annual_Nairobi_Kenya_5-13-2016.pdf
Glover, J. L., Champion, D., Daniels, K. J., & Dainty, A. J. (2014). An Institutional Theory perspective on sustainable practices across the dairy supply chain. International Journal of Production Economics, 152, 102-111.
Gray, G.W., 2004. Challenges of building clinical data analysis solutions. *Journal of critical care*, *19*(4): 264-270.
Guo, Q., Ola, O., & Benjamin, E. O. (2020). Determinants of the Adoption of Sustainable Intensification in Southern African Farming Systems: A Meta-Analysis. Sustainability, 12(8), 3276.
Guo, S., Wan, K. and Dillard, D., 2004. Water-Assisted Subcritical Crack Growth Along an Epoxy-Glass Interface. In *Proceedings of 2004 Adhesion Society Meeting* (pp. 81-83)
Han, S.H., An, J.Y., Hwang, J., Kim, S.B. and Park, B.B., 2016. The effects of organic manure and chemical fertilizer on the growth and nutrient concentrations of yellow poplar (Liriodendron tulipifera Lin.) in a nursery system. *Forest Science and Technology*, *12*(3): 137-143.
Harden, C. 1996. Relationship between land abandonment and land degradation: a case from the Ecuadorian Andes. Mountain Research and Development 16:274–280.
Hue, N.V., Bittenbender, H.C. and Ortiz-Escobar, M.E., 2006. Managing coffee processing water in Hawaii. *Journal Hawaiian Pacific Agriculture*, *13* (?):15-21.

Hunt, S. D., & Derozier, C. (2004). The normative imperatives of business and marketing strategy: grounding strategy in resource-advantage theory. Journal of Business & Industrial Marketing, 19(1), 5-22.

Ibanez, M., & Blackman, A. 2015. Environmental and economic impacts of growing certified organic coffee in Colombia. http://www.rff.org/files/sharepoint/WorkImages/Download/EfD-DP-15-02.pdf

Ibnu, M. (2020). Toward a More Sustainable Coffee Production: the Implementation Capacity of Indonesian Standard Coffee. Pelita Perkebunan, 35(3), 212-229.

International Labour Organization. 2004. Hazardous Child Labour in Agriculture. International Programme on the Elimination of Child Labour Safety and Health Fact Sheet. ILO, Geneva: March 2004. www.ilo.org/ipecinfo/product/download.do?type=document&id=5708

Iscaro, J., 2014. The impact of climate change on coffee production in Colombia and Ethiopia. *Global Majority E-Journal*, *5*(1): 33-43.

Jellason, N. P., Conway, J. S., & Baines, R. N. (2020). Understanding impacts and barriers to adoption of climate-smart agriculture (CSA) practices in North-Western Nigerian drylands. The Journal of Agricultural Education and Extension, 1-18.

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

Junior, L. M. C., da Costa Martins, K. D. L., & Carvalho, M. 2018. Carbon Footprint Associated with Firewood Consumption in Northeast Brazil: An Analysis by the IPCC 2013 GWP 100y Criterion. Waste and Biomass Valorization, 1-9.

Kabyanga, M., Balana, B.B., Mugisha, J., Walekhwa, P.N., Smith, J. and Glenk, K., 2018. Economic potential of flexible balloon biogas digester among smallholder farmers: A case study from Uganda. *Renewable Energy*, *120* (?) 392-400.

Kamau, J.W., Stellmacher, T., Biber-Freudenberger, L. and 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* (?): 171-185.

Kanyenze, G. 2004. Giving voice to the unprotected workers in the informal economy in Africa: the case of Zimbabwe (No. 22). International Labour Organization.

Karanja, R. H. N. 2012. Pollination of Coffea arabica L. and associated awareness of pollination significance among farmers in selected farms in Kiambu District, Kenya. Online. Available from: http://journals.jkuat.ac.ke/index.php/pgthesis_abs/article/view/187/168 [Accessed on 1st April 2020].

Keller J. and Blinser R.D., 1990. Sprinkle and trickle irrigation. New York, USA, Chapman and Hall.

Khanna, M, Millock, K and Zilberman, D. 1999. “Sustainability, Technology and Incentives.” Pp. 97-118 in Flexible Incentives for the Adoption of Environmental Technologies in Agriculture, edited by F. Casey, A. Schmitz, S. Swinton, and D. Zilberman. Norwell: Kluwer Academic Publishers.

König, C., Caldwell, N. D., & Ghadge, A., 2019. Service provider boundaries in competitive markets: the case of the logistics industry. International Journal of Production Research, 57(18), 5624-5639.

Kørnøv, L. and Thissen, W.A., 2000. Rationality in decision-and policymaking: implications for strategic environmental assessment. *Impact Assessment and Project Appraisal*, *18*(3): 191-200.

Kumar, S., Jha, G. K., Singh, D. R., & Biswas, H. (2020). Economic incentives for sustainable legume production in India: a valuation approach internalizing risk sharing and environmental benefits. Current Science (00113891), 119(7).

Lambe, F., Jürisoo, M., Wanjiru, H. and Senyagwa, J., 2015. Bringing clean, safe, affordable cooking energy to households across Africa: an agenda for action. Online. Available from: https://pdfs.semanticscholar.org/3ca9/466b777a2ba9531952fb1ad0b8049b4c949e.pdf [Accessed on 22nd June 2020].

Lesschen, J. P., Cammeraat, L. H., & Nieman, T. 2008. Erosion and terrace failure due to agricultural land abandonment in a semi-arid environment. Earth Surface Processes and Landforms, 33(10), 1574-1584.

Licht, M., 2016. Cover crops 101: Tips and tricks for getting started. Online. Available from: https://lib.dr.iastate.edu/icm/2016/proceedings/5/ [Accessed on 22nd June 2019].

Lucas, S.R., 2014. Beyond the existence proof: Ontological conditions, epistemological implications, and in-depth interview research. *Quality & Quantity*, *48*(1): 387-408.

Magina, F. L., Kilambo, D. L., Maerere, A. P., & Teri, J. M. 2016. Innovative Strategies for Control of Coffee Insect Pests in Tanzania: A Review. Huria: Journal of the Open University of Tanzania, 22(1), 63 72. https://journals.out.ac.tz/index.php/Huria_journal/article/viewFile/62/62

Maina, J. J. (2017). Evaluation and Mitigation of Greenhouse Gas Emissions from the Smallholder Coffee Supply Chain in Kenya (Doctoral dissertation, JKUAT AGRIC. ENG.).

Matinde, E., Simate, G. S., & Ndlovu, S. (2018). Mining and metallurgical wastes: a review of recycling and re-use practices. Journal of the Southern African Institute of Mining and Metallurgy, 118(8), 825-844.

McCarthy, B. and Schurmann, A., 2014. Sustainable horticulture: understanding barriers to the adoption of innovation. Online. Available from: https://researchonline.jcu.edu.au/36740/ [Accessed on 12th May 2019].

McDougall, N., Wagner, B. and MacBryde, J., 2019. An empirical explanation of the natural-resource-based view of the firm. *Production Planning & Control*, *30*(16):1366-1382.

Meneghetti, A., & Monti, L. 2015. Greening the food supply chain: an optimisation model for sustainable design of refrigerated automated warehouses. International Journal of Production Research, 53(21), 6567-6587.

Mont, O. 2002. Drivers and barriers for shifting towards more service-oriented businesses: Analysis of the PSS field and contributions from Sweden. *The Journal of Sustainable Product Design*, *2*(3-4), 89-103.

Mousavi, S., & Bossink, B. A. (2017). Firms' capabilities for sustainable innovation: The case of biofuel for aviation. Journal of Cleaner Production, 167, 1263-1275.

Mugo, S.N., Mwimali, M., Taracha, C.O., Songa, J.M., Gichuki, S.T., Tende, R., Karaya, H., Bergvinson, D.J., Pellegrineschi, A. and Hoisington, D.A., 2011. Testing public Bt maize events for control of stem borers in the first confined field trials in Kenya. *African Journal of Biotechnology*, *10*(23): 4713-4718.

Mureithi, L.P., 2008. *Coffee in Kenya: Some challenges for decent work*. Online. Available from: https://pdfs.semanticscholar.org/ba34/dc1f9d644d2d627a3f7647f0cf227014c9e4.pdf [Accessed on 12th May 2019].

Mwangi, H.W., Kihurani, A.W., Wesonga, J.M., Ariga, E.S. and Kanampiu, F., 2015. Factors influencing adoption of cover crops for weed management in Machakos and Makueni counties of Kenya. *European Journal of Agronomy*, *69*:1-9.

Nepal, S., 2010. An economic analysis of cover crops in corn-dominated production systems. Online. Available from: https://digitalcommons.lsu.edu/gradschool_theses/171/ [Accessed on 10th January 2020].
Njeru, M.K., 2015. Challenges and benefits of organic farming among farmers in Nembure Division, Embu County-Kenya. *International Journal of Humanities and Social Sciences*, *5*:12.
Njoroge, W. 2000. Field Notes on Organic Farming. Nairobi: Kenya Institute of Organic Farming
Nkomoki, W., Bavorová, M., & Banout, J. (2018). Adoption of sustainable agricultural practices and food security threats: Effects of land tenure in Zambia. Land use policy, 78, 532-538.
Notter, B., MacMillan, L., Viviroli, D., Weingartner, R. and Liniger, H.P., 2007. Impacts of environmental change on water resources in the Mt. Kenya region. *Journal of Hydrology*, *343*(3-4): 266-278.
O'Brien, C. (1999). Sustainable production–a new paradigm for a new millennium. International Journal of Production Economics, 60, 1-7.
Okoko, A., Reinhard, J., von Dach, S.W., Zah, R., Kiteme, B., Owuor, S. and Ehrensperger, A., 2017. The carbon footprints of alternative value chains for biomass energy for cooking in Kenya and Tanzania. *Sustainable Energy Technologies and Assessments*, *22*:124-133.
Passafaro, P., Livi, S. and Kosic, A., 2019. Local norms and the Theory of Planned Behaviour: understanding the effects of spatial proximity on recycling intentions and self-reported ecological behaviour. *Frontiers in Psychology*, *10*:744.
Pham, Y., Reardon-Smith, K., Mushtaq, S., & Cockfield, G. (2019). The impact of climate change and variability on coffee production: a systematic review. Climatic Change, 156(4), 609-630.
Place, F., & Otsuka, K. 2002. Land tenure systems and their impacts on agricultural investments and productivity in Uganda. *Journal of development studies*, *38*(6), 105-128.
Potts, J., Von Moltke, K., Taporaie, A., & Arda, M. 2003. Sustainability in the coffee sector: Exploring opportunities for international cooperation. United Nations Conference on Trade and Development (UNCTAD). Palais des Nations, Geneva, Dec. 8–9.
Presley, L (2014). Understanding barriers to agricultural conservation practice adoption. Professional Paper. Agriculture and Integrated Resource Management, Colorado State University. [online]. Available from: http://webdoc.agsci.colostate.edu/wcirm/ConservationPracticeAdoption_IRM2014_Presley.pdf (accessed December 2019)
Pretty, J. N., & Hine, R.(2001. Reducing food poverty with sustainable agriculture: A summary of new evidence. Colchester: University of Essex
Przewozny, A., Bitsch, V., & Peters, K.J. 2016. Performance-based pay and other incentive schemes on dairy farms in Germany. *Social Science Research Network (SSRN) February 11, 2016.* Online. Available from: www.ssrn.com/abstract=2851082 [Accessed on 10th January 2020].
Rapsomanikis, G. 2015. The economic lives of smallholder farmers: An analysis based on household data from nine countries. Food and Agriculture Organization of the United Nations, 1-39
Rodriguez, J. M., Molnar, J. J., Fazio, R. A., Sydnor, E., & Lowe, M. J. 2009. Barriers to adoption of sustainable agriculture practices: Change agent perspectives. Renewable Agriculture and Food Systems, 24(1): 60-71.

Sandberg, B., & Aarikka-Stenroos, L. 2014. What makes it so difficult? A systematic review on barriers to radical innovation. *Industrial Marketing Management*, *43*(8), 1293-1305.
Sanz-Uribe, J. R., Menon, S. N., Peñuela, A., Oliveros, C., Husson, J., Brando, C., & Rodriguez, A. 2017. Postharvest Processing—Revealing the Green Bean. In The Craft and Science of Coffee (pp. 51-79).
Saunders, M., Lewis, P. & Thornhill, A. 2012. "Research Methods for Business Students" 6th edition, Pearson Education Limited. Harlow, England
Schneeberger, W., Darnhofer, I., & Eder, M. 2002. Barriers to the adoption of organic farming by cash-crop producers in Austria. American journal of alternative agriculture, 24-31.
Scott, W. R. 2004. Institutional theory. Encyclopedia of social theory, George Ritzer, ed. Thousand Oaks, CA: Sage. Pp. 408-14
Sharifzadeh, M.S., Abdollahzadeh, G., Damalas, C.A. and Rezaei, R., 2018. Farmers' criteria for pesticide selection and use in the pest control process. *Agriculture*, *8*(2): 24.
Silverman, D. (2013). Doing qualitative research: A practical handbook. SAGE publications limited.
Simpson, D., Power, D. and Klassen, R., 2012. When one size does not fit all: A problem of fit rather than failure for voluntary management standards. *Journal of Business Ethics*, *110*(1): 85-95.
Sirmon, D. G., Hitt, M. A., & Ireland, R. D. (2007). Managing firm resources in dynamic environments to create value: Looking inside the black box. Academy of Management Review, 32(1), 273-292.
Su, L., Gong, Q., & Huang, Y. (2020). How do destination social responsibility strategies affect tourists' intention to visit? An attribution theory perspective. Journal of Retailing and Consumer Services, 54, 102023.
Teklewold, H., Kassie, M., & Shiferaw, B. 2013. Adoption of multiple sustainable agricultural practices in rural Ethiopia. Journal of agricultural economics, 64(3), 597-623.
Tittonell, P., & Giller, K. E. 2013. When yield gaps are poverty traps: The paradigm of ecological intensification in African smallholder agriculture. *Field Crops Research*, *143*: 76-90.
Tripathi, P., Kashyap, S. D., Shah, S., & Pala, N. A. 2017. Effect of organic manure on soil physicochemical properties under fruit-based agroforestry system. Indian Forester, 143(1), 48-55.
Van der Linden, S.L., Leiserowitz, A.A., Feinberg, G.D. and Maibach, E.W., 2014. How to communicate the scientific consensus on climate change: plain facts, pie charts or metaphors? *Climatic Change*, *126*(1-2): 255-262.
Vanclay, F., & Lawrence, G. (1994). Farmer rationality and the adoption of environmentally sound practices; a critique of the assumptions of traditional agricultural extension. European Journal of Agricultural Education and Extension, 1(1), 59-90.
Vermunt, D. A., Negro, S. O., Verweij, P. A., Kuppens, D. V., & Hekkert, M. P. 2019. Exploring barriers to implementing different circular business models. Journal of Cleaner Production, 222, 891-902.
Vogel, H. 1988. Deterioration of a mountainous agro-ecosystem in the Third World due to emigration of rural labour. *Mountain Research and Development*, 321-329.
Wang, W., Zhang, Y., Zhang, W., Gao, G., & Zhang, H. (2021). Incentive mechanisms in a green supply chain under demand uncertainty. Journal of Cleaner Production, 279, 123636.

Wang, X. J., Zhang, J. Y., Shahid, S., Guan, E. H., Wu, Y. X., Gao, J., & He, R. M. 2016. Adaptation to climate change impacts on water demand. *Mitigation and Adaptation Strategies for Global Change*, 21(1):81-99.

Water Resources Group. 2016. Agricultural & Irrigation Opportunity in Kenya. 2030 WRG Roundtable #3. Moving towards Solutions. [online] https://www.2030wrg.org/wp-content/uploads/2016/12/Agriculture-and-irrigation-opportunity-in-Kenya.pdf (accessed, 12th March, 2020)

Weber, M. 1978. *Economy and Society*. Berkeley: California University Press

Woolverton, A., Okello, J., Binci, M., & Neven, D. 2014. Attitudes and decision-making in smallholder commercialization. In Andrea Woolverton & D. Neven (Eds.), Understanding Smallholder Farmer Attitudes to Commercialization: The Case of Maize in Kenya (pp. 16–34). Rome: Food and Agriculture Organization of The United Nations.

Wreford, A., A. Ignaciuk and G. Gruère. 2017. "Overcoming barriers to the adoption of climate-friendly practices in agriculture", OECD Food, Agriculture and Fisheries Papers, No. 101, OECD Publishing, Paris. http://dx.doi.org/10.1787/97767de8-en

Yohannes, M.F., Matsuda, T. and Sato, N., 2016. Substitution in Consumer Demand for Coffee Product Categories in Japan. *Journal of Agricultural Science*, *8*(4): 50.

Zingore, S., Delve, R. J., Nyamangara, J., & Giller, K. E. 2008. Multiple benefits of manure: the key to maintenance of soil fertility and restoration of depleted sandy soils on African smallholder farms. Nutrient Cycling in Agroecosystems, 80(3), 267-282.