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Article

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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 countries and those whose livelihoods depend on the coffee industry (Bianco, 2020; Pham et al, 2019; Berlan, 2013). Furthermore, current farming practices such as mechanisation and increased fertiliser use has significant greenhouse effect (Pearce et al, 2018).

To address these potential impacts, sustainable (organic) agriculture was introduced into Kenya over 40 years ago through the combined efforts of non-governmental organisations (NGOs), faith-based organisations and commercial entities (Chiputwa and Matin, 2016). The coffee 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 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). Secondly, the global food supply chain is being shaped by sustainability efforts and other programs of multinational companies, aimed 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, leading to increased food production, resource efficiency and profit to meet the growing global demand for food (Ehiakpor, Danso-Abbeam, and Mubashiru, 2021; Rodriguez et al. 2009). 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 Practices (SAPs) like climate-smart farming (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, 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 different stages of the farming process. Further, Dora *et al* (2019) discovered that farm size and ownership are critical for sustainability, besides operational factors.

Therefore, this study seeks to examine whether barriers to SAPs adoption differ across the 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 nursery, planting, growing, and harvesting. Consequently, to collect primary data, we conduct semi-structured interviews with 32 smallholder coffee farmers from Nyeri county in Kenya.

We develop a taxonomy of barriers through field research. 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 identify targeted solutions for boosting SAPs' adoption amongst smallholder coffee farmers. In terms of theoretical contributions, the research explains the role of rational, institutional, attitudinal, and circumstantial factors in influencing the decision of smallholder farmers' towards adopting SAPs.

The subsequent section provides an overview of key stages of the coffee farming process, and a comprehensive literature review on barriers to the adoption of SAPs. We then discuss various SAPs, which are 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 to identify relevant articles (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 present a brief description of various activities in four (initial) stages of coffee cultivation and identified their associated sustainability impact. 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 with fertiliser application and regular (irrigation) watering irrigated 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 such as irreversible changes in soil structure and drainage/infiltration of hazardous chemicals (e.g., fertilisers) into freshwater. Most importantly, land clearing and tree removal activities during coffee seasons could reduce biodiversity. For example, the highlands and Mount Kenya where coffee is commonly grown in Kenya, host rare and endangered species like migratory birds (Carsan et al., 2013), which can become endangered.

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 to power 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 (Central Coffee Research Institute, 2008). The chemical substances associated with the use of herbicides, pesticides and inorganic fertilisers can contribute to the greenhouse gases emissions in the environment, such as methane, nitrogen, and carbon dioxide.

Concerning coffee harvesting, three broad methods can be used: stripping/mechanical harvesting and selective picking (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 exposure to snake (insect) bites, musculoskeletal problems, attributed to repetitive body movements and back bending, as well as skin irritation from abrasions (e.g Kanyenze, 2004; Mureithi, 2008). If these issues go unaddressed, they may seriously affect the productivity of 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, this concept gained more prominence in the manufacturing industry (O'Brien, 1999) because current industrial systems are not sustainable and put excessive pressure on the world's natural resources. However, organisations must develop environmental and social consciousness 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 in concurrent engineering designs. They believe that organisations can drive efficiency in costing 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.

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 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 that through such practices, farmers can reduce the impact on the environment and support social development. What can be deduced from the above-mentioned definitions is that 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 protects 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, which reduces 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 mills contains a considerable quantity of phosphorus and potassium that can boost organic nutrient contents in the soils (Hue et al. 2006). Thus, such wastewater 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 the reasons for non (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, this can help smallholder coffee farmers in Kenya that typically use manual (selective) harvesting method to cope with risks of musculoskeletal injuries and other hazards (Potts et al., 2003).

Using insights from the analysis in Table 1, we have demonstrated the contributory link between different SAPs and substantiality impacts of the 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 alternative 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 harvesting, which is often 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 barriers' categories identified from the literature on 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. 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.

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. TPB 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) used 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 Weber's 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. 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 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 different stages of the coffee farming process. In the next section, we gather and analysed empirical data from smallholders to illustrate barriers that occur in adopting SAP in different stages 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 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 in 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 to 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 plan for an analysis of barriers experienced in different stages of coffee farming. Furthermore, interviews offer 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.

Participants were asked three questions: (Question 1) to describe the stages of their coffee cultivation process and the farm practices (activities) 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, which they perceive to be relevant. However, they were neither forced to respond to all the listed items nor 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 categories to improve understanding of how the barriers mentioned by smallholder coffee farmers differ per type of SAPs. The themes categories were derived from the initial theoretical framework (in Table 2).

The systematic process of summarising and comparing emergent themes helped us to integrate, validate and finalise raw data into meaningful findings. 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 present the barriers identified and as they relate to the different SAPs. The findings generated from qualitative data analysis were discussed with supporting evidence in the form of quotations from participants. Direct quotes were presented anonymously using the following codes: R1, R2, R3 […] R32. Our findings show that there are four key barriers (internal and external factors) preventing the adoption of SAPs by smallholder coffee farmers in Kenya: 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 transaction 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 using 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); as 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 suggests that while participants were aware of drip irrigation and the associated benefits, they are discouraged by the cost and complexity of implementation. In a similar vein, participants know 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. This 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, and that 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).*

Thus, farmers' inability to obtain adequate amount of manure for their coffee plantations was another barrier identified. Interestingly, some participants said they learnt 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. While respondents were of the opinion that water is always available to them in their communities and easily accessible for irrigation purposes, they also 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) are cognizant of the health and safety risks associated with manual harvesting of 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 when 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 SAPs. 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 adopting SAPs, like erosion reduction, soil water retention and fertilisation, yet, as previously acknowledged by (Rodriguez et al., 2009), 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 fruits. 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 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 these barriers against the four stages of coffee farming as presented in figure 1. The taxonomy depicts that barriers to 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 barriers 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 manual harvesting of coffee, 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 believed these risks do not warrant investment in personal protective equipment. The issue is exacerbated by the dissenting action of labourers/farmworkers.

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 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 for individual smallholder farmers to 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, our evidence reveals that farmers coffee trees as firewood for cooking. 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, appropriate 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. This relates to adoption of drip irrigation, organic manure, and reusing wastewater from coffee mills for irrigation. The findings have 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.

Our findings have implications for the understanding of barriers to adoption of SAPs in other crops and other countries, beyond the context of coffee farming in Kenya. The main steps of coffee farming (e.g., plant nursery, planting, growing, and harvesting) are standard practices for other types of crops (such as cocoa, tea, rice) and transcend Africa. We argue that if a similar study is conducted in developed countries such as UK and USA, the details of findings would change, but structure formulation of the argument and solution would be similar. For example, our findings have shown that smallholder farmers in a developing country experience financial and behavioural barrier in adopting SAPs. The challenges that farmers go through in this country would affect their adoption of SAPs for other agricultural products, and similar issues can be observed in developed countries regarding the adoption of precision agricultural technologies (Barnes et al, 2019). Yet, scope or nature of such challenges will be different since social-cultural, environmental, political, economic situations in country is different from another country.

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 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 for 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 SAPs adoption barriers under a different small-scale agriculture model.

Existing evidence (Kumar et al., 2020; Antle, John and Bocar Diagana, 2003) suggests that incentives can be used to increase the adoption of SAPs. However, the current policy of the Kenya government still incentivises farmers to use NPK fertilisers to increase crop yields (Njeru, 2015). Yet, carbon emissions from using such fertilisers in farming, account for 94% of the total farm footprint (Maina, 2017). The government needs to formulate 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 use old 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. 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? How can the drivers and barriers to SAP adoption be differentiated across coffee values chains (such as production, processing, trade, roasting and marketing)? We feel these areas require 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 SAPs barriers and identify the barriers which influence or depend on other barriers. Researchers can adapt our proposed taxonomy for cross-country comparative analysis of SAP adoption barriers. It can also 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.

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Table 1: Sustainability issues related to key activities at different stages of coffee farming

Phases of coffee farming	*Associated practices/activities*	*Sustainability implications*
Nursery stage	- Coffee seeds are pre-germinated in shaded nursery beds, watered regularly before transplant to the farm field	- Unsustainable water uses due to regular irrigation to grow coffee seedlings
Planting stage	- Tree cutting, tillage, removal of stumps, ploughing, harrowing, contouring terraces, grass strips and cut-off drains - The subsoil is mixed with fertilisers to refill dog holes for planting	- Land preparation to pave way for coffee planting destroys natural habitats and biodiversity - Abandonment of terraces can lead to huge soil loss - Use of chemical fertilizers can pollute land and contaminate waterways
Growing stage	- Use of chemical substances to control weeds and pests: spraying herbicides/pesticides - Application of fertilizers - Regular watering is critical at this stage	- Fertilizer is the major source of carbon emissions from coffee farming - Use of chemicals can pollute land, contaminate waterways and cause adverse health effects for farmers - Excessive water consumption due to regular irrigation of growing plant
Harvesting stage	- Selective handpicking - a labour-intensive method of coffee harvesting -	- Poor working conditions for coffee pickers leading to injuries, diseases and irritation' - Coffee pickers' health is often endangered by the many chemicals used during growing and weeding - Respiratory problems attributable to pesticide exposure - Limited access to basic or affordable healthcare services

Source: developed from (Avelino et al. 2012; Harden 1996; Central Coffee Research Institute, 2008; Mugo et al, 2011; Magina et al, 2016; Sanz-Uribe et al., 2017Maina, 2017; Njeru, 2015; Potts et al., 2003; Craves, 2008; Carsan et al, 2013; Ibanez and Blackman, 2015; Lesschen et al, 2008; Vogel, 1988;Notter et al, 2007; International Labour Organization, 2004; Mureithi, 2008).

Table 2: Cost–benefit analysis of SAPs adoption

SAPs	Potential Benefits	Likely Costs
Crop rotation	- Improve soil texture (Brankatschk and Finkbeiner, 2015) - Tackle pests and weeds (Mazvimavi and Twomlow, 2009)	- Resources to buy legumes and cereals (Mazvimavi and Twomlow, 2009) - Time dedication (Brankatschk and Finkbeiner, 2015) - Access to or ownership of land (Alila and Atieno, 2006)
Growing cover crops	- Improve soil fertility (Licht, 2016) - Erosion control (Licht, 2016)	- Cost and uncertainty of benefits (Mwangi et al., 2015) - Lack of incentives (Nepal, 2010)
Biological pest control	- Cheaper pest control alternative (Mugo et al., 2011) - Material can be sourced locally (Mugo et al., 2011)	- Could be less effective (Sharifzadeh et al., 2018)
Reuse of coffee processing water	- Supplement other water sources (Hue et al., 2006) - Wastewater contains phosphorus and potassium to boost the organic nutrient contents of the soil	- Availability of sufficient wastewater (Water Resources Group, 2016).
Drip irrigation	- Can help reduce water use by (Water Resources Group, 2016) 50% - Can help increase crop yields by 55% (Chartzoulakis and Bertaki, 2015) - More efficient for avoiding water loss (Keller and Blienser, 1990)	- Costs of investing in drip irrigation technology (Water Resources Group, 2016; Chartzoulakis and Bertaki, 2015)
Organic manure	- Increase soil carbon to boost plant growth (Zingore et al., 2008) - Microbes thrive (Tripathi, et al., 2017) - Reduced soil erosion and runoff (Zingore et al., 2008)	- Relatively cheap more expensive that NKP (Han et al., 2016) - Time needed to produce compost (e.g. McCarthy and Schurmann, 2014) - Health risks i.e. skin rashes (e.g. Brandt and Mølgaard, 2001)
Protecting health and safety of workers in agriculture (e.g. Using personal protective kits, first-aid)	- Avoid hazards like skin burns, musculoskeletal injuries, insect bites and snakes attack (Kanyenze, 2004; Mureithi, 2008)	- Limited financial resources to acquire the required kits

Table 3: Linking SAPs with key stages of coffee farming

Phases	Sustainability Impacts	SAPs (to potentially address impact)							
		Crop rotation	Growing cover crops	Biological pest control	Reuse of coffee processing	Drip irrigation	Organic manure	Personal protective kits	First-aid kit in the farms
Nursery Stage	Watering of plants in the nursery →→Water scarcity challenge				x	x			
Planting Stage	Land preparation and soil tillage →→ Loss of biodiversity and soil degradation		x						
	Fertilizer application →→ contamination of waterways, land pollution and greenhouse gas emissions.	x					x	x	x
Growth Stage	Use of chemicals (herbicides) to control weeds →→ Land pollution, waterways contamination, human health risks		x					x	x
	Use of chemicals (pesticides) to control pests →→ Land pollution, waterways contamination, human health risks			x				x	x
	Fertilizer application →→ contamination of waterways, land pollution and greenhouse gas emissions.	x					x	x	x
	Water usage for irrigating growing coffee plants →→ Water scarcity challenge				x	x		x	x
Harvesting Stage	Manual harvesting of coffee/using hands to pick cherries→→ the risk of musculoskeletal injuries (i.e. strain injury, cuts)							x	x

Table 4. Barriers reported for SAPs adoption.

Barrier categories	Description of barriers (themes)	References
Internal		
• Rationality factors	- Lack of financial resources for adopting drip irrigation and biological pest control	McCarthy and Schurmann (2014); Drost (1996); Teklewold et al (2013); Presley (2014); Wreford et al (2017); Barrett et al (2001); Jouzi, et al (2017); Njeru (2015); (Ajzen, 1988)
	- Chemical fertilisers are cheaper than organic manure	
	- Lower yields in comparison to conventional farming systems	
	- Compost making is time consuming and hectic	
	- Lack of access or shortage of raw materials for making enough manure	

	- Perceived ineffectiveness of biological pest control - Perceived behavioural control (ease or difficulty of implementation)	
• Knowledge and skills	- Awareness of government support programmes for sustainable agriculture - Lack of awareness of sustainability impact of farming - Understanding the composting process - Lack of technical know-how to implement SAPs	Drost (1996); Presley (2014); Wreford et al (2017); Jouzi, et al (2017); Njoroge (2000); Mwangi et al., (2015)
• Attitude and behavioural factors	- Negative attitudes towards SAPs - Perception of risks relating to using conventional farming methods (subjective judgment) - Lack of understanding of the potential health & safety hazards associated with farming	Wreford et al (2017); Njeru (2015); Mureithi, (2008); Rodriguez et al., (2009); Nepal, 2010;
External		
• Institutional factors	- Rules guiding use and land ownership - Conflict with promoters of inorganic chemicals - Influence of cooperative associations - Inability to influence prices in the value chain	Rodriguez et al., (2009); Darnhofer et al. (2005); Pretty and Hine (2001); Khanna et al (1999); Antle and Diagana (2003); Arellanes and Lee (2003)
• Circumstantial factors	- Smallholders limited ability to influence their social and economic circumstances - Ease of getting wastewater from coffee processing plants for irrigation purpose	Tittonell and Giller (2013); Vermunt et al, 2019; Rapsomanikis (2015); Global Agricultural Information Network, (2016).
• Infrastructural factors	- Lack of transport links - Lack of electricity/power - Lack of communication networks	Pretty and Hine (2001); Khanna et al (1999); Rodriguez et al., (2009)

Table 5. Research participants

Interviewees	Roles	Age (years)	Experience (years)	Education level	Farm location	Other crops grown
Respondent 1	Farm-owner	41	14	Primary	Gichatha-ini village	Maze
Respondent 2	Farm-owner	53	20	Primary	Gichatha-ini village	Millet & vegetables
Respondent 3	Farm-owner	51	23	Primary	Gichatha-ini village	Millet & vegetables
Respondent 4	Farm-owner	44	25	Primary	Gichatha-ini village	Maze
Respondent 5	Farmer's wife	40	14	Primary	Gichatha-ini village	Maze
Respondent 6	Farmworker	60	35	Primary	Gichatha-ini village	Maze

Respondent 7	Farmer's wife	46	16	Primary	Gichatha-ini village	Sorghum
Respondent 8	Farm-owner	43	33	Primary	Gichatha-ini village	Vegetables
Respondent 9	Farmworker	49	18	Primary	Gichatha-ini village	Millet
Respondent 10	Farmworker	42	10	Primary	Gichatha-ini village	Maze & vegetables
Respondent 11	Farmer's wife	58	20	Primary	Gichatha-ini village	Maze
Respondent 12	Farm-owner	57	35	Secondary	Gichatha-ini village	Millet
Respondent 13	Farm-owner	45	34	Primary	Gichatha-ini village	Sorghum
Respondent 14	Farm-owner	40	22	Primary	Gichatha-ini village	Vegetables
Respondent 15	Farmer's wife	44	11	Primary	Githiru village	Maze & vegetables
Respondent 16	Farmworker	56	12	Secondary	Githiru village	Millet & vegetables
Respondent 17	Farmworker	60	13	Secondary	Githiru village	Sorghum
Respondent 18	Farm-owner	62	15	Secondary	Githiru village	Sorghum
Respondent 19	Farm-owner	43	20	Primary	Githiru village	Maze
Respondent 20	Farm-owner	41	10	Primary	Githiru village	Millet
Respondent 21	Farm-owner	41	17	Primary	Githiru village	Sorghum
Respondent 22	Farm-owner	54	15	Primary	Githiru village	Vegetables
Respondent 23	Farm-owner	52	11	Primary	Githiru village	Maze & vegetables
Respondent 24	Farmworker	55	12	Tertiary	Muringato, Othaya	Maze & vegetables
Respondent 25	Farmer's wife	50	14	Primary	Muringato, Othaya	Vegetables
Respondent 26	Farmworker	42	15	Primary	Muringato, Othaya	Vegetables
Respondent 27	Farm-owner	50	22	Primary	Muringato, Othaya	Maze
Respondent 28	Farm-owner	49	30	Tertiary	Muringato, Othaya	Millet & vegetables
Respondent 29	Farm-owner	43	31	Primary	Muringato, Othaya	Maze & vegetables
Respondent 30	Farmer's wife	47	18	Primary	Muringato, Othaya	Maze & vegetables
Respondent 31	Farm-owner	53	14	Primary	Tetu, town	Maze & vegetables
Respondent 32	Farm-owner	51	21	Primary	Tetu, town	Maze & vegetables

Table 6: Major barrier categories mentioned by smallholder coffee farmers, per type of SAPs.

Types of SAP	Barrier categories			
	INTERNAL BARRIER		EXTERNAL BARRIER	
	Rationality factors	*Attitude and behavioural factors*	*Institutional factors*	*Circumstantial factors*
CROP ROTATION			• The rules guiding land use and ownership hinders the adoption of crop rotation due to restrictions on type of crops that could be cultivated on leased farm	• Impracticality: disinclination for flexible cropping approaches due to farm size
GROWING COVER CROPS			• The rules guiding land use and ownership: farm community does not allow cover crops growing	
BIOLOGICAL PEST CONTROL	• Lack of finance: cost of implementing biological pest control as an alternative to pesticides. • Perceived ease or difficulty of implementation: lack of enthusiasm for biological pest control techniques is largely due to its time-consuming nature			

REUSE OF COFFEE PROCESSING WATER	• Perceived ease or difficulty of implementation: wastewater would be insufficient for all farmers using the processing plant			
DRIP IRRIGATION	• Lack of finance: to invest in drip irrigation facilities	• Insensitive attitude towards water scarcity: farmers are implicitly unmindful about water scarcity		• Impracticality: coffee processing plant are too far from farm locations
ORGANIC MANURE	• Shortage of raw materials to make sufficient compost manure. • Perceived ease or difficulty of implementation: compost making is laborious and time consuming			
PERSONAL PROTECTIVE KITS		• Risk perceptions: subjective judgement that farmers make about the severity of farm accidents		
FIRST-AID KIT IN THE FARMS		• Risk perceptions: subjective judgement that farmers make about the severity of farm accidents		

Figure 1: Taxonomy of barriers adoption of SAP

	SUSTAINABLE AGRICULTURAL PRACTICES							
STAGES OF COFFEE FARMING	Crop rotation	Growing cover crops	Biological pest control	Reuse of coffee processing water	Drip irrigation	Organic manure (compost)	Personal protective kits	First-aid kit in the farms
Nursery				$CirF_1$ RaF_3	RaF_1 AbF_1			
Planting						RaF_1		
Growing	InF_1 RaF_3	InF_1 $CirF_1$	RaF_1 RaF_3	$CirF_1$ RaF_3	RaF_1 AbF_1	RaF_2	AbF_2	AbF_2
Harvesting							AbF_2	AbF_2

FACTORS	BARRIERS
Rationality (RaF)	RaF_1 = Lack of finance
	RaF_2 = Shortage of raw materials
	RaF_3 = Perceived ease or difficulty of implementation
Attitude & Behavioural (AbF)	AbF_1 = Insensitive attitude towards water scarcity
	AbF_2 = Risk perceptions
Institutional (InF)	InF_1 = Land tenure system
Circumstantial (CirF)	$CirF_1$= Impracticality
	$CirF_2$= Social and economic circumstances