The Social Sustainability of Digital Information Services in Sub-Saharan Africa

– A Social Practice Perspective on Smallholder Farmers' Use of Mobile Phone-Enabled Services for Agricultural Development in Kenya

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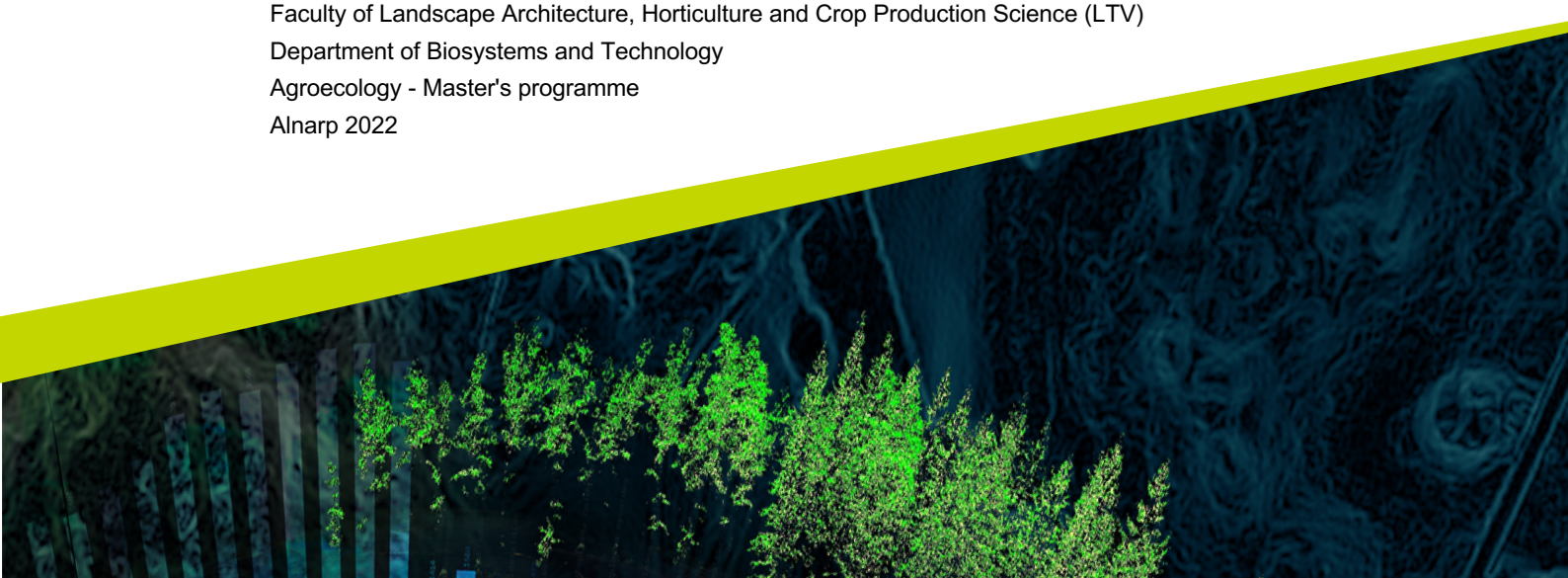

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Abstract

Nowadays, mobile phone-enabled services are reaching the rural poor farmer in Sub-Saharan Africa (SSA) with digital information for agricultural development. These digital services consist of access to social networks and customised information that are expected to enhance farm management due to knowledge exchange and learning. This thesis aimed to analyse the farmers' use of digital services and discuss its implications for social sustainability in agriculture by looking at how digital information merges, coexists or competes with other bodies of local knowledge. The analysis was based on participant observation with eleven farmers that use iShamba, a digital platform providing agricultural information services to smallholder farmers in rural Kenya. A social practice perspective implies that digital information must consider the contextual realities of farmers in terms of material, competence and meaning. Considering that access to inputs is constrained in the context of the study, this thesis suggests that digital services could contribute to social sustainability by promoting biological-based innovations that are locally applicable in terms of the materials available to farmers. Moreover, digital services could complement their service with field advisory visits or training courses, where the role of human intermediation appeared to be fundamental. Social sustainability in agriculture is that associated with the generation of knowledge and meaning that legitimises a particular model of agricultural development. This thesis found that digital services increase the diversity of knowledge by offering several options to farmers which contributes to social sustainability in agriculture. However, digital services do not encourage innovation, directing research toward attending to the demands of poor rural farmers but rather provide farmers with the available innovations. Additionally, a key point is the potential of digital services to co-construct the meaning associated with agricultural development. But since digital information integrates diverse trajectories of agricultural development, social sustainability requires that the institutional arrangement promote and support models of sustainable agriculture at the landscape level.

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Preface

As students of the master's program in agroecology, one of the introductory tasks was to define what agroecology means. As a group, we defined agroecology as *"a holistic response to global food webs in crisis. And which acknowledges that the interconnected social, economic, and environmental issues require an ecology-driven sustainable transformation of science, society, and practice to restore ecosystem resilience and food sovereignty."* This definition attempts to solve, among others, previous issues with scientific knowledge transfer by acknowledging the construction of agricultural knowledge and practices in the social context.

For me, responding to the crisis of global food webs was highly connected with the place where I grew up in northern Spain, Espinosa de los Monteros, and the autochthonous people that live there, the Pasiego. Espinosa locates in a rural, mountainous area with harsh climatic and orographic conditions, which has suffered an important depopulation in the last decades. Today, society moves towards new forms of social organisation leaving rural lifestyles behind. Until recently, the Pasiego has maintained an authentic and somehow archaic lifestyle, raising dairy cattle in a semi-nomadic way, which is perceived as not efficient today. The loss of the Pasiego represents not only the abandonment of culture, but also the loss of infrastructure, knowledge, and agroecosystem. Over the centuries, the Pasiego has shown an admirable capacity for survival, adapting its whole existence to the cow and its needs in harmony with the natural environment. Thus, the types of questions that have motivated my studies, like this thesis, are related to the roles of local knowledge as well as scientific knowledge in the co-construction of meaning associated with the sustainable development of agriculture.

One of the major challenges faced in the development of science and technology is the transmission of the type of discursive knowledge that has developed. Discursive knowledge is developed through language and expressed in the format of statements, arguments, rules, theories, norms, and propositions and is thus a sort of knowledge that proceeds by linguistic interaction rather than intuition. However, Bourdieu (1977, 1990) observed that practical knowledge and skill are socially inculcated in the form of *habitus*. Our understanding and consciousness of the world and ourselves are rooted in non-discursive forms of knowledge that are unconsciously adopted by the body in interaction with the physical environment (Archer 2000). Nonetheless, people integrate knowledge in their social practices,

resulting in diverse configurations of local and scientific knowledge, which becomes part of the *habitus* of participants. Knowledge processes are fundamental for the sustainable management of agroecosystems. Therefore, this thesis aims to study knowledge processes through digital information services for agricultural development in Africa and to reflect on their social sustainability.

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Abbreviations

BOP	Bottom of the Pyramid
CAN	Calcium Ammonium Nitrate
CBO	Community-Based Organisation
CTA	Technical Centre for Agricultural and Rural Cooperation ACP-EU
DAP	Diammonium Phosphate
KES	Kenyan shilling
ICT	Information and Communication Technology
LEDCs	Less Economically Developed Countries
MDCU	Meru Dairy Co-operative Union
MLP	Multi-Level Perspective
PHI	Preharvest Interval
Q&A	Questions and Answers
SDGs	Sustainable Development Goals of the United Nations
SMS	Short Message Service
SSA	Sub-Saharan Africa
WB	World Bank

1. Introduction

1.1. Problem statement

Farmers' performance is affected by their human capital[1], in terms of knowledge, skills, and health, being a decisive factor in improving farm management. Thereby technology augmenting human capital is at the core to increase efficiency in the economy (Deichmann et al. 2016:23), highly associated with the Information Age (Castells 1999). The Information Age is a new historical period of profound social transformations driven by the emergence of new Information and Communication Technology (ICT), which is characterised by the development of new productivity sources, new organisational forms, and a new global economy. ICTs include computers, mobile phones, the internet, and media platforms that facilitate the collection and utilisation of different sorts of data. In agriculture, this involves the monitoring of animals, soil, water, plants and humans, the prediction of future outcomes based on historical data and the enhancement of knowledge exchange and learning. ICT has continued to evolve with increasing attention on the use of mobile phone-enabled information services for agricultural development (Emeana et al. 2020). These services provide farmers with access to social networking platforms and customised information that are hoped to increase productivity, profitability, and sustainability. Rural farmers are thus engaged in processes of communication and information exchange through their mobile phones to generate contextualised agricultural knowledge. ICT is expected to enhance poor management due to the lack of knowledge, which much scientific research considers a key constraint affecting farm decisions in resource-poor contexts (Lysholm et al. 2020). In this thesis, it is investigated if one of these ICTs can be of support to smallholder farmers in a resource-poor context in Sub-Saharan Africa (SSA).

[1] The World Bank (2021) calls for investing in human capital as a central strategy to end extreme poverty by 2030 with the promotion of sustainable, inclusive growth across the Less Economically Developed Countries (LEDCs). The World Bank (WB) defines human capital as consisting of "the knowledge, skills, and health that people invest in and accumulate throughout their lives, enabling them to realise their potential as productive members of society." Therefore, one of the key aspects of not leaving anyone behind is to guarantee that everyone gets the appropriate skills and opportunities to participate in a more competitive global economy.

While science and technology are seen as fundamental to achieving most of the Sustainable Development Goals (SDGs), the benefits of dominant innovation processes do not generally reach the most disadvantaged and marginalised poor rural farmers[2] (Molina Maturano 2021). However, there is a growing interest in attending to the needs of the Bottom of the Pyramid (BOP), the poorest two-thirds of the economic human pyramid who are disproportionately resource-constrained and socially disadvantaged (Muthuri & Farhoud 2020). The World Resources Institute classified the African BOP in 2018 as including 486 million people in 22 surveyed counties, in which it represented 95% of the population. Technologies now emerge that are designed specifically to reach the BOP, often driven by wider aims of combining value generation for enterprises and inclusive growth, meeting the needs of poor and marginalised communities. These types of constraint-based and frugal innovations are, by definition, affordable, and accessible to the BOP socio-economic group (Molina Maturano 2021). Until now, the study of constraint-based and frugal innovations has mainly focused on the final product and business potential but overlooked adoption processes and user-centred approach (Agarwal et al. 2017). This calls for more attention to the user to avoid the same patterns of dominant innovation processes and generate site-specific agronomic knowledge that reflects the realities of local communities.

While ICT for agricultural development is often suggested to potentially contribute to adopting more sustainable practices, the dynamics of transition in which it is supposed to take part have hardly been studied (Klerkx et al. 2019:11). According to the Technical Centre for Agricultural and Rural Cooperation ACP-EU (CTA), whose headquarters is in Wageningen, Netherlands, "Africa needs a digitally-enabled agricultural transformation" (Tsan et al. 2019). However, the trajectories of such transformation are not very well defined yet. Bill Gates' vision is that digitalisation can improve communication, facilitating a "two-way conversation between Africa's producers and Africa's consumers," and extending formal markets to the point that informal institutions are not necessary (Gates 2018:93). Brooks (2021:382) denounces that this thought intends to accomplish the long-standing mission of reorienting traditional subsistence farming to commercial farming based on scientific research. However, there is no clear evidence of how ICT as a transformative force supports diverse models of agricultural development, including those of conventional agriculture or alternative models of sustainable agriculture, and how they tend to co-exist (Plumecocq et al. 2018).

[2] The World Bank (2003) defined the rural poor in five categories, one of which is "those with a low asset base, or smallholders (farmers with up to two hectares of cropland)." Including smallholders in the WB's renewed strategy acknowledged their qualities for rural development, describing at least four desirable traits: more labour intensive, community-based, more sustainable, and contextual poverty (World Bank 2003). Targeting smallholder farmers can thus contribute to several SDGs, including nº1 (No Poverty) and nº2 (Zero Hunger).

1.2. Focusing on the social dimension of sustainability in the study of ICT for agricultural development

The social dimension of sustainability in agriculture is still underrepresented in the scientific literature (Janker et al. 2019). Commonly, sustainable agriculture is examined in relation to the management of agroecosystems which leads to a contradiction between economic viability and natural resource conservation. Consequently, less attention has been paid to the social aspects in the management of agroecosystems. A farm is an agroecosystem that involves social, economic, and ecological elements, being its social dimension associated with the human activity of the system. This includes aspects such as the social health and well-being of farmers and farm workers; the production and reproduction of knowledge and skills, which is a fundamental prerequisite for changing agricultural practices (Röös et al. 2019:269); and the meaning and values that legitimise a particular model of agricultural production (Plumecocq et al. 2018). Hence social sustainability is associated with both the wider societal impact of the farm and the social impacts on those located at the farm or household level (Schader et al. 2014).

To define the social dimension of sustainability here, I draw on the sustainable livelihoods framework (Morse 2010:164). The sustainable livelihoods framework group the resources that households draw on in constructing agricultural livelihoods into five types of assets or capitals: (1) Natural capital (natural resource stocks and ecosystem services); (2) Social capital (networks, social relations, and norms); (3) Human capital (skills, knowledge, labour, and health); (4) Physical capital (infrastructures and technologies); And (5) financial capital (credit/debt). Using this framing, this thesis is concerned with the social and human capitals, as well as with the physical capital (in this thesis represented by a specific ICT). The thesis focuses on how a form of physical capital can impact social and human capitals and might facilitate sustainable transformations of agriculture.

1.3. The relationship between knowledge and practice in sustainable agriculture

While there is continued investment in technology and research that supports that investment (Walker et al. 2014), there is little understanding of the real impacts of technological change for smallholder farmers in SSA. Glover et al. (2016) argue that agricultural research in Africa uses a flawed concept of adoption, which consequently provides an inadequate picture to those making decisions to invest, or not. According to whom, it is a linear model of diffusion focused on individual decisions and experimental studies that disregard other fundamental aspects of

technological change. The reductionist tradition of science has focussed on analysing the behaviour of individual farmers while failing to contextualise these individuals in the larger social structures in which they live and act (Fischer et al. 2019). A large number of research studies aiming to provide advice on how to transform agriculture for sustainability focus on the need that farmers are educated so that they know how to farm sustainably. While education can be an important component in moving towards sustainable practices, these studies often fail to put knowledge in the social context and look at what the role of knowledge is in determining practice. In the terms of capitals, these studies focus only on the human capital but fail to conceptualise how the human is created in the social.

In contrast to this reductionist approach, this thesis understands knowledge and information as social constructs that exist as part of people's actions. Both of which are constituted and constitutive elements of social practices, as people act according to the available knowledge and generate new knowledge through social interaction and practice. One can say that certain information becomes knowledge when people can put it into practice. Thus, digital information obtained on the phone becomes part of the farmers' knowledge when they implement it in their farm activities. The existence of a practice is dictated by the physical and mental elements that enable or inhibit its performance, such as tangible physical things, technologies, skills and know-how, techniques, symbolic meanings, ideas, and motivations (Shove et al. 2012:14). This means that digital information requires a conjunction of established elements to be implemented in the farming system. In this conjunction, knowledge or information is just one element of the farmers' context. Hence, increasing the availability of information does not necessarily result in increased adoption of new management skills unless it is integrated into farmers' practices (Jones et al. 2016). The inability to merge with established practices explains why innovations often fail to accomplish their purpose (Kokko & Fischer 2021).

This introduction indicates that there is a need for further research on the elements that enable or inhibit a practice if we want to understand why farmers adopt digital information. In addition, access to digital information does not directly contribute to social sustainability in agriculture, but social sustainability depends on the processes in which farmers construct (produce and reproduce) knowledge. This thesis mainly takes into consideration the key concepts of social capital and human capital in the analysis, which are associated with the social dimension of sustainability. However, the analysis of the knowledge process from a social practice perspective implies that the analysis must include the other mental and physical elements of which social practices are composed.

1.4. Aim and research question

This thesis aims to analyse knowledge processes from a farmer-centred perspective, looking at aspects of social sustainability involved in social practices at the farm level and as a result of the farmers' use of digital information services. It contributes to existing literature on the topic by answering the following research question:

How do knowledge processes due to digital information services merge, coexist or compete with other types of knowledge among farmers?

1.5. Delimitations

It is relevant in this thesis to distinguish between farm owners and farm workers. On the farms studied in this thesis, some farmers work their farms alone, and some (comparatively wealthier) farmers hire farm workers to perform parts of the work, or during particularly labour intense periods of the year. The farm workers are commonly farmers with their own farming as well, but due to significant resource constraints, they need to combine their own farming with labouring on other farms to provide for their subsistence. Farm workers are thus the poorest and most marginalised farmers. This thesis does, due to time and resource constraints (e.g., lack of possibility for the translation needed as farm workers rarely spoke English) unfortunately not include farm workers' perspectives. This means that the findings do not reflect the most marginalised farmers and households and must be interpreted in the light of this.

1.6. Outline of thesis

After this introductory chapter follows the background chapter, which briefly introduces the field of innovation-diffusion research in agriculture. This second chapter conceptualises how the transfer (versus construction) of knowledge is understood in terms of sustainability, and throughout this thesis. The third chapter reviews the previous social science research on ICT for agricultural development. This review found that the meaning associated with the farmers' use of digital information services and how it supports diverse models of agricultural development is underrepresented in the literature. This thesis aims to fill such a research gap by answering the research question. Afterwards, the theory chapter enunciates the overarching framework of social practice theory with the key concepts of human capital and social capital and the multi-level perspective of sustainability transitions. Both theories complement each other in the analysis of

knowledge processes. To investigate the farmers' interpretations and adaptations of digital information to their local knowledge and everyday practices is used an ethnographic approach which defines the methodology chapter. This chapter also includes: first, a presentation of the location (Meru County) where the research is carried out (including the conditions for agriculture); second, a presentation of the case study, a digital information service (iShamba) operating in Kenya; and third, an overview of the participant farmers; as well as the methods of participant observation used to collect and analyse the data. Next, the results and discussion chapter is subdivided into two sections. The first section outlines the finding that results from analysing the uses of digital information through the theoretical framework. Such an analytical process has identified themes which divide this section. The second section discusses the implications of digital services for social sustainability in agriculture. To conclude, the last chapter summarises the findings and contributions to the literature, together with suggestions for further research, policy, and practice.

2. Background: From the transfer to the construction of knowledge as a discipline

Innovation can be understood as the development and application of technology, including new knowledge, materials, tools, and practices, that generate a beneficial change for society (Glover et al. 2016:4). There is extended literature on why innovations do not succeed in producing the intended change (Kokko & Fischer 2021). The field of innovation-diffusion research has always centred on the adoption of agricultural technologies (Rogers 2003:164). Rogers' adoption process is defined by the following stages: First, the farmer learns about the innovation and its functions (knowledge); Second, the farmer develops an attitude toward the innovation (persuasion); Third, the farmer evaluates the innovation and decides if to acquire it or not (decision); Fourth, the farmer puts the innovation into use (implementation); and fifth, the farmer evaluates the performance of the innovation (confirmation). These series of actions and choices represent the behaviour of individuals in assisting a new idea and in deciding whether to incorporate it into the previously existent practices (Rogers 2003:163). Moreover, innovation-diffusion has always been concerned with the social variables of adoption, such as education or social connectivity (Stone 2007:70–71). Thus, the adoption of knowledge involves understanding both the actions of farmers (their agency) and the wider social context in which these actions occur (the structures) (Fischer et al. 2019), which is the interest of social practice theory.

In the process of information diffusion, Röling and Engel (1990) argue that knowledge is internalised by the farmer and cannot be transferred; only information can be transferred. This partially explains the clashes and frictions between external standardised information that is not able to build upon the heterogeneous local bodies of knowledge and experience of farmers (Long 2001:39). Local knowledge is not only composed of implicit and tacit knowledge that the individual has cognitively developed, such as skills and know-how, but also the inter-subjectivities and shared understanding among people that are the product of a socio-cultural process and which are central for understanding the nature of knowledge (Leeuwis et al. 1990:20). Consequently, Röling and Engel's view of information diffusion still expects that information flow will adjust the farmers' knowledge and meaning,

and it implies a sort of objective realism that assumes that information and the real world are there while knowledge is a social construction. This thesis does not find it helpful to dichotomise information and knowledge; it rather considers both elements as part of a single interpretative process since the information must be internalised to acquire meaning, and by doing so, it becomes part of the bodies of knowledge (Leeuwis et al. 1990:20).

Moreover, this thesis studies knowledge as a dynamic element, which is embedded in a social process of continuous change. As part of the same social process, social agricultural practices, which are based on local knowledge, also change (Agrawal 1995). Stone (2004, 2007) argues that agricultural practices are bound to change according to the context in space and time. He explains, "each plot, each year, is an experiment, and practices may change in response to population density; market signals; the arrival of new crops, tools or neighbours; pests and diseases; government policies; and even ideas" (Stone 2004:127–128). This reflects that the farming system is an organic, biological entity that requires a certain level of experimentation and understanding to be managed in our self-interest. It is not a linear, mechanical process, and understanding it in such a way consequently creates many of the problems that characterise conventional farming today. The social sustainability of farming systems requires that local knowledge is maintained and applied in combination with modern scientific knowledge to facilitate and stimulate innovations (Altieri et al. 2015; Olsson 2019:203–204).

In development research, it has since long been recognised that for agricultural development interventions to be sustainable, the incorporation of local indigenous knowledge is key (Chambers 1979; Gliessman et al. 1981; Altieri 1987; Agrawal 1995). This literature suggests approaches that work jointly with western scientific knowledge and local bodies of knowledge. Similarly, the contemporary strands of agricultural science that take a more holistic approach emphasise that such approaches are needed to reverse the environmental problems caused by mainstream agricultural technologies, such as pest resistance to pesticides or soil depletion due to intensive farming. Francis et al. (2003) and de Molina (2013) argued that the reductionist tradition of agricultural science, in which each element of the agroecosystem is studied in isolation, is not able to solve the complex issues that farming presents today. Sustainability implies that agricultural research places farming and knowledge in its environmental and social contexts and centres the analysis on the interactions between the different elements of the agroecosystem, so that research becomes multi- or transdisciplinary.

3. Previous research: ICT for agricultural development

While there is substantial natural science research on the topic of digitalisation in agriculture, social science has recently become interested in investigating processes of technological change (Klerkx et al. 2019). Previous scientific research has focused on technical aspects to optimise the means of production; however, the emergence of more knowledge-intensive agricultural development paradigms is a topic that concerns the social sciences. Social science contributes to the study of both positive and negative effects that digitalisation might have on the sustainable development of agriculture, food systems and rural areas. Being cautious of the many promising studies about the contributions of digitalisation, Klerkx et al. (2019) point out the still existing uncertainties about the actual uses of ICT by farmers. Therefore, Klerkx et al. (2019) suggest that it is important to understand the emerging reconfigurations of practices and institutions to counteract the possible negative consequences of ICT on agricultural development.

Sociological and ethnographic approaches have focused on the provision of information and trust through ICT platforms. This field of research suggests that such factors may, in part, explain some of the disparate results observed in economics studies and why improved farmers' knowledge is not necessarily translated into higher yields or profits (Aker et al. 2016:36). However, while some studies have investigated aspects of trust, which are important to understand how users interpret and use information, hardly any have investigated behavioural factors that influence how farmers interpret, accept, and act upon digital information (Baumüller 2018:146). Additionally, Baumüller (2018) claims that most of the reviewed studies of ICT in farming rely on farmers' perceptions rather than more experimental studies, which according to whom, might lead to weak evidence of actual impacts. The limitations of asking farmers to evaluate the impact of using digital information services were noticed in Baumüller's (2015) study of M-Farm, a digital service that connects buyers and sellers and provides price information in Kenya. The study found that actual prices were almost always lower when compared with M-Farm prices, even though farmers reported that they usually received equally good or better prices. Baumüller (2018) also notices that

some issues such as spill-over effects of mobile phone use, leakage of information or isolating impacts where digital services offer multiple functions might be challenging to assess if experimental studies are not carefully applied. Contrary to Baumüller's proposal to apply well-designed experimental studies, this thesis takes on an ethnographic approach, as proposed by Long (2001), to grasp the cognitive psychology of farmers. The intention is to collect implicit and tacit types of knowledge such as skills, habits, rules, and norms, beyond the type of explicit knowledge that is generally extracted by verbal conversations.

Farming is a complex system that involves constant decision-making throughout the year, on which the farm productivity and profitability depend (Awuor et al. 2016:77). Farmers obtain agricultural knowledge from their own empirical experience and practice (which includes observation, imitation and trial and error), local social networks, agricultural extension services, and broadcast media, such as the radio (Aker et al. 2016:36). Awuor et al. (2016) argue that this system of local knowledge is often inadequate to make informed decisions due to limited quality information available to farmers, and high transaction costs and time delays. As a communication technology, ICT was initially expected to effect a change in individual behaviour leading to the empowerment of the marginalised poor communities (Heeks 1999). The study of innovation systems is interested in the coevolution between technology and broader social and institutional environments to facilitate agricultural innovation in complex systems (Eastwood et al. 2017). Agricultural innovation research is still dominated by the attitudes and practices of the main actors, with an emphasis on collaboration, trust, and culture in business and innovation (World Bank 2007). Processes of innovation require interaction among the main actors so that enhanced communication and knowledge flows lead to social and economic change (Hall et al. 2001). However, a common criticism of ICT-based projects is that they have failed to take a more participatory approach rather than the mere dissemination of information (Sulaiman V. et al. 2012:336).

Disease and meteorological information are generally critical requirements for farm management decisions that are hard to predict, creating significant uncertainty in farm management tasks. Historically, information on weather, soil health, diseases and pests, etc. has been provided to farmers through agricultural extension and advisory services. Agricultural extension is defined as a system that should provide farmers with access to knowledge, information, and technologies, encourage interaction with research and other institutions and assist them to develop their own technical, organisational and management skills and practices (Christoplos 2012:3; Brouwer 2019:260). In areas where agricultural extension and advisory services were non-existent, ICT is expected to exert preventive and palliative functions improving farmers' and other rural peoples' welfare. In the Less Economically Developed Countries (LEDCs), most farmers have no access to science-based

agricultural advisory services (Fabregas et al. 2019). Consequently, ICT can present an important advance in the provision of services, which can be easily integrated to exchange information between agricultural extension and advisory services and farmers (Anderson 2020).

Better information about agricultural practices, new tools or new seeds delivered through extension services remains one of the most common components of the World Bank's (WB) agricultural development projects (Deichmann et al. 2016:24). The potential of Big Data in agricultural research is the ability to predict pest outbreaks, livestock behaviour, or soils and weather by combining large amounts of data collected from various sources (Deichmann et al. 2016:28). Timely and precise information about farm management according to weather forecasting and other indicators such as soil health is expected to help farmers to raise on-farm productivity. For instance, agricultural productivity is currently at its lowest level in Kenya as in many parts of SSA in general (Awuor et al. 2016:80). There is thus a potential gap between actual yields and optimum yields that could be improved by implementing soil management strategies (On 2018:34). The WB states that raising agricultural productivity is a key driver for stimulating inclusive economic growth (Fuglie et al. 2020:4). Herein the collection of digital data through ICTs offers the possibility to differentiate between different soil conditions and deliver different messages accordingly. Although there might be several methods to solve a certain issue (e.g., agricultural lime or fertilisers) and it would depend on how the tool is designed that would, or would not, promote a particular solution.

Often, the solution that both public and private extension agents propose to alleviate the problems of poor farmers is to modernise their subsistence agriculture systems by transferring the latest science-based technologies (Awuor et al. 2016; Anderson 2020:2). The advice to modernise farming systems aims to reduce the technology and the management gaps, among those who have access to science and those who have not, by transferring information that helps farmers in resource-poor contexts to improve their agricultural practices. It blames traditional technologies and practices for generating poverty and the fact that the latest technologies, such as improved seed varieties, nutrient management, and pest control methods, are not reaching many of those farmers in poor regions (Deichmann et al. 2016:26). Here extension has the function to bridge theory and practice by articulating agricultural research that solves the problems and constraints faced by farmers (Anderson 2020:2). This involves that the new technology accounts for the socioeconomic and agroecological circumstances of farmers. In this context, the transfer of technology requires that, for example, diagnosing diseases or plant deficiencies through digital photography consider the farmers' access to inputs, which many times is not the case (Sulaiman V. et al. 2012:339). The same goes for the provision of farmers with market price information. When market price information has helped farmers to

reduce transaction costs related to information asymmetries in the value chain (De Silva & Ratnadiwakara 2008), other constraints faced by farmers such as access to credits and infrastructure have been overestimated (Sulaiman V. et al. 2012:339).

It is widely acknowledged that digital services cannot entirely replace field advisory visits, but they can still pose a positive impact on farm management and practices (Deichmann et al. 2016:27). The dissemination of information through ICTs allows for both virtual participatory approaches and increased scope capacity reaching a larger number of farmers than through field advisory visits. Participatory approaches through digital devices allow extension agents to interact with farmers and to better understand their context to provide more accurate solutions for their needs. ICT implementations might provide more cost-effective extension services, although they must consider the institutional environment and constraints in which the technology is deployed (Deichmann et al. 2016:31) to avoid making the same mistakes as traditional extension. When ICTs might provide more accurate solutions in LEDCs with small-scale farm structures, poor public infrastructure, and insufficient human capital investments by providing relevant advice and services, it is not enough to guarantee access to information for the most marginalised poor farmers. Farmers must also know how to effectively use the technology, and they must believe that it is beneficial to them (Deichmann et al. 2016:27).

The study of Sulaiman V. et al. (2012) critiques that ICTs, when necessary to put new knowledge from research and elsewhere into use, do not bring innovation. They argue that much of the ICTs, including the radio, TV, media, etc., support traditional lines of knowledge diffusion such as information dissemination and training. These ICTs consist of one-way transmission of generic information disseminated in a top-down approach. In agricultural development, this represents call centres or SMS services that offer farmers advice on cultivation practices of crops, weather updates, prices of outputs in major markets, etc. One-way transmission implies that information is not customised. The development of customised information has cost implications which divert the attention so that most ICT-based projects focus on connectivity. Consequently, the generation of locally relevant content, such as the management, value addition and marketing of the available resources in resource-poor contexts, gets little attention and support. Sulaiman V. et al. (2012:340) point out that the only ICTs that generate content in consultation with local communities are community radio and participatory video, which have helped to create great awareness of issues and solutions. Thus, when ICTs have improved communication and networking among researchers, they have not been able to direct research and technical support to solve the farmers' demands. Accordingly, a meaningful contribution to innovation management requires a radical rethinking of agricultural and rural development approaches.

Furthermore, efforts to include poor farmers in market-led agricultural development might detach farmers from traditional relations of informality and mutuality while being digitised throughout their mobile phones. Farm management decisions are increasingly automated, thus social and cultural functions of farming practices are being delegated to the cyber brain. Brooks (2021) denounces that this view of making markets work for the poor also means making more effective market subjects. The digital farmer can be seen as a "cyborg," which is both still "human" to continue farming and "non-human" to function as a reliable market subject. These initiatives follow the logic of the 'long' Green Revolution (Patel 2013), whose narrow conceptualization of agricultural technology has eroded the more holistic foundations of farming based on social practices of continual experimentation and innovation (Brooks 2021:390). It is also urgent a deeper understanding of the functions that can or cannot be done by machines, which level is optimum to automate farm management and when it undermines the integrity and wellbeing of farmers (Deichmann et al. 2016:31).

Although some scholars have expressed concern about issues with digitalisation in agriculture, there has been limited attention to the issue of value derived from the use of digital information (Lioutas et al. 2019). A value-oriented approach includes the value co-created beyond the digital services, entailing farmers' interpretations, appropriations, and adaptations of digital information to their local knowledge and everyday practices for their personal, best-suited interests. This calls for research and analysis at the micro-level of what value means for farmers and other community members and how access to such values is affected by transition dynamics. Examining the micro-level requires an increasing emphasis on management skills and knowledge of farming practices concerning emerging values of what it means to be a digital farmer (Jakku et al. 2019).

4. Theoretical framework and key concepts

In this thesis, social practice theory is used as the overarching framework to analyse how farmers' knowledge processes due to digital information services merge, coexist or compete with other types of knowledge among farmers. The thesis draws on the definition of social practices as an entity or as a performance, which allows for the configuration of diverse compositions of material, competence and meaning that enact and reproduce practices (Shove et al. 2012). This theoretical framework aims to analyse the interpretations of knowledge processes as part of the practices of farmers. It focuses on the everyday life of farmers in which the farmers' adoption of knowledge is contextualised, which reflects both the agency of farmers and the larger social structures. As chapter 2 introduced, the use of knowledge depends on both the agency of individuals and the larger social structure, which fits perfectly under the framework of social practice theory.

Social practice theory is complemented with the multi-level perspective (MLP) of sustainability transitions and the key concepts of human and social capital. The MLP allows for the disaggregation of social structures into three levels which refer to different social processes and degrees of stability (Geels 2010). These different levels represent either the farm where the farmers experiment and innovate or the organisational and institutional structures affecting the farmers' systems that are uncovered by social practice theory. Both social practice and sustainability transitions theories offer an analytical framework to understand social change and processes of transformation (Shove et al. 2012; Hinrichs 2014:146), such as the digitalisation of African agriculture. However, both complement one another, as the MLP offers a vertical approach and social practice theory a horizontal approach in the analysis of innovations and knowledge processes for the sustainable development of smallholder farmers.

The key concepts of human capital and social capital are used throughout this thesis as analytical tools. Both concepts have gained large attention from research scholars in the fields of economics, sociology, behavioural science, and organisational theory among others. This attention is due to increasing awareness of the crucial role that human resources play in the performance of any entity, such as a firm, a nation, or the economy. Consequently, aspects that depend on human

resources, such as knowledge, innovation, and learning have become the focal point of today's knowledge economy (Sharma 2014:114). Following the definition of economic capital as a resource which is invested to earn a profit, human capital would be an investment in individual knowledge and skills and social capital would be an investment in social networks and values, both with the intention of obtaining benefits in the long run (Sharma 2014:113). Thus, the major distinction between them is that human capital is associated with the agency of individuals while social capital is associated with the social relations and networks among individuals (Schuller 2001:14). Sharma (2014) found synergies between human and social capitals to enhance individual and collective performance at the organisational and societal levels, however, she observed that investing in social capital, while strengthening human capital, limits individual performance. Hence, an interesting research angle would be to look at human capital as an outcome of social relations, as this study does by analysing individual farmers' use of knowledge due to the connectivity to a social network of digital information services.

4.1. Social practice theory and sub-concepts

Social practice theory is a type of cultural theory that explores how social structures and individual agency interact. After the "interpretative turn" of the 1970s, cultural theory has become a conceptual alternative to classical modern social theory and its theories of human behaviour: *homo economicus* and *homo sociologicus.* Cultural theory differs from both *homo economicus* and *homo sociologicus* in its explanation of human actions and social order (Reckwitz 2002:243). *Homo economicus* gives interpretative prerogative to individual self-interest in explaining human behaviour. The analysis is thus focused on the independent actions of individuals. *Homo sociologicus* explains action by looking at collective norms and values, and the focus of analysis is thereby put on normative structures. These two conceptually contradictory camps have historically divided the field of social action theory, which cultural theory aims to transcend with an ontological turn. When this new type of social ontology is perceived as breaking with previous classical theories of action, it can also be seen as mediating a reconciliation since it integrates both the agency of single individuals and the structures of normative rules and expectations into the same theory. Giddens' theory of "structuration" understands agency and structures as complementary concepts, two forces of the same social phenomena, that Giddens (1979) termed the "duality of structure." Giddens (1984) explains that human activity is shaped and enabled by social structures of rules and meaning, which are simultaneously reproduced in relation to human action. Accordingly, human action is constituted, rather than by discursive consciousness, by capabilities and practical knowledge embedded in the social order of routinised daily life.

Social practice theories share a common understanding of social phenomena with other cultural theories; however, they differ in where they locate the social (Shove et al. 2012:8–9). What is unprecedented in practice theory is the novel explanation of the social and human agency by focusing the analysis on the context, the "site," in which social life and actions transpire (Schatzki 2005). Social practice theory is thereby characterised by placing the social in practices (Reckwitz 2002). By doing so, social practice theory explores the interconnectedness of physical and mental elements embedded in a complex of doing. For Reckwitz (2002:249), a practice is a pattern or systematic behaviour which consists of several interconnected elements, including forms of both bodily and mental activities, "things" and their use, background knowledge and skills, and states of emotion and motivation. In this definition, practices are carried out by agents who are neither autonomous nor mere puppets who conform to norms, they rather act according to their understanding of the world and their place in it.

Following Reckwitz's definition of practice, Shove et al. (2012) developed a theoretical framework to understand social change and processes of transformation. Reckwitz (2002:250) defines practice as a "block" of specific interconnected elements, each of which is essential for the existence of the practice. This conjunction of elements can be analysed as *entity* and *performance* at the same time; "It is only through successive moments of performance that the interdependencies between elements which constitute the practice as entity are sustained over time" (Shove et al. 2012:7). In this analysis, individuals are understood as the carriers of a practice. This means that understanding, know-how, meanings, and purposes are not taken as attributes of individuals, but as "elements and qualities of a practice in which the single individual participates" (Reckwitz 2002:250). This analysis of practices either as entity or as performance allows us for the configuration of diverse elements that are enacted and reproduced (Shove et al. 2012:11). Shove et al. (2012:14) have simplified the conjunction of elements into three broad categories: (1) *materials*: things, technologies, tangible physical entities and the stuff of which objects are made; (2) *competences*: skills, know-how and techniques; and (3) *meanings*: symbolic meanings, ideas and aspirations. Interpreting the evolution of these three elements in conjunction, if the connection between the three is made, sustained or broken, provides a useful account to study if practices emerge, persist, shift, or disappear (Shove et al. 2012:14–15). This simplified framework helps us to focus on the occurrence of stability and change while recognising the recursive relation between practice-as-performance and practice-as-entity.

Practices are always context-dependent, in that they require a sequence of physical and mental elements that generate the site through which they occur (Jaffe 2017:395). The physical context determines farming practices in that the farmer needs to have land and material equipment in addition to skills and knowledge to

be able to produce crops. Besides advice and financial support, it might be that he or she also needs some sort of machinery or labour force at certain times from the community. It might also be that, depending on the type of farming, the farmer needs to acquire new seeds, synthetic fertilisers and/or chemical pesticides. As elements of a practice, science and technology are not objective, neutral, or value-free, they favour certain outcomes or practices and not others. Schatzki et al. (2001:3) argue that a certain practice depends on physical elements that are configured and apprehended in a particular way. When agricultural technologies are designed to assist farmers in improving their farming systems, such as those of pest management and seed production, they can potentially erode the knowledge and skills of farmers (Stone 2004:132). For example, the studies of Bentley (1991, 1992) about pest management in Honduras have shown that "the less the farmer knows about insect ecology, the more insecticide is used." It is important to take into consideration this interdependence among the knowledge and skills of farmers and the farming techniques and practices employed by them when working with ICT, since the ICT format probably leads to easy-to-communicate-information.

Practices are engendered in a path of dependency that constructs the availability of knowledge and the possibilities of what makes sense in a particular context (Jaffe 2017:395). Much of our capacity to construct the world around us depends on practical or tacit knowledge. It is through interaction in everyday life practicing and experiencing that know-how and skills are naturally rooted and acquired, in opposition to "knowing something" kind of discursive knowledge. Thus, farming skills differ from agronomic knowledge in being more experimental and implicit; and they are many times embedded in social institutions shared by a whole community, such as, for example, cultural pest control and irrigation management, that individual farmers might not fully understand (Stone 2004:130). Such complexity inhabited in knowledge processes is acknowledged by social practice theory, which contributes with an analytical framework to identify different forms of knowledge, and how they emerge, evolve and associate over time (Jaffe 2017:396). Knowledge is differently embodied by people, resulting in diverse conjunctions of elements. In *learning* processes, scientific knowledge is merged with diverse bodies of local knowledge. This way, knowledge is seen as consisting of multiple "overlapping skill sets" that are mutually intertwined (Jaffe 2017:396). Here the acquisition of one skill set can support the acquisition of others, and the loss of one set of skills can similarly undermine the maintenance of another.

While discursive communication allows for the creation of meaning and knowledge detached from context and experience, language exists in connection to everyday practice in which participants ascribe meaning to objects in relation to a routinised use (Jaffe 2017:396). This explains processes of local knowledge co-generation in connection with the farming system. For instance, the abandonment of certain

practices and the side-effect loss of culture and languages is interconnected with biodiversity loss, in such a way that elements of biological matter become obsolete and disappear due to the erosion of local knowledge. There is thus a profound interrelation between biological diversity and cultural and linguistic diversity associated with agroecological practices that are fundamental for the maintenance of agroecosystems. This interrelation is described by the concept of biocultural *diversity*, which refers to the wisdom in biodiversity conservation that is embedded in the knowledge, practices, and beliefs of local communities. Thereby the importance of supporting local communities to maintain their native tongues and traditional livelihoods based on local natural resources (Wilder et al. 2016). This indicates the interrelation among social and environmental sustainability in farming systems, being crucial the maintenance of diverse bodies of local knowledge embedded in traditional farming for the conservation of biological diversity.

In Kenya, Muthee et al. (2019) defined several forms of indigenous knowledge that are applicable to enhance agricultural production. First, agroforestry practices such as plating rows of nitrogen-fixing trees and planting trees along the hillside to control soil erosion. These practices can enhance soil fertility, ensure water retention, and encourage climate-smart agriculture through the planting of drought-resistant trees that subsequently produce fruits, firewood, or timber. Second, polyculture systems of production such as crop rotation and intercropping, especially nitrogen-fixing legumes. Third, integrating livestock into the farming system, so manure can be applied in the field to increase yields, and fodder crops and other green residues can be used to feed the animals. These practices have shown to be beneficial in comparison to conventional agriculture for the management and conservation of natural resources in Kenya, also considering that they are applicable in modern farming practices (Muthee et al. 2019:25). Additionally, traditional mixed farming practices that integrates different crop and livestock species have shown to have multiple benefits, including the reduced incidence of diseases and pests, stabilize yields, and enhance resilience to shocks and stresses, e.g., the market (Pimbert 2018:13). This again indicates the interconnections between cultural and biological diversity and the social, economic, and environmental sustainability dimensions of the farming system. These interconnections reaffirm the position of Missimer et al. (2017a:34) who argue that social sustainability issues are inextricably interlinked with other aspects of sustainability and planning a transition towards social sustainability would intrinsically lead to ecological sustainability. However, this thesis suggests that there is a need for better understanding of when and how diverse knowledge impact the different dimensions of sustainability.

To put knowledge in the social context and prevent the failures of previous agricultural research, this thesis uses social practice theory together with the key

concept of social capital. Most authors define social capital in terms of networks, trust, and norms that allow agents and institutions to achieve common goals (Schuller 2001:4). These definitions assume a certain level of vulnerability as individuals decide to take the risk of trusting in social networks, especially in the absence of a long history of reciprocity. However, Bews & Martins (2002:14) distinguished between two stages. The first stage in which trust is pre-conditioned, and the second in which it depends on the individual's perception of trustworthiness. Therein interpersonal *trust* necessitates trustworthiness, which involves an emotional component that cannot be controlled but must be earned (Missimer et al. 2017b:46). Mayer et al. (1995) define trustworthiness in three components: (1) Competence, that is the knowledge and skills that enable the perception of trustworthiness in a network; (2) Meaning, that is the belief and motivation in the benevolence of a network; and (3) integrity, that is the consistency with the values inherent in a network. Thus, trust in networks can be understood in the light of this.

At the societal level, Rothstein (2005) defined social capital as a matter of networks and trust, in which the quantity of connections (networks) and the quality of connections (trust) determine the social capital. He comes to say that institutional trust is the main variable in social capital, and its erosion can consequently cause the dysfunction of the social system. Governmental institutions are responsible to design the rules and incentives that govern individual behaviour, and therefore trust-generation within society depends on their effectiveness (meaning competence at achieving common goals) and impartiality in policymaking (Rothstein 2005). Hence trustworthy institutions imply the aspect of competence mentioned by Mayer et al. (1995) before and add the aspect of impartiality. As a design principle, impartiality is an important way to reduce high levels of inequality (Missimer et al. 2017b:47), which, in correlation with trust, shows to be higher in more equal societies (Wilkinson & Pickett 2009).

It is also acknowledged that common culture and meaning play a key role in the creation of social capital (Missimer et al. 2017a:37). Common meaning is used in sociology, anthropology, and other social sciences disciplines (Kurzman 2008). For example, Giddens (1984) speaks of structures of signification, that is the common meaning that individuals use to make sense of their cultural context and experience. As defined by Mayer et al. (1995), trust in digital information is a dynamic concept that includes the farmers' perception of digital services in terms of competence, meaning and integrity. Consequently, social capital does not necessarily come by hand with trust as suggested by Rothstein (2005), but trust and common meaning are intrinsically interrelated concepts. This means that trust in digital information is necessarily constructed in relation to other elements of the social context. On the one side, common meaning that is defined by the values and norms that are socially

accepted in such a context. On the other side, integrity that is defined by the level of individual members' satisfaction to comply with the shared values and norms. *Common meaning* is thus expected to condition farmers' behaviour, including the models and techniques of agricultural production that they employ as well as the use that they make of digital information services. Changing agricultural practices involves understating the common meaning within a group, such as, for example, conservatism and conformity that, as argued by van Rijn et al. (2012:113), impedes the emergence of innovation and new ideas that might benefit the wider society.

To summarise, the practices of farmers are composed of physical and mental elements. This theoretical framework represents the physical by material element and the mental by competence and meaning elements associated with practices. To make a clear distinction and draw the line between the three, *material* represents the physical environment, including the farm and the technologies and objects in it, *competence* represents the practical knowledge and skills embodied by farmers, and *meaning* represents the farmers' rationalities and motivations associated with practices. Social practice theory is used to analyse knowledge processes and the adoption of digital information in the management skill sets of farmers. Here digital information can merge, coexist, or compete with already established knowledge and skills. Processes of both learning and adopting digital information depend on the farmers' meanings and perceptions of digital information. This thesis uses the sub-concepts of *learning, diversity, trust*, and *common meaning* that fell into the categories of human capital and social capital; being learning and diversity aspects of *human capital*, and trust and common meaning aspects of *social capital*. These concepts are used to elaborate further on the theoretical elements of competence and meaning, as learning and diversity are associated with *competence* and trust and common meaning with *meaning*.

4.2. The multi-level perspective on sustainability transitions

The notion of a transition management approach appears for the first time in the 1987 Brundtland report as a companion framing to "sustainable development." It arose in response to the increasingly more obvious environmental issues due to current models of global economic development, which required a transition to new systems of production, consumption, and governance (Brundtland 1987). Markard et al. (2012:956) defined sustainability transitions as "long-term, multi-dimensional and fundamental transformation processes through which established socio-technical systems shift to more sustainable modes of production and consumption." Importantly, sustainability transitions research builds on previous studies of socio-

technical transitions with consequences for social change and development (Hinrichs 2014:146). Such as those of technology and innovation studies that have sought to understand the dynamic of broad systems, examining the diverse patterns of change in the co-evolution of technologies, knowledge, and institutions.

The *Multi-Level Perspective (MLP)* is an analytical framework to study socio-technical transitions to sustainability that draws on visualising the complexity and the dynamic of different levels of interaction and change in socio-technical regimes (Geels 2010). An MLP defines transitions as socio-technical regime shifts that stem from the evolutionary process of interactions and change at three different levels: niches, regimes, and landscapes. These three levels refer to different social processes, each governed by structures composed of different degrees of stability. First, socio-technical regimes are characterised by more rigid, interlocking and path-dependent structures. Innovations that take place at this level tend to follow the mainstream, general trajectory of the regime and complying with the existing structures. Second, niches are emergent activities taking place in the everyday life context where innovative technologies and practices are developed, tested, and adjusted. The type of innovation that prompts in niches is more radical and might challenge the existing regimens (Rip & Kemp 1998). Third, the structural landscape refers to the exogenous development policy paradigm and institutional arrangements that affect the activity at both the regime and the niche level. Adequate development policies and institutions can promote the emergence of business incubators and niches of opportunity for change and sustainability. For instance, private initiatives in collaboration with public governments and international agents might work for sustainability by providing protective space in several ways. First, they might *shield* innovation from initial competition in the presence of structural disadvantages; second, they might *nurture* innovation by enhancing capacity building, learning processes and productive networks; and third, they might *empower* innovation to occupy the mainstream regimens through the promotion of recruitment and scaling up (Hinrichs 2014:147). Thus, transitions come about through processes of interaction within and between these three MLPs.

Contesting and completing the MLP, Plumecocq et al. (2018) argue that different systems of social values coexist in models of sustainable agriculture, and, thus, multiple sustainability transitions of agriculture are possible, depending on the coevolution of values that legitimise these models. According to them, it is crucial to understand in depth the variety of farmers' motivations for choosing a particular pathway. First, they have identified two variables in which diverse models of agricultural production can be categorised. The first variable is the dependence of the farming systems, being the one extreme dependence on external inputs and the other one dependence on ecosystem services. The second variable is the level of territorial embeddedness, being the one extreme globalised commodity-based food

systems and the other one local food systems. Second, they have categorised three main models of agricultural production with their correspondent subdivisions, which represent different compositions within the two variables (see Figure 1).

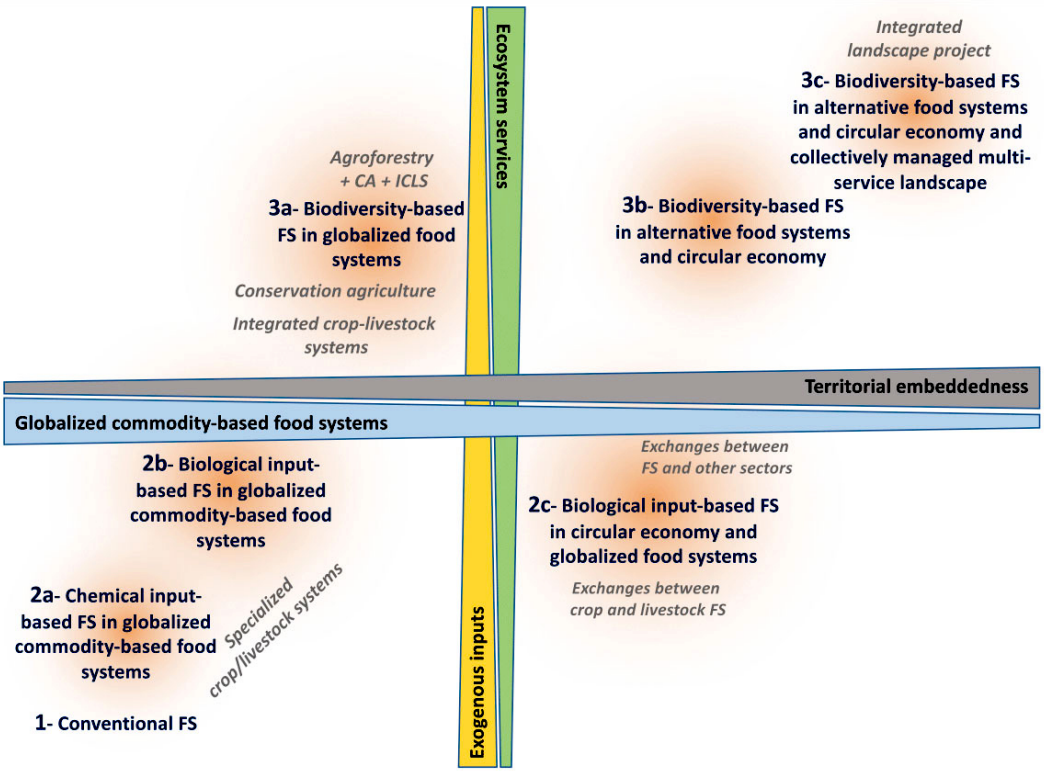


Figure 1. Main models of agriculture (Plumecocq et al. 2018). The first model is conventional farming (1) which is highly dependent on external inputs and based on globalised commodity food systems. The second model is input-based farming systems which are subdivided into: (2a) Chemical input-based farming systems in globalised commodity-based food systems; (2b) Biological input-based farming systems in globalised commodity-based food systems; And (2c) biological input-based farming systems in circular economy and globalised food systems. Models 2a and 2b represent specialised crop/livestock systems, while 2c represents exchanges between crop and livestock farming systems as well as exchanges between farming systems and other sectors. And the third model is biodiversity-based farming systems which are subdivided into: (3a) Biodiversity-based farming systems in globalised food systems; (3b) Biodiversity-based farming systems in alternative food systems and circular economy; And (3c) biodiversity-based farming systems in alternative food systems and circular economy and collectively managed multi-services landscape. Farming systems such as agroforestry, conservation agriculture or mixed farming fall under category 3a or 3b, while only integrated landscape projects fall under category 3c.

Plumecocq et al. (2018) conclude that the possibility of hybridization between models questions and complements the theory of socio-technical transition defined by Geels and Schot (2007). Rather than radical innovation challenging the dominant socio-technical regime, they identified new models of sustainable agriculture emerging within the dominant regime, based on a principle of legitimacy that differs from the dominant regime. This opens space for several trajectories within the dominant regime that represents the complex dynamics of conflicts and

negotiations between the multiplicity of meaning and values in agricultural development, as described by Long and Long (1992).

The MLP has been criticised for taking a more deterministic view of human activity because of vertical analyses that, for example, focus on how states and markers enable or prevent innovations for sustainability, and locate technological change at the centre of analysis. These types of vertical analyses might overestimate the role of human agency in influencing social formations and organisational change (Shove & Walker 2007). Social practice theory aims to cover this angle by analysing the organisation of social life from a more horizontal perspective. Understanding organisational change passes by analysing the elements and patterns that construct the everyday life of people where practices are routinised (Hinrichs 2014:149). Sustainability requires the embodiment of practices that make sense and that are confirmed by the socio-cultural context for a long time (Schatzki 2002). Hence, focusing on practices instead of socio-technical systems acknowledges that organisational change is a social phenomenon of "shared behavioural routines," instead of individual choices (Spaargaren 2011:815). However, keeping in mind that the everyday life context and the broader macro-structures and the socio-technical regimens are inherently interrelated, sustainability transitions research increasingly acknowledges the cross-connections between vertical and horizontal focuses of analyses, such as the MLP and social practice theory (Hinrichs 2014:150; Kokko & Fischer 2021:1).

5. Methodology

5.1. Epistemological and ontological positions

This thesis is part of a learning process in which the student is involved, and it might err on a vague understanding of the vast biological processes taking place in the farming system. Nevertheless, this thesis is concerned with the question of why farmers consider something good, rather than if something is good for them. This epistemological position that aims to understand how farmers make sense of the world around them focuses on the interpretive type of knowledge. Here the researcher has the responsibility and double stance of interpreting the farmers' rationalities and interpretation of the world around them. Although there is a third level of interpretation since the researcher places the interpretations into a social scientific framework. The researcher is thus providing an interpretation of others' interpretations, while further interpreting the researcher's interpretations in terms of the concepts, theories, and literature of a discipline (Bryman 2012:31).

The organisational framework that conducts this thesis is social practice theory. It focuses on analysing the context in which knowledge takes place and is transformed into the farmers' agency and capacity to act. Understanding such context requires studying the meaning and perceptions of farmers about their transformative capacities. And it implies an ontological position that considers information and knowledge socially constructed as part of the same interpretative process. Consequently, the nature of knowledge consists of implicit and tacit knowledge internalised by the individual in the form of human capital and intuition and by the group in the form of social capital and inter-subjective behaviour.

5.2. Research strategy and design

The analysis of social practices as well as the interpretations of its participants are often investigated by qualitative methods, consisting of in-depth interviews and participant observation that offer more detailed information about the study and its

participants. Qualitative methods are typically associated with an inductive approach to the role of theory in relation to research (Bryman 2012:37). So, the research attempts to generate theories from empirical knowledge, while using the literature review as a starting theoretical point. However, in grounded theory is particularly evident that induction entails elements of deduction, as the researcher might want to go back and forth from the analysis to the data to establish the conditions in which a theory is held or not (Charmaz & Mitchell 2001; Bryman 2012:26–27). These more theoretically grounded methods of social research engage with understanding the rationalities and interpretations of participants that give meaning to their actions. This thesis includes elements of both inductive and deductive research. Inductive research is found in that it aims at collecting empirical data that represents the farmers' perspective and is used to formulate the research question(s) together with the literature and theory. Deductive research is found in that the researcher did come back to the field during the analysis to test the findings.

This type of qualitative research that attempts to understand human behaviour in a particular social context is best suited to case study research (Bryman 2012:12). A case study entails the analysis of the complexity of a case (Stake 1995) that may be just one or two units of analysis selected according to criteria relevant to the research. This thesis is based on a single, convenience case due to the conditions under which the student is assisted by a private company to have access to farmers in a limited time. Some of the most typical examples of single case study research tie to a location: a community or an organisation (Bryman 2012:67), as is the case of this research. This research uses as a case study a group of smallholder farmers in Meru County (in Kenya) who uses iShamba digital services to obtain or exchange knowledge about agricultural-related practices. iShamba is a mobile-based farmer information service and call centre that helps farmers in Kenya to improve their farming practices and management with the objective of getting better yields and becoming a profitable business (https://ishamba.com/).

This thesis consisted of a time plan of six months; one month for planning the fieldwork, two months for conducting the fieldwork, and three months for analysing the data with the possibility of coming back to the field. For planning the fieldwork, the first step was delimiting the case study. The area of the study is Meru Country where smallholder farmers are reached with the help of iShamba. The criterion of selection was to assess areas with a diversity of agro-climatic zones, also expecting to find diverse conditions of farmers. This thesis is driven by the quality of information rather than the quantity of information, therefore, there were not a preselected number of farmers to be visited. iShamba helped the student to access farmers subscribed to the digital services. iShamba offers a premium- and a free-subscription service for smallholder farmers. First, subscribed farmers were sent an SMS asking if they would be interested in participating in the research. The farmers

who responded were contacted by phone call to inform them further about the research and confirm their participation. Additionally, we (iShamba and I) decided to write the same SMS in the Meru County WhatsApp group to get farmers subscribed to the premium service. And last other farmers were randomly contacted by iShamba to complete the list so that it was also representative of the study.

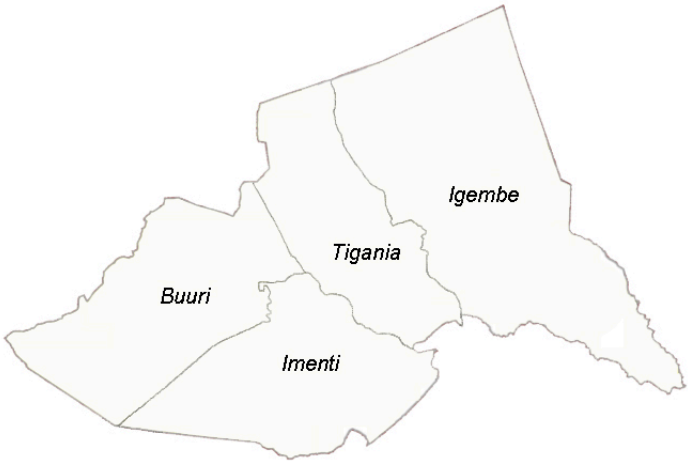
This thesis faces two limitations. First, since digital information services are not widely used and available among the rural poor, it is difficult to access farmers in marginal contexts that use digital services, which means that the study does not provide the data needed to respond to how the poorest farmers use and perceive ICTs. The study about iShamba conducted by 60 Decibels (2020) resulted that 75% of the farmers were using a digital information service for the first time, and 83% could not easily find an alternative source of agricultural information. Second, the poorest farmers are not accessing digital information services yet. Smartphones are still accessible only to the wealthier (Krell et al. 2021) and most farmers might interact through basic mobile phones by using SMS and voice-based mobile phone applications (Aker et al. 2016:45). However, iShamba offers free services that target the poorest farmers, so this thesis was designed to include free subscribers in the analysis. Although framing smallholder farmers that use digital information services still implies that both the commercial, more advanced and the most extreme poor farmers are not represented. This study is better represented by poor or low-income smallholder farmers who still present notable constraints, as defined by the World Bank (2003).

5.3. Presentation of the case study

5.3.1. Presentation of Meru County

Kenya was chosen due to the high accessibility to ICTs[3], especially mobile telephony, and the numerous mobile phone-enabled services for agricultural development that have appeared during the past decade (Brouwer 2019:257). Meru County was selected due to the good conditions for agriculture (see figure 1 to locate Meru County within Kenya), although rainfall is increasingly irregular and unpredictable, and droughts are frequent in some regions during the long rainy season (MoALF 2016). Additionally, MoALF (2016) reported that governmental, non-governmental, faith-based and private organisations provide agricultural extension and training, youth-friendly technologies and engagement, and credit and insurance schemes, which is of interest to the study.

[3] Touted as Africa's Silicon Savannah, Kenya hosts the most mobile phone-enabled services for agricultural development in the African continent, with 95 services on the current date (GSMA 2020).



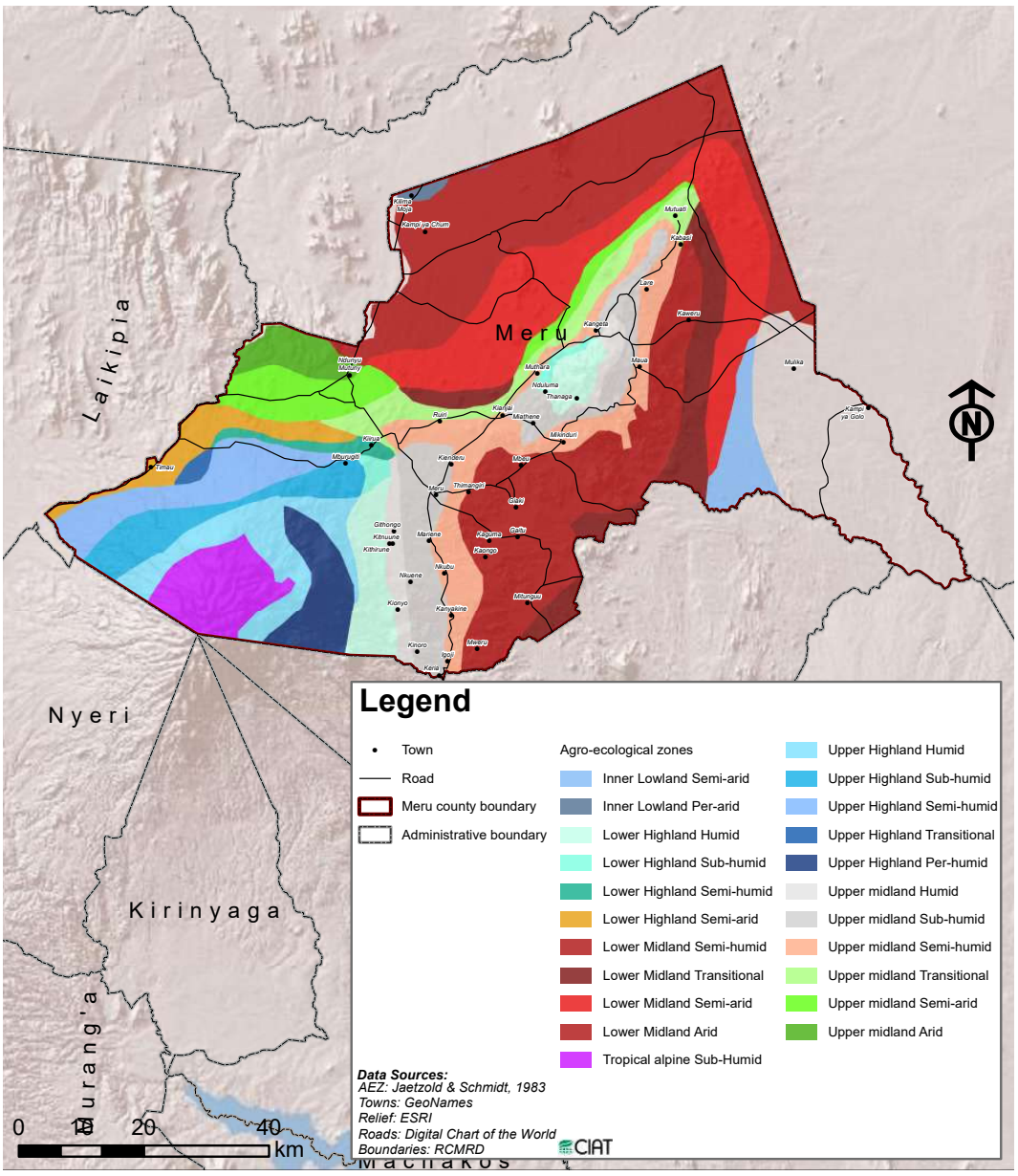


Figure 2. Map of Meru County location in Kenya (Nairobi123 2013); Figure 3. Map of sub-counties in Meru; Figure 4. Agroecological zones in Meru County (Map Book in MoALF 2016).

Agriculture is the major economic activity in Meru County (MoALF 2016). High-input, rain-fed agriculture complemented by irrigation contributes about 80% to the average household income. The key value chain commodities contributing to food security and livelihoods are maize, bananas, potatoes, and dairy cattle. The overall household mean income is 258,028KES per year, the on-farm mean income is 97,740KES per year and the non-farm and off-farm mean income is 86,576KES per year (GoK 2014). The land is unequally distributed in the County. While most households own small parcels of land, a minority of large-scale farmers own most of the fertile land in Buuri (see figure 2 to visualise and locate the different sub-counties in Meru). Smallholder farms also differ in land size, being larger in semi-arid lands due to population density (544 persons per Km2 in the fertile lands of Igembe to 134 persons per Km2 in the semi-arid parts of Buuri) and livestock predominance that requires larger land size for grazing. Overall, the average land size of smallholders is 4.45 acres (GoK 2013). Farmers use a variety of inputs, such as fertiliser, pesticides, and improved seed varieties (up to 80% of farmers). Although due to high prices, distance to markets, and lack of access at the right time, households experience constraints in acquiring them (GoK 2014). The absolute poverty level is 28.3% which is well below the national poverty line of 47.2% (CRA 2011). This can be attributed to the diversity of income sources available to most households in the County, which goes from one up to four income sources. Meru County has a huge irrigation potential, however, only about 14% of the households have access to water for irrigation (GoK 2014).

The closure of the miraa[4] market and the increasingly unreliable weather patterns are two relevant trends represented in the study, both of which directly compromise food security and livelihoods in the County. Miraa is a cultural institution embedded in the Meru traditional culture and reinforced due to the economic development of the miraa trade since the 1950s, which has supposed regional integration into the world economy (Goldsmith 1994). However, the miraa market collapsed in 2014, when the UK government, followed by Somalia and Tanzania, catalogued the plant as a class C drug and banned its commercialisation. Consequently, many farmers in Igembe, where miraa is mostly cultivated, are facing severe economic difficulties and trying to diversify and/or engage in other farming and/or economic activities. When miraa has been the main driver of economic development and source of income for the people in Igembe, it has not been translated into empowerment, better education and health care standards, investment in innovation, diversification, or other socio-economic development strategies (Kieni 1996). The low literacy rate in the County (53% compared to the national rate of 72%) is partly attributed to child labour in the agricultural sector

[4] Khat (*Catha edulis*), commonly known as miraa in Kenya, is a tree with stimulatory and medicinal properties indigenous to eastern Africa.

with a particularly high incidence in the miraa production and supply chain system (GoK 2013). When significant in the study of social practices, such as farming and the everyday life of farmers, the Meru culture is a complex institution which is not this research's priority and thus represented. Food insecurity is a current issue in the County (USAID 2022). Especially, it is attenuated in the semi-arid parts of Igembe and Tigania where droughts have prevailed in the last two years, causing the total loss of the harvest for many farmers (observed). Most farmers are highly vulnerable to weather variability despite the potential for irrigation in the County since they are still dependent on rain-fed agriculture (MoALF 2016). Households are thus expected to adopt irrigation technologies. Farmers were installing different water systems (observed): most economically advanced farmers were drilling boreholes with solar pumps and flooding irrigation (using the retirement payment as a livelihood strategy); farmers living nearby rivers were extracting water from the river with a pump (organised through Community-Based Organisations (CBOs)); and less economically advanced farmers and with no access to water were harvesting rainwater with tanks (for human consumption) and constructing terrace, and/or planting drought-resistant varieties.

The study started in Igembe intending to cover more marginal areas, although it moved afterwards to Tigania, Imenti and Buuri to find a wider diversity of farmers, especially those who are not so dependent on cash crops, such as miraa. In the end, the participant farmers were distributed throughout the whole of Meru County, being 5 in Igembe, 4 in Tigania, 1 in Imenti, and 1 in Buuri.

5.3.2. Presentation of iShamba

iShamba is part of a larger for-profit social enterprise called the Mediae Company (https://mediae.org/). Mediae was founded in 1997, based in Nairobi, Kenya, and is small in size (11 to 50 employees; 35 employees on LinkedIn). Its commitment is to empower East Africans by addressing their informational needs through sustainable and research-based media productions. Mediae started making radio programmes, although expanded to make TV shows, such as Shamba Shape Up[5] (https://shambashapeup.com/), which has 7 million weekly viewers in Kenya, as well as engaging through social media platforms. In 2019, the iShamba service had about 350,000 free subscribers, which raised to almost 500,000 free subscribers in 2020 through different marketing strategies (Girvetz 2020). In 2019, iShamba had 1800 premium subscribers (Etchells 2019). The iShamba team is formed by rather less than half of Mediae employees which can show indications of the level of

[5] Shamba Shape-Up is a knowledge-based agricultural entertainment TV program. It aims to provide practical demonstrations of improved farming practices and bring the advice of agricultural experts close to farmers eager to learn while highlighting the potential of agriculture to enhance rural livelihoods.

tailored advice (if they provide the same advice to the whole country, or specific to each agroecological zone). Mediae gets funding for these projects from donors, commercial sponsors, and research organisations.

Table 1. iShamba services for premium and free subscribers.

iShamba services	***Premium subscribers***	***Free subscribers***
Call centre	X	
WhatsApp groups	X	
Q&A SMS		X
Agri tips	X	
Market prices	X	On request
Weather updates	X	X
Other information	X	X

iShamba provides premium subscribers with a call centre of agricultural experts, access to a WhatsApp group, Agri tips on four commodities (crops and livestock), and weekly market prices and weather updates (see table 1). Free subscribers have access to a more limited service, which consists of the Q&A SMS service, weekly information about the weather forecast and market prices on request. Users can subscribe to the premium service for 80KES per month or 800KES per year.

- The Q&A SMS service consists of sending SMS to get advice from the iShamba team of farming experts at zero cost.

- Agri tips are messages that farmers receive on their mobile phones to know how to grow the requested crops and increase productivity. By following a crop calendar of the farmer's region, iShamba ensures that farmers know what to do and what to expect at every step. Free subscribers were getting Agri tips for two commodities, however, the service was stopped as iShamba was not able to sustain it free of cost.

- Subscribers receive weekly information about weather forecasts accurate to 9 km from their location and advice on which variety to plant and when to plant or harvest them regarding the amount of expected rain.

- Subscribers also get weekly information about crop market prices from major markets countrywide. Information on market prices is supposed to avoid the hassle of negotiating with brokers and middlemen by guiding farmers on when and where to sell their products and how much to sell them for. Premium subscribers can get regular information on two main markets, and free subscribers on request.

- Premium subscribers have access to a WhatsApp group where there is space for farmer-to-farmer interactions with the intervention of the iShamba team of farming experts. This implies that the premium subscription requires a smartphone so that the subscriber can enjoy the benefits of the WhatsApp group. On the WhatsApp group, farmers share pictures and descriptions of their farm, ideas or issues and are assisted by the iShamba team of farming experts who control the quality and accuracy of shared information. Previous research has indicated that the WhatsApp group is the most appreciated tool among iShamba premium subscribers (Etchells 2019).

This case study is suitable for this research as it fits into the category of constraint-based and frugal innovations that target poor farmers who belong to the BOP socio-economic group. 60 Decibels (2020) analysed the data that iShamba collected from 256 of its farmers and found that iShamba is reaching wealthier farmers than the Kenyan rural average; 65%, 35%, and 12% of iShamba farmers were respectively below the $5.5, $3.2, and $1.9 line compared to 88%, 65%, and 34% of Kenyans. However, 60 Decibels (2020) considers that iShamba "has an opportunity to reach poorer farmers with its services", and it might be enough to draw some conclusions by comparing the situation of different smallholder farmers using the service.

Curiously, all the premium subscribers were in Tigania, while all the farmers in Igembe subscribed to the free service, which might be representative of Igembe's marginal context. Last, the data was collected from 11 farmers subscribed to iShamba, of which 8 had a free subscription and just 3 had a premium subscription. The premium subscribers were mainly using the WhatsApp group, while the free subscribers used the service available in different ways. Four of them were using the Q&A SMS Service and Agri Tips, one of them was only using the Facebook group, another was only using the received information without using the Q&A SMS services, and two of them were not using the service at all. The Call Centre is only available for premium farmers, none of whom reported using it.

5.3.3. Presentation of the farms

The farmers are organised in farm households in which different members take different roles and agriculture is one of the main activities. The interviews were mostly conducted with one representative member of the farm households, to whom this thesis refers as "farmer X." The introduction to each farm household shortly describes the livelihood situation, the type of farming, and the use of iShamba. A table with the list of farms is included below to help the reader to follow each farm's history and main characteristics (Table 2).

Farm 1 is represented by a six-member family who cultivates miraa for selling, and maize and beans for self-consumption on a 0.65-acre farm in Igembe. Since the miraa market collapsed, they face severe economic difficulties and are trying to unsuccessfully commercialise other crops and rear poultry. The husband subscribed to the free service one year ago but makes limited use of it.

Farm 2 is represented by a soldier in the process of retiring and his wife, who is a teacher. They have three kids and cultivate two farms of 2- and 5-acre size in Tigania. They have in recent years developed a fruit tree farm (mangoes, oranges, lemons, macadamia) adapted to the climatic environment and recently also expanded to commercial poultry and dairy farming, all as a retirement plan. The husband is a premium subscriber for five years and uses the WhatsApp group.

Farm 3 is represented by an older pastor and his wife who live together with his four sons and their families. The sons are in charge of cultivating a 14-acre farm in Igembe. They have recently installed an irrigation system (a borehole and a solar pump) and practice commercial horticulture (tomatoes, watermelon, bananas). They subscribed to the free service two years ago but do not use it.

Farm 4 is represented by a wife and her husband, both of whom are primary school teachers and who together cultivate four farms of one-acre size each in Tigania. They practice mixed farming and produce miraa, tea, bananas, macadamia, beans, maize, and livestock. The wife subscribed to the free service one year ago and uses the Q&A SMS service.

Farm 5 is represented by a commercial farmer who cultivates 3 farms of 4-, 2-, and 1-acre size in Igembe. They cultivate miraa and practice horticulture (tomatoes, pawpaw, watermelon, maize, beans, bananas) with a small irrigation system from the river, and since the COVID-19 pandemic, have opened a store in town to sell their products. They subscribed to the free service two years ago but do not use it.

Farm 6 is represented by a husband and his wife, both tailors living on a 0.5-acre farm in Igembe. They are starting a chicken farm and for which they subscribed to iShamba one year ago. The husband only uses the free-of-charge Facebook group to learn about chicken keeping.

Farm 7 is represented by a mason and his wife, who is a hairdresser. They cultivate two farms of 0,5-acres size each in Igembe and grow maize, beans, and bananas for self-consumption but also for selling. The husband subscribed to the free service four years ago and uses the Q&A SMS service, and Agri Tips while it was available.

Farm 8 is represented by an educational officer and a teacher, both retired, who cultivate a 3.5-acre farm in Tigania. They have installed an irrigation system (a

borehole and a solar pump) to practice horticulture (kale, tomatoes, and maize). They subscribed to the premium service 8 months ago and use the WhatsApp group.

Farm 9 is represented by a secretary of the church and her husband, who run a store in town, and cultivate two farms of 3- and 1-acre size in Tigania. They practice mixed farming and produce macadamia, avocados, bananas, mangoes, coffee, sorghum, maize, beans, and livestock. Both are in the process of retiring and installing a water system (a borehole and a solar pump) to practice commercial horticulture and dairy farming. The wife subscribed to the premium service three years ago and uses the WhatsApp group.

Farm 10 is represented by a primary school teacher and his family who live on a 10-acre farm in Buuri. They practice mixed farming, integrating livestock and crop production in a semi-arid area. They produce fruits (Kei apples, oranges, passion fruit), maize, beans, shrubs, Brachiaria grass, and livestock. The husband is a free subscriber for three years and knows other digital services, e.g., iCow[6].

Farm 11 is represented by a commercial farmer and his family who live in a sub-humid area in Imenti. They do mixed farming and produce bananas, maize, beans, green grams, Napier grass, livestock, and grevillea trees on three farms of about 2,5-acre size each. The husband is a premium subscriber for three years and uses the WhatsApp group.

[6] iCow is an integrated ecosystem of services and tools which help smallholder farmer in Kenya to optimise their production systems using regenerative practices (https://icow.co.ke/).

Table 2. List of the farms and their characteristics

Who is interviewed and where?	Profession of the household members	Number of farms and size in acres	Type of farming and business plan	Type of labour	iShamba subscription and use of the service	Use of other digital services
Farm 1 (Husband) **Igembe**	Farmers? (assumed) Housewife	0,65-acre farm but live in another very small plot	Miraa and subsistence; trying to commercialise new crops and start a poultry farm	Employ temporary workers	Free, 1 year LIMITED USE	NO
Farm 2 (Husband) **Tigania**	Soldier (retiring) Wife primary school teacher	2 farms of 5 and 2 acres	Developing a fruit tree farm adapted to the climate, poultry, and dairy farm	2 permanent workers	Premium, 5 years WhatsApp group	Shamba Shape-up (TV programme)
Farm 3 (Sons) **Igembe**	Farmer and business (one of them had a store in town) Father pastor	14-acre farm between the whole family (4 sons)	Commercial horticulture (tomatoes, watermelon) with flooding irrigation (borehole and solar pump)	2 permanent workers 4 temporary workers	Free, 2 years DON'T USE IT AT ALL	NO
Farm 4 (Wife) **Tigania**	Both wife and husband primary school teachers	4 farms of 1 acre each	Mixed farming (miraa, tea, bananas, macadamia, beans, maize, and livestock)	4 temporary workers	Free, 1 year Q&A SMS service	NO
Farm 5 (Husband) **Igembe**	Farmer Wife politician	3 farms of 4, 1 and 2 acres	Miraa and horticulture (tomatoes, green grams, pawpaw, watermelon, maize, beans, bananas), irrigation from the river and a store in town to sell his products	Employ temporary workers (observed)	Free, 2 years DON'T USE IT AT ALL	NO

Farm 6 (Husband) **Igembe**	Both husband and wife tailors	1 farm of 0,5 acres	Starting chicken farming	Family labour? (assumed)	Free, 1 year Facebook group	NO
Farm 7 (Husband) **Igembe**	Mason (construction professional) Wife hairdresser	2 farms of 0,5 acres each	Maize, beans, and bananas for self-consumption and selling	Family labour	Free, 4 years Agri Tips, Q&A SMS service	NO
Farm 8 (Husband) **Tigania**	Educational officer Wife teacher Both retired	1 farm of 3,5 acres (Owe additional land distributed to their sons)	Commercial horticulture (kales, tomatoes, and maize) with flooding irrigation (borehole and solar pump)	Employ workers (observed)	Premium, 8 months WhatsApp group	Kilimo Faida (WhatsApp group)
Farm 9 (Wife) **Tigania**	Secretary of the church Husband business (has store in town)	2 farms of 3 and 1 acres	Mixed farming (macadamia, avocados, bananas, mangoes, beans, maize, coffee, sorghum, and livestock); Plans to install a solar pump for irrigation and develop a dairy farm	Employ temporary workers	Premium, 3 years WhatsApp group	Shamba Shape-up (TV programme)
Farm 10 (Husband) **Buuri**	Primary school teacher Housewife	1farm of 10 acres (Semi-arid)	Mixed farming (Kei apples, oranges, passion fruit, maize, beans, shrubs, Brachiaria grass, and livestock)	Family labour (3 people) + hire a tractor	Free, 3 years Agri Tips, Q&A SMS service	Apollo Agriculture, Digifarm, iCow, Shamba Shape-up (TV programme)
Farm 11 (Husband) **Imenti**	Farmer Housewife	3 farms of 2,5, 2,5 and 2 acres (Sub-humid)	Mixed farming (bananas, maize, beans, green grams, Napier grass, livestock, and grevillea trees)	?	Free, 3 years Agri Tips, Q&A SMS service	Digifarm

5.4. Methods of data collection

This thesis makes use of methods of participant observation which are intended to develop understanding and interpretations of meaning in a social context. Participant observation is a type of ethnographic research method that focuses on understanding the nature of phenomena in an interactive process that involves the participation of the researcher in a specific empirical context (DeWalt 2010:13). The researcher observes and takes part in the everyday life activities of the people subjected to study in order to learn about the explicit and tacit aspects of their life routines and culture. Participant observation tends to be used as a synonym for ethnographic research; however, it does not necessarily aim to fully grasp the "totality" of a culture, but it might concentrate on discussing a particular aspect of social life (DeWalt 2010:18). Participant observation might involve looking together at the farm's daily activities for several days and taking part in other everyday life activities to get a full insight into farming practices and farmers' lives. With this, the researcher develops a tacit understanding of the most fundamental processes of social life that enhances the quality of data and interpretation.

There are different levels of participant observation; this thesis is designed to participate in the core activities of farmers as much as possible but not as a full member (Bryman 2012:442). When the level of participation was initially expected to depend on the farmers' willingness to let the student be involved in daily activities, one of the limitations was the geographical dispersion of the farmers. This is a master's thesis research with limited financial resources, so farmers were reached by public means of transportation (local buses called *matatus* that only run by the main roads and when all seats are full, and motorbikes called *boda bodas* that offer transportation were matatus do not go). Therefore, the investigation consisted of a one-day visit to each farmer, in which I was able to learn about their farming practices and take part in some activities of farmers' daily life, but not actively participate in farming. Another limitation to participating in farming activities was that most farmers were employing agricultural labour for 350KES per person a day, so it was more convenient for me to give 200KES (about $1.65) to farmers for each visit in compensation for their time.

In participant observation, the most common method of data collection is taking detailed field notes based on the researcher's observations (see Appendix 1 for an example of taken field notes). Taking notes is fundamental to reconstructing the development of understanding and being able to be reflective on the growing relationship between the researcher and study participants (DeWalt 2010:139). There are several types of notes; for instance, the researcher might take jot or

scratch notes during fieldwork out of observation and informal conversations. Jot notes are words or sentences that help the researcher to chronologically memorise the events and discussions of the day. Jot notes must be translated into field notes ideally on the same day after the events take place. The translation of field notes is a time-consuming activity, as it should aspire to include detailed summaries of events and behaviour as well as the researcher's initial reflections (DeWalt 2010:144–145; Bryman 2012:447). Thereby, field notes are both a data collection and analytic tool that encourages the reformulation of the research questions grounded based on the observations of an empirical context (DeWalt 2010:19).

One of this research design's limitations is the reduced time characteristic of a master's thesis of six months to conduct the fieldwork and the analysis. The type of ethnographic research in which the researcher is immersed in a specific social context is characteristic of (1) living in the context of study for an extended period of time, (2) learning local languages, (3) participating in a wide range of daily activities, (4) using everyday conversation as an interviewing technique, (5) observing the behaviour of the members of the group, (6) recording observations in field notes and (7) interpreting both tacit and explicit information in the analysis (DeWalt 2010:15). In contrast to this description, the fieldwork conducted for this thesis was planned to be carried out in about two months with the possibility of returning to the field during the analysis. Therefore, this compromises some of the characteristics presented here including the capacity of the student to learn local languages and grasp the tacit and explicit aspects of a culture to the extent of full-scale ethnography. Nevertheless, this research fits better into the category of *micro-ethnography* (Wolcott 1990; Bryman 2012:433) that only focuses on a particular aspect of a topic, and which can be carried out in the available time.

The use of language is another limiting factor, as I do not speak any of the local languages generally spoken by most farmers in Meru County (Meru or Kiswahili) and I was not able to learn them during the time of the study. When the initial idea was to find the support of a local interpreter, fortunately, all the interviewed farmers had good communication skills in the English language, and it was not needed. This has unavoidably left out some important aspects that appeared relevant at some point, such as how knowledge is internalised by farm workers who were not confident in speaking English, however, time and the physical ability to find them on the farm were also important. These are aspects that can be considered for further research but are not within the scope and budget of this master thesis.

Additionally, participant observation does not necessarily imply that data is only collected through observation. It is significant that observation is accompanied by informal interviews with key informants to obtain more reliable data. The use of informal or unstructured interviews allows the researcher to access other types of

information, which, otherwise, would be impossible to access just by observation. Unstructured interviews are designed to stimulate an open conversation where the interviewee's point of view is at the centre of focus (Bryman 2012:471). Here the role of the interviewer is simply directing the conversation to points that seem worthy as the interviewee is allowed to respond freely. By collecting data through different methods, the researcher obtains what is termed triangulation so that one's method information gap is complemented with another's method information. It is frequently observed that interviewees do not necessarily do what they say and vice versa. Therefore, observations and oral communication are both fundamental sources of information to understand farmers' context and rationalities.

5.5. Methods of data analysis

Analysing field notes consists in carefully categorising, organising, summarizing, and reviewing large quantities of data to be able to draw well-supported conclusions. In order to do so, the analysis of field notes is an interactive process of reading, thinking, and writing; and redoing it again (DeWalt 2010:156). There are three fundamental activities characteristic of data analysis: data reduction, data display, and interpretation and verification, which are interactively intercalated throughout the analysis (DeWalt 2010:158). Data is reduced by two approaches, indexing and coding. *Indexing* refers to the categories drawn from the initial theoretical framework previously to starting the fieldwork and *coding* refers to the development of categories that emerge from reviewing the data with concepts and patterns. The concepts used in the analysis, are the concepts outlined in the theoretical chapter above, which helped me interpret the participant observations in the light of practice theory, and with a specific focus on answering the overall research question: *How do knowledge processes due to digital information services merge, coexist or compete with other types of knowledge among farmers?*

Both indexing and coding consist in establishing a codebook. *Codebooks* are documents that include the labels (codes) that are assigned to the categories and ideas for which pieces of the text are extracted and abstracted (coded), together with the conceptual and operational definitions of the labels (DeWalt 2010:160). Each label follows a conceptual definition and thereby falls into an idea or concept that characterises a number of pieces of text with a common meaning. Labels are thus used to reduce a series of pieces of text to a few central concepts, which the researcher revisits and rebuilds until the pieces fit in place, also as the researcher gains a better understanding of the content of the study. Therefore, labels are abstracts of pieces of text that are used to visualise, organise, find patterns, and draw conclusions.

As the total amount of data collected was not so extended (a document of about 40 pages), the process of identifying, abstracting, and organising was not so arduous. The first step was to identify categories and labels that fit into the general ideas and concepts relevant to the research purpose. Categories were identified during both process of indexing and coding, and labels within the categories were identified along the analytic process. I used the "text highlight" function in the document to select different colours according to categories to pieces of text. Pieces of text were also labelled, and reflections that were emerging along the process were included in the text as comments or notes. Simultaneously, I identified labels that were included in the codebook within the categories. Second, I created a list of farmers with their main characteristics to have a visual reference book of who is who. Third, the highlighted pieces of text were organised by categories in a second document. This reduced document composed of a series of pieces of text with colours and labels was fundamental to finding themes (connections and patterns) that lead to general conclusions. Themes are ideas repeated in different contexts and which allow drawing general conclusions from them. Coding for themes is thus the process of coding pieces of text that fits into that theme (DeWalt 2010:165–166). General conclusions were rather interpreted by finding connections between pieces of text than by finding patterns. The amount of data might be limited to finding patterns, but it was enough to find connections that complement each piece of text. This was used to write a third document that included the constructed argument in an organised manner. Inevitably, making general conclusions work depends on the process of reviewing, comparing, and writing (find the codebook for each document in Appendix 2). This thesis adopted these themes as subdivisions in the results and discussion chapter.

5.6. Ethical considerations

Research ethics are norms that the research community has reflected upon and gathered to offer guidance concerning which are good research practices (Swedish Research Council 2017). A crucial concern in research ethics is how to treat people who participate in research, ensuring that the research will not cause any harm to them, while not undermining the research purposes of contributing to both society and citizens. This research does not deal with any sensitive questions that can condition the integrity of the participants; however, some actions have been taken as outlined in the sections below.

5.6.1. Informed consent

Informed consent means that participants in a research study are informed about the purpose of the study, and how they will participate, as well as that they have the possibility to withdraw their participation at any time, without explanation. At the beginning of each visit, farmers were informed about the research and the expectation on their participation, as well as their possibility to withdraw at any time. They were also given a consent form to sign for this purpose.

5.6.2. Confidentiality

Overall, most farmers did not seem uncomfortable with the visit, and they were quite open to talking and showing their lives and farm activities. Although, in a few situations, they were more cautious with their own words and asked me to keep them confidential. When promising confidentiality (also referred to as anonymity), it must be considered that process of reviewing the research might require the disclosure of data to verify research results. However, confidentiality can be promised when the identity of the individuals is not relevant to the research, such as in studies about behavioural change towards a specific issue (Swedish Research Council 2017:41). As the identity of the farmers is not relevant for this study, the data could be disclosed in case of an accusation of research misconduct, always keeping the anonymity of the participants. Additionally, the researcher signed an independent research agreement with iShamba about data privacy and to guarantee the right use of it.

5.6.3. Power relations in participant observation

Ethical issues with asymmetrical distribution of power in research interviews are typically defined by hierarchical relationships between the researcher and the subjects. As Kvale (2006:484) put it, “it is a one-way dialogue, an instrumental and indirect conversation, where the interviewer upholds a monopoly of interpretation.” This requires that the researcher critically reflects on his/her “position of power.” The researcher has the power to dictate what, how, when, and where to observe and participate. Within the fieldwork, the researcher makes continuous decisions about what is interesting to include and what is not, refining the research questions and design (DeWalt 2010:158), to the point that DeWalt (2010:139) describe field notes as “a product, constructed by the researcher.” This thesis’ fieldwork has mainly consisted in visiting farmers and spending some time in their daily life to learn about their farming practices. During this time, conversations have come naturally, and the research design has left space for the farmers to bring their views, although the interviewer had the task of producing knowledge related to societal needs, which is one of the moral obligations of the researcher (Swedish Research Council

2017:13). When the student had the position of asking questions, farmers have decided what, how, when, and where. They have hosted me and set the agenda about what to share including their own concerns. By my side, I was flexible and open to spending a day at their places and getting out of the strictly necessary.

Participant observation, as well as grounded theory, invites the researcher to reformulate the research questions, key concepts, and connections to the empirical context to refine congruent arguments (DeWalt 2010:165–166). Here the capacity of the researcher to be self-reflective becomes important to challenge his/her ideas and interpretations and look for inconsistence and what is different than expected.

5.6.4. Positionality

Another ethical consideration is that values influence the conduct of all research. Therefore, the researcher must acknowledge that research cannot be free of value and be self-reflective throughout the research process (Bryman 2012:39). This implies being transparent with the reading and including how the researcher's own biases and assumptions may have influenced the findings of the research.

As a white person doing research in Africa, the first factor that comes to the surface is my position as an outsider, which conditions my perception and understating of African society and cultures. I have been self-aware of my own cultural values and assumptions about how the world is constructed to not influence on the research process. Although it was not my first contact with the African continent, my perception of African society has enhanced along this journey. I spent one month preparing the fieldwork, three weeks in Nairobi with iShamba who were very helpful with any request from my side and one week with an organisation that works in Meru and Laikipia counties and who invited me to learn about the region and their work with rural communities. I also made good contacts with three researchers and one agronomist from the region who have helped me to clarify queries and to increase my awareness of the context. By increasing my contextual understanding, all this has helped me in interpreting the data in a context-sensitive manner.

An important aspect of being an external student coming to do research in Africa, when, on the one hand, carrying the errors of inexperience, on the other, at least in my case, being open to acquiring new ideas from a new context. Throughout this process, I have tried to understand what the farmers communicated to me from their standpoints and to understand the wider meaning of this by engaging with the literature and theories to generate knowledge that can be valuable for the research community, policymakers, digital services, farmers, and the large society.

6. Results and discussion

6.1. The farmers' use of digital information

There are several empirical findings and aspects relevant to the discussion about farmers' adoption of digital information in the context of the study. This thesis conceptualises that farmers make use of digital information when they adopt it within their farming practices and thus assumes that the adoption or use of digital information depends on the farmers' contextual realities. The farmers construct their possibilities to use digital information within their physical and mental realms. This includes the financial situation and availability of physical resources, the natural environment and climatic condition, the learning capacities and diversity of knowledge, and the aspects of trust and common meaning in digital information. This analysis identified different processes in which digital information merges, coexists or competes within the contextual realities of farmers in terms of material, competence, and meaning. The use and adoption of digital information thus depend on the availability of these three elements, which differs amongst the participants in the study.

6.1.1. The relation between digital information and the socio-economic circumstances of farmers

This thesis found that digital information is easily adopted when it relates to the socio-economic circumstances of farmers. Some farmers (4, 7, 10) reported adopting new crops or varieties according to different agro-climatic zones and the weather forecast. Farmer 7 obtained Agri tips for two crops on his phone, bananas and maize. He explained, "there was a time when I chose sweet potatoes, but it did not go well, so I changed. Since then, bananas and maize have done great." iShamba advised him to change the varieties of bananas and maize to other more convenient for his location. "iShamba told me that the ones that I was using were not good for this place." iShamba advised him to plant sweet bananas apart from traditional bananas, which he could freely get from a neighbour. "The sweet banana variety needs less time to grow and be ready for harvest and can be sold more expensive so

give more money." This strategy allowed the farmer to introduce new elements into the farming system at no additional cost. The preference of farmers for commercial bananas over indigenous also appeared other times. Farmer 11 explained that "indigenous bananas have no market. They are sweeter, and we plant them for self-consumption. But the indigenous ones ripe faster than the commercial ones, and no one buys them." Therefore, farmers in Meru County are rather pragmatic and find the adoption of new varieties as an opportunity to increase their profitability.

The same occurs with the application of manure. A practice that farmers abandoned with the introduction of synthetic fertilisers, although this process is recently reversed due to the rampant rising in fertiliser prices. Farmer 6 argues, "some years ago, my wife came with that knowledge of using fertiliser. But due to the lack of money to buy fertiliser we have decided to use manure again and it is also good for soil health." Some farmers (1, 5, 6) have adopted the spread of manure as fertiliser on their farm that is bought from a local neighbour. This strategy is especially doable in Meru County where farmers can easily buy manure from pastoralists nearby in Isiolo County, where the climatic condition is less conducive to agriculture and there is a surplus of manure from rearing livestock. Therefore, practices can be easily readopted in contexts in which they were previously established and that are socio-culturally interconnected with the physical and natural environment. In addition, this shows evidence that the market creates an incentive that shapes farmers' behaviours, in this case, having a positive effect as manure is more accessible than synthetic fertilisers. This was also noted by Odame et al. (2009) who studied the maize, tomato, and dairy sectors in Kenya and argued that markets, in an open economy, are the most important drivers of innovation.

iShamba also advised Farmer 7 to buy hybrid maize seeds, instead of using his own. The farmer reported a much higher production and crop resistance to diseases now. The production has increased from 2 sacks (200kg) to 4,5 (450kg), and the cost of the seeds was 600KES for 2kg, which was used for planting the whole 1-acre farm. If the farmer sells the maize for 20-30KES per kg, the economic difference is huge according to the farmer. He also said that he has had plenty of fall armyworms before but has gotten none in the last three years since he uses the hybrid seeds. The findings are consistent with Ouma et al. (2014) who found that the adoption of hybrid maize varieties in the sub-humid regions of Meru and Embu Counties has increased productivity and income. However, farmers in the region are highly dependent on rainfall. Two of the farmers (1, 10) reported zero maize harvest the last two years due to droughts, and Farmer 11, who is in a sub-humid area, reported very poor harvest, all of them having planted hybrid seeds. This correlates with Wang et al. (2017) who found that farmers in Kenya perceive the development of hybrid maize with higher yields positively, although they attribute equal importance to other qualities such as drought tolerance. This was evident with Farmer 10 who

reported having issues with the sorghum because of the drought this year. “Someone will tell you that sorghum is a climate-resilient crop. Well, look how poorly they grow,” he complained. Nonetheless, drought-tolerant technologies do not necessarily consist of improved crop varieties, but also other water, soil or pest management methods integrated in a holistic manner.

Hybrid maize seeds are generally promoted together with other complementary technologies and/or practices. Musafiri et al. (2022) argue that climate-resilient crops must be cultivated together with minimum tillage to mitigate and adapt to climate change. This corresponds with Farmer 7, the only participant in the study practicing minimum tillage. He explained that he got the information from iShamba and that it consists of making a small hole and putting one seed with fertiliser inside. Minimum tillage is a practice of conservation agriculture which has a low rate of adoption, only 14% in SSA, despite being promoted for a decade (Jena 2021). According to Jena (2021), this gives some evidence of farmers’ hesitance of its profitability, which also explains that Farmer 7 reported practicing minimum tillage to reduce soil erosion and not necessarily to increase yields even though both are interrelated. Another factor that could have motivated Farmer 7 to adopt minimum tillage is the fact that it significantly reduces labour (Jena 2019). For soil fertility, Farmer 7 makes sure that each seed has the appropriate dose of fertiliser. This matches the high association in use between improved maize varieties and synthetic fertiliser found by Ogada et al. (2014). They observe that smallholder farmers adopt improved maize varieties only when they can apply synthetic fertiliser. From a social practice perspective, the successful adoption of hybrid seeds depends on the financial capital of the farmer to access both complementary technologies, hybrid seeds and synthetic fertiliser, which might reduce the adoption rate of hybrid seeds.

Another example appeared at the end of my visit to Farmer 7 when he invited me to pass into his home, and we started a conversation about some plants he had at the entrance. It is typical of participant observation methods that data which was not previously visible emerged in the interaction with the physical space. The farmer said that the plants are called Amarandas and are drought resistant. He added that he did not know they were edible, even though they were there for some time until he got the information from iShamba. He assured me, “you can make greens out of it and even sell it.” At that moment, he was collecting some seeds on a bucket to plant more or even to make flour together with maize. It is a clear example of a practice that is available in terms of materiality but lacks the competence to make it applicable. In such cases, digital information services could have a key role in disseminating information that farmers could easily adopt, such as how to create and add value to available materials. This is a type of niche innovation that challenges the dominant socio-technical regime by reducing input dependence.

6.1.2. The unavailability of material resources in the use of digital information

This thesis found that the lack of material resources constraints the use of digital information. Most of the participants of the study reported not being able to use the digital information due to material constraints at some point, although the reasons were multiple and very uneven. One of the common issues was the unavailability of effective pest and disease control products in the local markets (Agrovet stores). Farmer 2 reported some challenges with different types of diseases and not being able to find chemicals in the market to treat such diseases. As a result, for example, he had to cut some trees. Additionally, several farmers (2, 3, 4, 8, 10) reported having used chemical methods to control pests that were not effective. Another example is Farmer 7 who reported to have used effective chemicals to control fall armyworm, but he complained that they were very expensive. Farmer 1 reported not being able to purchase pest control products at all. Instead, he relied on cultural methods such as hand picking. All these different cases indicate the impact of material constraints to operationalise digital information into practice.

Three farmers (1, 5, 10) commented that they do not mainly need new knowledge, but what they need is someone to help them financially. While this might be true, the effects are very different in the three cases. Farmer 1 is in the most precarious situation and needs both financial support and knowledge. Farmer 5 has his own sources of agricultural information, and even though he does not face important financial difficulties, he has no good records and is unable to get a loan. Farmer 10 is very knowledgeable and believes that knowledge is very important, however, he says that "knowledge without money is useless." And referring to a farm nearby with a solar pump and sprinkler irrigation, he added "you see where I live is dry but if you have money, you can do farming." He tries to plant many different types of grass to feed the animals in semi-arid climatic zones also without much success. He said having planted Rhodes grass, Sudan grass, etc. but all dried out. Further, he was trying out other grass that he got from a friend, and which he did not know the name of. Now, he is planting Brachiaria grass, which, according to him, does well and grows fast with enough fertiliser and water. However, he expressed that he was not satisfied with his own performance, and he was ashamed as a farmer, although his performance (competences) was directly associated with the lack of access to water (material). "This grass can grow up to 1,5m. You see, this is far below what it could be. Now, the difference is water." However, he thinks that Brachiaria does well in dry areas, and he would recommend it to other farmers in similar climatic conditions. He said that he learnt about it from iShamba, although it was difficult to get the seeds. They were ordered from the Agrovet store in Nairobi and sent to Meru town, where he could travel and collect them. This indicates that the construction of reality starts from the physical space. Farmer 10 proved to be

competent (knowledgeable), and motivated (experimental) but the financial, physical, and natural capitals condition his practice. This confirms that while knowledge is an important asset, the material condition cannot be overlooked.

Two of the farmers (2, 10) mentioned that they plan to develop intensive zero grazing for animals and start mechanised grass-growing. Zero grazing, which has attracted increased attention among farmers in Kenya since its first introduction in 1979 (Nalunkuuma et al. 2015), consists in keeping the cows in an enclosure and producing hay and other crops to feed them. Farmer 2 considers zero grazing an optimal innovation due to the small size of his farm, also affected by the persistent land fragmentation. Farmer 10 reported other benefits such as wasting less animal feed and controlling vectors of animal disease such as tics or flies. In addition, Farmer 10 argued that "in dry areas, you cannot rely only on livestock or cultivation. You are bound to integrate both in a holistic system." In such a context, the efficient integration of livestock with crop production is a persistent necessity. Hence, zero grazing that attends to optimise such integration is perceived as a positive practice that can complement the existing farming systems. These two farmers showed to be some of the participants in the study with more knowledge about farming. This corresponds with the study of Nalunkuuma et al. (2015) about zero grazing adoption in Western Kenya which demonstrated that farmers who practise zero grazing had more knowledge of cattle reproductive parameters. They assumed that the practice of zero grazing increased farmers' knowledge, although it could also be that more knowledgeable farmers had more interest in adopting zero grazing. In this study, the farmers do not practise zero grazing yet although they have the knowledge and interest. Farmer 10 explained that the main investment is constructing the zero-grazing unit. He already wanted to do it 30 years ago when he bought some beams, which he showed to me. He explained that, at that time, there were no phones to do research, so he had to figure out how to do it by himself, and these beams resulted not enough. He was looking for the money to finish when his neighbours offered him to buy his land, which he found to be better than the completion of the zero-grazing unit. So, he stopped that project until now that he is retiring and plans to invert the retirement payment on it. This example demonstrates how materiality constraints the adoption of a farming practice such as zero grazing.

Farmers also reported getting information that they were not able to use. Farmer 10 explained, "there is also another grass, Napier grass. I got the information from iShamba again. This one they are calling 'Pakchong.' It is a hybrid over two types of grasses then they came out with it. It was done in Bangladesh or those areas there. Then, the seedlings are being brought here. A bunch of 100 cuttings cost 5.000KES. Now, where do I get them? The information you have, right? Now, who has them? That's another problem for the farmer. You want them, yes! Where would you get them?" Farmer 10 was complaining about the challenges to access

agricultural technologies that are exhibited in the agricultural shows. The farmer was saying that he works in the school as a teacher and after attends the animals at home, so he has not the time to assist to the agricultural shows. Also, Farmer 11 explained, “For example, they told you that there are cows producing 40-60l per cow, but you might not afford to buy such a cow.” He saw some cows in a dairy-cattle show in Kiambu that were very impressive, however, he could not afford to buy them. Each one of them costs 150.000KES plus transportation. He said that “with one of those you can get enough milk and thereby money.” He was asking me: Let me know what we can do to get such a cow. Can those companies help us to get such a cow although the prices are very high? It shows that iShamba, rather than providing advice anchored in the specific situation, gives too general advice that is not always helpful for farmers.

Additionally, Farmer 1 showed difficulties in adopting new practices, which contradicts the success of Farmer 7 in adopting sweet bananas and hybrid seeds. Farmer 1 expressed financial constraints in acquiring inputs, such as fertilisers and pesticides. He was in a difficult situation since he could not harvest any maize due to poor rains for two consecutive years and consequently had to purchase seeds to plant maize (instead of using his own seeds). He also said that he bought a few chickens, but all got sick and died. When I asked him if he used the iShamba Q&A SMS service, he answered, “I have seen the symptoms, and I do not know, and now I ask you (iShamba), and you tell me, it is this kind of disease, and you need this kind of medicines. And you know now, sometimes, it might be that I am broke, and I do not have money for that.” Therefore, Farmer 1 knew about the Q&A SMS service, although he did not think that iShamba could help him as the advice might involve the acquisition of inputs. Once again, information becomes impossible to act on for the farmers when they do not have the means to obtain the needed material, which means that, in such cases, digital information does not consider the contextual realities of farmers.

6.1.3. Diverse trajectories of agricultural development in digital information

This thesis found that the use of digital information integrates different trajectories of agricultural development. Three farmers (2, 9, 11) reported obtaining information about the nutritional value of cow feeding and how to improve the milk production of the cows. Farmer 2 learnt from iShamba that maize stover has little nutritional value and must be mixed with Calliandra and Napier grass to make it more nutritious as fodder, both of which are available on his farm. Farmer 11 learnt that when the rainfall is not enough, the cows produce less milk. He says that “this year that there is little rain, the milk production per day has diminished from 45 to 20l. Thus, iShamba advised me to plant Calliandra, Desmodium or Mulberry, which

have high nutritional value." This way, iShamba is also covering aspects of adaptability to environmental change. Farmer 9 got information on iShamba about how to complement the cows' diets with dairy meals. The farmer explained, "since I followed their instructions, I have increased the milk production from 2l to 5l per cow. But they also teach you how to make your own forage, so you do not have to buy the dairy meal. The forage is made with maize stover, mixed greens (Napier grass, Calliandra and leaves), and ash." By providing multiple options adapted to the circumstances of the farmers, iShamba increases the diversity of knowledge and so doing it contributes to the social sustainability of farming systems. It might be that some farmers are not able to produce enough nutritious forage and it might be more convenient for them to give their cows a supplement feed. However, while digital information services increase knowledge diversity by putting new knowledge into use, their main commitment is not the management and co-construction of local knowledge and practices together with local communities (Sulaiman V. et al. 2012). Digital information services are still intermediaries that do not successfully accomplish to bridge the gap between theory and practice. Rather than directing innovation to solve the problems of poor rural farmers, they put the current available information and research to the disposition of users.

The information about cow feeding corresponds with the information provided at the Agrovet stores. Farmer 4 reported spending 70KES per cow a month on cow dairy meals and got this information from the Agrovet store that sells such products. Moreover, some farmers said that they use the maize for feeding the animals, and even Farmer 4 is making her own compound powder by adding sunflower plants. Although Farmer 4 has heard about Calliandra from other neighbours, she said she did not have it on her farm. Consequently, she is hoping to get some seedlings from some neighbour so she can try it out. This example again indicates the importance of combining material, competence and meaning for enabling practices; in this case, the competence and meaning elements are present, but the material element is lacking. Nonetheless, all the proposed options rely on material elements to be put into practice, ones more in the financial sense, and others in the physical sense of the element. By providing several options adapted to the farmers' demands, iShamba complies with the coexistence of diverse models of agricultural development described by Plumecocq et al. (2018). This reflects the several trajectories within the dominant socio-technical regime, which Plumecocq et al. (2018) determined as innovation "from within," for example, innovations that do not challenge the dominant socio-technical regime.

These models of agricultural development follow both the general mainstream of products offered by agricultural industries and businesses such as those found at the Agrovet stores and other alternatives that consider the need of farmers and imply aspects of circular economy, which Plumecocq et al. (2018) include under the

category of biodiversity-based farming systems. However, the possibilities of hybridization between the models found in the context of the study vary from those defined by Plumecocq et al. (2018). The farming systems presented in the study often include cash crops that are exported to the globalised commodity-based food systems and staple crops that are commercialised in alternative food systems such as the local market. Also, they can combine different elements of chemical input-based and other biological input-based models in the same system, including the utilisation of their own seeds, hybrid seeds or genetically modified seeds. These different combinations between the different models lead to new models that are not represented in the categories proposed by Plumecocq et al. (2018).

6.1.4. Digital information in the co-construction of the social context

Digital information is not the only knowledge affecting farmers' practices but is integrated with diverse bodies of local knowledge and practices. Thus, digital information is reconstructed in the farmers' context. Farmers adopt information about issues that they have an interest in while information that does not fit into their farming system and meaning is, more rarely, adopted. For example, Farmer 6 said that he has his cropping system and is not interested in getting information from iShamba for that. As he has established a system that works for him, he is reluctant to take the time and effort to change it. Farmer 11 ignores information that is not of interest, for example, the one that is not related to dairy farming. This reflects the disparity of information and sources to which users and people are often exposed so that they do not take digital information quality for granted. This trust issue is reversed by comparing the information from different sources and validating its reliability. Farmer 8 is subscribed to another WhatsApp group called "Igembe Kilimo Faida" with similar conditions to iShamba. He said to register both to compare which one is better. Farmer 11 also uses other digital services to get information, such as iCow and Digifarm. He said to receive messages from different companies and combine them. Digital information is thus compared, countered, and validated with other sources of information and knowledge.

Digital services have promoted the management of cropping systems to some extent; crop rotation and intercropping are the techniques commonly found among farmers. Farmer 11 got a message from iShamba about the right distance while intercropping maize with beans. It said to leave a space of 4ft between maize rows and plant a row of beans in between. In each row, leave a space of 6in between maize seeds, and only use one seed per whole. Farmer 2 uses the space between the trees to plant maize intercropped with beans. In the short rainy season, he intercrops maize with black beans, which, according to him, is good for the acidity of the soil. In the long rainy season, he plants only beans and potatoes in a separate plot. He

explained that potatoes did very well this year as the soil was very fertile, and when the soil fertility is low, he does crop rotation and plants beans. He explained further, "in the short rainy season it rains more but for a shorter time, which is optimum for the maize that needs water to grow and mature. In the long rainy season, it rains less but a longer time, being enough for the beans to mature." He said that he got the information from iShamba and the agriculture classes at primary school but later he also acknowledged that it is traditional knowledge widely spread among farmers. Most likely, different aspects of it can be identified at one or several of the sources where it is compared, countered, and validated. Thus, information that is validated over time becomes part of the structures of signification (Giddens 1984), the common meaning that defines the cultural context of rural farmers in Meru County.

Another example is Farmer 9, whose father was an agricultural officer who advised her not to intercrop maize with beans but to rotate them. She explained, "last season I planted only maize. This season, I am planting beans (with some rows of maize; maybe inspired by the neighbour). This area is not good for beans but this season I decided to give it a try instead of always planting maize." The neighbour was intercropping maize with beans the same way, leaving a 5ft distance between maize rows and putting two seeds of maize in each hole. The neighbour got the information from a one-full-day training course with an agricultural expert that the church in which she is a member organised at no cost. In the training course, they were advised to plant the maize within 2ft distance from one row to the other and 1ft between maize plants in the same row, using only one seed in each hole. But she did not follow the instructions, she did it in her own way. The maize was intercropped with beans leaving a 5ft distance between maize rows and putting two seeds of maize in each hole. She explained that "beans do not need much rain, and this season we do not have much rain. So, I planted more beans, but next time, I will do as I have been told." Moreover, the neighbour, unlike Farmer 9, was weeding the farm manually. Farmer 9 applies herbicides, also as a way to reduce labour. "We do not employ too many casual workers. It is very expensive." Even though they were using similar systems, they explained that you should not apply herbicides when intercropping. The chemicals are different for maize and for beans, so if you apply the chemical of maize to the beans, they will dry and vice versa. "The herbicide is called 'selector' because of that," they explained. Although Farmer 9 was planting the maize first, applying the herbicide for maize and planting the beans after three days, it can be said that intercropping is generally incompatible with the use of herbicides, and it consequently requires increasing the amount of (paid) labour. It indicates how a certain practice requires material, competence and meaning elements, which are not interchangeable. Here, the acquisition of one skill set, such as the application of herbicides, can undermine the maintenance of another, such as intercropping, but also both chemical and biological input-based innovations coexist as part of the same local knowledge.

Another relevant aspect regarding the information on expected rain and when to plant was obtained from the same conversation between the two neighbouring farmers. While talking with Farmer 9 and her neighbour, it could be realised with a naked eye that the neighbours' maize and beans had grown much higher. They explained that the difference was that the neighbours did not wait for the rain to come, while Farmer 9 did so. The neighbour planted the maize and beans in the soil before so when the rain came the seeds were already there and started to germinate earlier. This way, the farmer does not need to know if there is rain and how much, especially when the farmer plants his own seeds and is not planning to change variety or practice. This aspect was also represented by Farmer 6, who plants maize, beans and potatoes intercropped in rows for self-consumption and is not interested in getting information about it from iShamba. Here digital information conflicts with other farming practices.

The farmers compare and integrate digital information with other local knowledges. The stage before deciding if to implement it or not corresponds with the farmers' persuasion described by Rogers (2003). In this stage, the farmer is developing an attitude toward an innovation before deciding if to acquire it or not. Here the farmer considers his capabilities to adopt and integrate such innovation into his farming system. This does not only include how useful is perceived by the farmer, but also if the farmer can access the required resources and has the interest and time. One can say that farmers construct an attitude toward innovation while evaluating it. Premium subscriber can learn on the WhatsApp group from the evaluations of other farmers that had already implemented it, but also from neighbours who share impressions and ideas from training courses and past experiences. Additionally, in the stage of implementation, in which the farmer puts the innovation into use, this thesis found that farmers innovatively reconstruct the information according to their circumstances and understandings.

6.1.5. The perception of agriculture and the use of digital information

This thesis found that the perception of agriculture (traditional and modern) determines the use of digital information. Farmers are advised by iShamba on which variety to plant and when to plant them regarding the amount of rain expected for the season. For instance, Farmer 11 said, "I was advised that there will be little rain this season, therefore, I planted crops that work well with little rain. Cowpea, cassava, or green gram are some examples that take long in the shamba[7] and do not dry quickly." He said he knew about these species and their capacity to work under conditions with limited rain before, so he found it reasonable to follow the advice

[7] Shamba is land or farm in Kiswahili.

of iShamba. This indicates the path of dependency in which practices are engendered and sustained as a performance and an entity over time. As the availability of knowledge (competence) constructs the possibilities of what makes sense (meaning) in a particular context. Discursive knowledge that is already integrated into the local knowledge of farmers does not present any challenge to be adopted and practised. Additionally, Farmer 11 also exhibits a positive disposition towards new knowledge. He continued explaining that "we cannot do as we did before (referring to always plant maize and beans), but we need to use the new formulas of today to adapt to the environment and to plant maize and beans only when there is plenty of rain." Therefore, the acquisition of new knowledge might not be only affected by the previous knowledge (competence) of the farmer, but also by the farmer's perception (meaning) of science and innovation (external new ideas, methods, and practices).

However, not all the farmers showed to consider digital information positively. This was represented by Farmer 8 who asked for advice as his maize was not growing properly. He was answered that "it is always advisable to practice crop rotation, this helps to break down disease and pest cycle and restores nutrients exhausted by that particular crop especially when you rotate with leguminous crops like beans. However, use Lavander total at the rate of 20ml/20l, it will help to restore dark green colour and the plant rigour. Incorporate Optimizer 10ml/20l for stress management and growth enhancement. Do not forget to add Integra (Stricker) 3ml/20l for spray efficacy." This information was not coming from iShamba but from a similar WhatsApp service that Farmer 8 is subscribed to, however, what is important here is the farmer's interpretation of the issue and solution. He explained that the first time that he planted them they did very well, but not the second time, despite that he had applied at least two of the indications (Integra and Optimizer). Furthermore, he has applied cattle manure, DEP fertiliser and CERES fertiliser as did the previous year, so he deduces that it might be the seed variety. Then, talking further, he acknowledged to have not rotated the crop. He has planted maize in the same plot two consecutive times without intercropping beans. He said that beans do not do well when planted with maize. Maize grows a lot, and they need light, so they do not grow well because of that. Moreover, the farmer is flooding his field for irrigation, which can also be a cause of nutrient leakage. However, Farmer 8 did not seem concerned with the impact of these practices on the maize growth, he was convinced that the problem was the seeds. Hence meaning and competence become decisive elements as the farmer perceives traditional knowledge as backwards and manages inadequate information about crop rotation or intercropping practices. It could also be that an SMS is limited to educating farmers about complex practices such as intercropping or crop rotation, although it might be very helpful with simple actions such as the minimum space between plants or the appropriate doses of fertiliser, which Jena (2019) found to be deficient among farmers in SSA.

Similarly with Farmer 6 whose perception of traditional knowledge and modernity is conditioning his farming practices. When I asked him if he got any traditional knowledge from his father, he answered, “the only knowledge that I got from my father is that I can make money by doing poultry. No traditional knowledge from him. Maybe how to construct the houses for chickens. But my father had a small farm, and the chickens were freely in the shamba and fed themselves with grass and worms. I am not doing this. I keep them in a closed space within the house fenced with an iron sheet. I fear that they are poisoned or something.” Instead, Farmer 6 is trying to implement new information obtained through the Facebook group. For example, he learnt that chicks are given a liquid called Paraffin just once when they are one day old that is for digestion issues; the food they need to grow well when they are chicks (chick mash), when they are older than a year (growers mash), and when they produce eggs (laying mash). He also got pictures and instructions about how to construct poultry yards, which has inspired him to make his own although they look very different as were constructed with recycled materials. Therefore, while pictures can be useful to show farmers how things could be or inspire them, it might be unrealistic in certain contexts. If farmers are constructing a shelter themselves, it might be more practical to include pictures and instructions of shelters done by other farmers also with the available materials.

The farmers’ perception of agriculture is constructed in correlation with the reality around themselves, being the digital information services part of such reality. For example, Farmer 5 complains that money goes to chemicals, “we use them heavily. Traditional methods do not work for some reason. Handpicking is tiresome. Someone told me about intercropping tomatoes with chilli peppers, but I ignored it. I prefer to apply chemicals and not take risks. If you do not spray tomatoes and pawpaw, you do not get anything. There are fake fertilisers that do not work. This is why I consult those who work for that purpose (agriculture officers).” To know when and how much fertiliser to apply, Farmer 2 takes a sample of soil to be tested at the Agriculture Office Centre. He says that it is not expensive, but many farmers do not know about it. He also explains that using manure is better than synthetic fertilisers as the latter has a high concentration of acidity. However, he still applies DAP and CEN fertilisers, using different amounts depending on the crop and using the crop measuring containers. Farmer 4 buys maize seeds although she thinks that they are not better. She uses her own seeds for self-consumption and ensures that they even produce more sometimes. “It all depends on the care you put in,” she explains. She thinks that it would be possible to use her own seeds, “you only need a product to preserve the seeds that cost 100KES. There is still a belief in the minds of people that buying seeds is more secure in terms of productivity, but it is not a fact.” Therefore, when there exist different solutions to the issues that characterised agriculture in the context of the study, surely with different degrees of complexity

and effectivity, the practices of farmers are conditioned by the meaning associated with agriculture and modernity.

Changing the meaning associated with agriculture certainly requires the availability of feasible alternative innovations to the issues faced by farmers in terms of both material and competence that can be applicable and effective. Among these innovations are effective pest control that not only include semiochemicals and pheromone traps, biopesticides made from neem or other available plants, but also preservation of natural enemies for biological control, none of which are present in the context of the study. A local agronomist explained, "the methods that we advise to treat fall armyworm pests are still chemical, sprayed at night when they feed. Due to pesticide resistance, other methods that we advise to farmers are physical control or spaying a solution with a detergent that wash the eggs away. This method is very effective, but we just advise them to do it once when the chemicals are not effective. This method is not recommendable due to other disadvantages. It affects the rooting system and dries the crops when used regularly. You can use OMO (a brand of a locally common washing powder) or Soapy Water (10gr) dissolved in 20l of water applied in ¼ acre, so it is very accessible. Other methods are handpicking, applying soil on the top, and tobacco solution." Thus, farmers might perceive cultural control methods as non-scientific, advanced, or just effective. The integration of biological-based innovations for pest control does not mean dispensing with chemical innovations but reducing the dependence on them when is not strictly necessary. However, it necessarily requires changing the meaning associated with agriculture and modernity among smallholder farmers. To conclude, the three elements of material, competence and meaning that sustain a practice are needed to effectively promote more sustainable agriculture, including pest management.

6.1.6. Learning capacity and human intermediation in digital services

The learning capacity of farmers is a central point throughout this thesis. An example of success is the dissemination of information in relation to chemical management, in particular which indications to follow when using chemicals for controlling pests and weeding. For example, Farmer 8 learnt through the iShamba service the importance of Preharvest Interval (PHI) to reduce chemical residues in the crops that he sells. He explains, "before I was using chemicals, but I did not know how long I should wait before harvesting. It is serious to do it correctly, people are getting cancer because of it." Other information that Farmer 8 learnt from other farmers by being in the WhatsApp group is that chemicals must not be stored in the same house where humans live, but in a separate room. This proves that farmers' knowledge (competence) is a fundamental element that can influence

farmers' mentality (meaning), and practice when the required materials are in place. In this case, information about chemical management is a very important aspect that has direct consequences on the awareness of human health issues. Herein the farmer has understood the importance of chemical management for human health and adopted the information provided through the digital services within his farming practices.

Since social relations increase the human capacity to learn from each other, digital services that facilitate farmer-to-farmer interactions, as the WhatsApp and Facebook groups do, can potentially increase the learning capacity of farmers. The theory says that farmers learn from interacting with the natural environment and through their social networks (Stone 2004:130), in this case, other farmers and agricultural experts. Therefore, farmers make meaning out of their interactions with specialised agricultural content and experiences, which can then be applied as knowledge. By using the WhatsApp groups, Farmer 2 expressed that he learnt to interact with different types of farmers and ideas while learning from other farmers' challenges, such as market and pest constraints, and how to overcome or treat them. Similar results were experienced by Farmer 6 who uses the Facebook group to learn about poultry farming. In the Facebook group, people share their ideas with others and get information about their queries and answers (from other farmers or the iShamba agricultural experts' team). Farmer 6 does not use other iShamba digital services on the phone, but instead, he asks in the Facebook group when he has a question. In this way, he uses the Facebook group similarly to premium subscribers using the WhatsApp group. In this study, it is underexplored how digital services impact the learning capacity of farmers by using social networks and connecting with other farmers. This is an interesting area for further research, together with how meaning is co-created on these ICTs and how to implement new forms of user-driven knowledge co-creation (contrary to the more expert-driven knowledge dissemination that digital services, such as iShamba, represent today).

The role of human intermediation for managing innovation in organisations is underestimated by ICT-based projects (Sulaiman V. et al. 2012:342). The same could be applied to the role of ICT-based projects to provide customised and locally relevant content and to offer different educational formats that meet different needs, such as field advisory visits and training courses. For instance, Farmer 6 believes that the reason why he is not keeping a larger farm is that he did not attend any course. He added that "some farmers that have attended a general course share information in the Facebook group, such as, for example, how to produce your own chicken feeds. They send you the information via PDF Reader for 200KES." But Farmer 6 did not want this information, he wanted to take a course about general information first. He explained that once he has it, he does not mind obtaining what he considers additional or complementary information. Farmer 6 feels that he needs

to have general knowledge first to be able to use the other information correctly. He expressed that he does not see how someone can get all the information from the Facebook group or instructions in a pdf without having been first trained in poultry farming. This example shows evidence of two factors. On the one hand, the limitation in the amount of information than can be provided through ICTs in comparison with an in-person training course. On the other hand, the role of human intermediation in facilitating the learning process compared to getting the information in a pdf. Furthermore, Farmer 6 said to be waiting for a training course in the Facebook group to be published so he can join. There were one last year, but he saw the advertisement late and he could not join. It was a three-day course providing general information about poultry farming for 2.000KES in Nairobi. Farmer 6 thus suggested that iShamba could also organise training courses once a year. "They could offer different courses about farming that complement their digital services and help farmers to have good production systems," he explained. Accordingly, some of the limitations of digital learning can be satisfied with the support of human intermediation.

Moreover, two farmers (9, 11) reported taking courses in agriculture besides using the digital services. For example, Farmer 11 was in a three-day course about mixed farming, imparted by the Ministry of Agriculture at the nearby Farmers Training Centre free of cost (the only cost was transportation). He explained that "when I hear about a course, I always attend. I have attended many of them, as two or three per year. For example, there is one coming in June with about 70 attendants. But you know, some people do not want to attend these courses." Farmer 11 gets to know about the courses through the Meru Dairy Co-operative Union (MDCU), of which he is a member. So being part of an organisation might influence the access to and awareness of courses, which could be also the case of being subscribed to a digital service. Hence, the social capital contributes to the human capital of farmers.

Another aspect that is underrepresented in this study is the potential of digital services to connect sellers with consumers. The study however provides some anecdotal evidence on this which could be further explored in future studies. As explained on the iShamba website, iShamba provides their premium subscribers with information about when, where and for how much to sell their products. Free subscribers can get this information on request through the Q&A SMS service at no cost. Two out of three premium subscribers (2, 9) reported using the WhatsApp group either to find buyers for their products or to know where to buy or find something, assisted by the iShamba team of experts. Farmer 2 said, "iShamba assists you in marketing your products and directs you to where to sell them. Similarly, they assist you when you need to buy something. They connect you with the closer seller and provide you with the fair price information so you can negotiate." He gave the example of a Friesian cow that he bought from a nearby

farmer, a breed that he has requested, although he commented that "finding the cow was not easy, which was bought from an Italian priest in Maua." Additionally, Farmer 9 said, "I sell most of the production to the middlemen, but also market online with what I have in the iShamba WhatsApp group. Not so much though, just a few." Thereby, farmer-to-farmer interactions through the WhatsApp group not only allow for the exchange of information (competence) but also products (material). Thereby, the provision of a smartphone can help farmers to market their products through social networks. Farmer 10 said that "there is a nursery here, which just post the seedlings on the WhatsApp group and, in one day, they are sold," so he is planning to buy one to sell his cows. Undoubtedly, in this context, ICTs facilitate the emergence of market participation and innovation, which goes beyond the mere provision of market price information explained by Sulaiman V. et al. (2012) and studied by Baumüller (2015, 2018).

6.1.7. The perception of digital services and the use of digital information

This thesis found that the perception of digital services determines the use of digital information. Most of the farmers that participated in the study did not present opposition to obtaining digital support, which is obvious since they subscribed to the digital service. However, this study has identified two general patterns of how farmers perceive digital services: First, farmers who *lack the motivation to learn* (meaning) do not make good use of the digital information. Lacking motivation has been identified due to two factors: (1) Ignorance of digital services; (2) Farmers rely on other sources of information. Second, farmers find digital information services as *the only available alternative*. This aspect makes us question if the farmers use the digital services because they are good for them or because they do not have a better option. However, the farmers have described both benefits and *limitations* of their use of digital information and services.

The first pattern of farmers who do not have the motivation to learn is found in Farmers 3 and 5 who do not use the services at all. Farmer 3 received a message about joining iShamba on the mobile phone and decided to sign for the free subscription about two years ago. He checks the messages occasionally but he kind of ignores the information. He seems very reluctant to use the services, since, he explained, he only gets messages about the weather forecast which are not very accurate. He remarked that he faces challenges such as lack of information about pest control, the timing for planting a particular crop or a proper weather forecast, however, he does not try to get the information through the Q&A SMS service. It might be that he has not been informed about the different uses that he can make out of the iShamba services. Free subscribers have indeed limited options, but still, other users have positively valued, for instance, the Q&A SMS service. Farmer 4

said to be very satisfied since iShamba is helping her with information issues, "when I have an issue or a question about my farm, I just write an SMS to iShamba and they provide me with the answer shortly." Like Farmer 3, Farmer 5 registered for the free subscription before the pandemic about two years ago. He explains, "I was looking for those who could finance me when I saw an advertisement on social media. Then, I was called; I explained my situation on the phone; I was answered that they will get in touch with me and until today. What does iShamba do? Personally, who is iShamba? I do not know who iShamba is." Farmers 3 and 5 have shown ignorance and mistrust about iShamba. Ignorance and mistrust can interrelate, not knowing about iShamba creates mistrust and the lack of trust in iShamba prevents the interest in learning about it. Both farmers might have subscribed to the iShamba services out of pure curiosity about what they could get from it but iShamba has not been able to convince them about the usefulness of their services. It indicates that just a call and an SMS are not enough to inform and create trust with the user, and consequently they do not perceive digital information services as a helpful source of agricultural information.

Additionally, this study shows that establishing a new network, such as obtaining information from digital services, is affected by the already established networks. Farmer 5 gets the agricultural information that he needs from the sub-county agricultural extension officers. He explained, "once I suffered a loss of 200.000 KES. The causes were poor management and lack of knowledge. I did not know how to take care of the tomatoes in a way to make them grow well and enable me to make profits. It was when I was starting, before consulting the extension officers. Since then, I go to the office and take them to my shamba at my cost. I also tip them for lunch. Then, I invite all my neighbours for a meeting when the officers are here. One of the meetings was attended by more than 100 people." He believes that not many farmers know about the possibility to consult the extension officers, for which he defines himself as an 'enlightened farmer.' "When I started planting pawpaw for the first time, I had to consult them four times, from the seedling to the harvesting time. And the local people that I employ to do the work were there that day with the officers learning the whole process." The farmer has thus established a relationship of trustworthiness with the extension officer (network). He has requested their help several times, so he knows what to expect from them and how (competence), has evaluated the results from previous interactions and is satisfied with them (meaning), and the solution offered from them goes in line with his philosophy and farming strategy (integrity). Hence, trusting a source of information is a dynamic phenomenon, in which the first stage of pre-trust conditions unfolds into the second that depends on the perception of trustworthiness and that continues throughout the length of the relationship (Bews & Martins 2002:14). Therefore, trust in a source of information depends on the establishment of social ties, and once the ties are established, as this study shows, it might inhibit the use of other

sources. Farmer 5 disposes of an established source of agricultural information which he considers more reliable than (iShamba) digital services. From a social practice perspective, digital information competes with the already established competence and meaning of agricultural extension.

Conversely, Farmer 8 opts for using digital information services instead of the agricultural extension services, which he finds more complicated. He explained that "bringing the agricultural officers to my shamba costs me the time to go there and pick them, the money to pay for their transportation and lunch, and sometimes they might not even be (available) there." Most participants agreed with this perception of the agricultural officers. Therefore, public services are being discouraged in favour of digital services to provide agricultural extension. From the MLP, digital information services represent a landscape innovation that is articulated to replace the agricultural extension services with limited availability.

Trust in the source of information is an important factor determining the use that farmers make of them, including the agricultural officers, the digital services, and the Agrovet stores. For example, Farmer 9 uses the Q&A SMS service to ask for information about which pesticide to use for a particular crop. Farmer 9 explained that even though she could have asked for the information about pesticides directly from the Agrovet store where she buys them, she prefers to have the information from iShamba beforehand. She explained, "I would rather get the information from agricultural experts before getting to the store. Agrovet might not have learnt in the same way that the experts of iShamba." Similar issues of trust were also manifested by other farmers who explained how, even if they should, Agrovet stores are not qualified; since the owner can obtain a license but then employs dependents who do not have the required qualifications. Farmer 10 complained that "there was a day that I had a problem with some tiny insect, I went to our (Agrovet) market here. I wanted a chemical that would preserve my seedlings. The one that I was given was horrible. It did not work. They are just selling. They want to make a profit. Some do not even know what it is." Talking with Farmer 11 about a cow that he had on heat, he complained that "private providers, such as Agrovet, might tell you that they service you with a good breed but after you realise that the outcome is of a very poor one. But because the union is not after making money, they will give you the right breed. So, this is the problem with these agents." Here the farmer was also reflecting the benefits of being part of the MDCU which provide members with agricultural advisory services. Overall, the agricultural officers and Agrovet stores are not supportive to farmers in the context of the study, and farmers perceive digital services and the iShamba team as qualified experts.

6.1.8. The limitations of digital information services

This thesis has found that digital information presents some limitations, which are worthy to extend in another section, as they can infuse further investigation about how to improve or define what cannot be simply done throughout the phone.

1. Diagnosing and treating some diseases digitally.

Farmer 8 complained that "no one is coming to see how you are doing on your shamba, it would be good when they (iShamba) come." Farmer 8 noted that even though the phone is good, it is not enough. For him, a physical visit of an expert can be much more helpful than sending pictures on the phone and sometimes necessary. This limitation was apparent in the case of Farmer 2 who had an issue with the poultry and sent the description and pictures to the WhatsApp group. The iShamba team of experts diagnosed the anal prolapse that is a consequence of constipation and he had to apply Liquid Parafin and Stressmix. He followed the instructions but 9 of them died. He emphasised that they died because of another disease and had not the time to send pictures to iShamba and get a response. This shows evidence of the limitation of digital services to diagnosing and treating some diseases that require physically examining the animal. Instead, Farmer 11 reported not using the (iShamba) digital services to treat or diagnose animal diseases but calling to the veterinary doctors when the animals are sick. It must be considered that Farmer 11 is a member of the MDCU from where he can get access to veterinary services. He explained that "the union does not ask for money and directly discount it from the milk that I sell to them." So, the union does not only provide more trusted services than private providers, according to the farmer, but also facilitates its accessibility. On the contrary, Farmer 2 pointed out that iShamba was the only available option to get advice. In any case, digital services are not effective in supplanting veterinary services that require a medical visit. However, digital services could improve their service by providing or finding veterinary and field advisory visits to users at an affordable price.

2. The unavailability of specific skills and knowledge.

Considering that the study participants are not the most marginalised poor farmers, and therefore, the least educated, this study assumes that all participants know how to read and interpret messages and make proper use of their mobile devices' basic functions. This was also confirmed during the visits, in which it was possible to observe to some extend the digital skills of the participants. However, it should not be overlooked that digital skills present a problem for the less educated farmers.

In addition, the use of digital information, as well as the learning capacity of users is affected by previous skills and knowledge. This was expressed by Farmer 6 who

did not want to obtain information about poultry farming in a pdf, but he wanted to obtain general information in a training course first. He felt that he could understand it better and increase his learning capacity in this way. Similarly, someone who has never heard about a certain agricultural practice, such as the push-pull technology[8], would hardly show interest or ask questions about it. This was observed in Farmer 1 who was not using the Q&A SMS service at all. His capacity to formulate questions could be hindered by two factors. First, the inability to use the digital information due to financial constraints as explained in the previous section 6.2.2. However, this factor assumes that the digital information through the Q&A SMS service necessarily involves the purchase of inputs and ignores other types of information that do not require the acquisition of inputs. Considering the diversity of digital information reported by other farmers in section 6.3.3, the lack of skills and knowledge (competence) about a certain practice could be a second limiting factor to formulate questions in the Q&A SMS Service. During the time I was there, Farmer 1 showed to be eager to learn about the push-pull technology (meaning), and he was able to bring a Desmodium plant from a neighbour (material), so the major impediment to implementation was know-how. In this case, the lack of knowledge about push-pull technology limits the farmers' capacity to formulate questions about it. This is another aspect for further research that can shed light on the limitations to assist farmers digitally who perform poor management.

The limitation to formulate questions due to the lack of knowledge might be especially noticeable in the case of free subscribers who receive no information about Agri tips on crops and livestock and have no access to the WhatsApp group. Even if the information that you can get in message might be limited sometimes, Farmer 10 said that "once you get a little information, you can go and expand it, if you have the interest." He explained that you can go into the internet and obtain further information, although it might be that not everyone knows how to use, and have access to, the internet.

3. Inaccurate digital information.

While the weather forecast and planting advice might be useful to plan the season, and some farmers were satisfied with the service, others have complained of the weather forecast not being accurate and have consequently failed in their planting plan. For example, Farmer 10 complained, "they were predicting to receive a very large amount of rain (111mm) in the next 7 days. Well, I am still waiting for the

[8] The push-pull technology was developed as an integrated approach for managing stemborers, Striga weed and soil fertility. It consists of intercropping maize with two locally available plants (Greenleaf Desmodium and Napier grass). The companion plants have several functions; Desmodium repels 'push' stemborers and produces chemicals which inhibit Striga attachment to maize roots, and provides nitrogen fixation enhancing soil fertility and increases fodder production with low water and nutrient requirements; Napier grass attracts stemborers to deposit their eggs/larvas reducing their reproductive capacity (Pickett et al. 2014).

rain. I am not criticising them too much, but if they have the weather forecast from the whole of Meru County, just do not send the same to everyone. Sometimes, I even used the weather forecast from Isiolo, which is more accurate to my location. These days, we have smartphones and GPS, so I am just saying that there are means to provide more precise information." This contradicts the information given on iShamba's website that they provide weather forecasts that are accurate to 9km from the farmers' locations, although it might be that some locations are not correct in the system. Nonetheless, similarly that adequate information can direct farmers to improve their farming practices, inaccurate (weather) information can lead the farmers to make wrong decisions. Farmer 10 complained, "I actually planted so much maize because I was expecting more rain." The crops were additionally infected with fall armyworm. He continued, "when there is little water is when the fall armyworm attacks much." Meaning that water as a control method was not available this year and at the same time, the lack of water makes it harder to invest in any other control method. He concluded, "this is a lost project, you cannot put money on it. The lack of rain is preventing me from putting money on pesticides." This proves that relying much or only on digital information and predictions can also lead to poor management with disastrous consequences. Therefore, technology must be used to serve humans, not humans being served by technology, meaning that farmers should not base all their decisions on predictions. The farmer could have counteracted the information with other sources or planted half farm with maize and the other half with another crops that requires less water.

4. Limited level of participation.

Farmer 10 said, "I try to learn from iShamba as much as I can. However, you cannot rely only on iShamba, the information that you get is limited. They give you some information, but you want to know more." He explained that "sometimes, they also even inform me on what program (Shamba Shape-Up) to watch on the TV, especially on the weekends. They give you that information so that you learn from the TV station as you carry a program (Agri tips)." This way, users can complement the information obtained on the (iShamba) SMS with the information obtained on the TV program. Talking further, Farmer 10 said that the Agri tips are programs of about 5 SMS a week with information about a topic of your preference. He added that "they might give you a half answer. Then you have to wait until the next day or two days to get the other information in the next message. Now, why should I wait if I have the access to go on Google?" Farmer 10 continued, "I would not say I learnt it from iShamba. iShamba, yes, I have got it through them, I came across them. But, you know, now there is also another interesting me. I always go through Google. Google has more information because it gives you what you want to know. It is not random information like iShamba, if you want to know about something you go and google about it. If it's a crop, a seller, or anything." The farmer noted

some benefits and negatives outcomes of using the internet. On the one hand, "Google will be more specific because it will be answering the question that you are asking. If the question does not come satisfactorily, you ask again. But with iShamba, how do you ask again? And the way that I am understanding someone is programming those answers." The farmer was referring here to the fact that the Q&A SMS service only allows for a one-way communication where the user can make a question and get an answer but cannot reformulate the question in multiple ways and obtain the answer according to oneself interest as Google does. On the other hand, the farmer said that the information on the internet can be a scam, you can find someone who is a liar or pictures that do not represent the reality. Additionally, the farmer also acknowledged that "you google for more information, but even the information on Google is limited sometimes." This suggests that digital information tends to be incomplete and there are gaps that are left for the user to guess.

6.2. The social sustainability of digital information services

The social aspects of agroecosystem management entail the health and well-being of farmers, the generation of knowledge and skills, and the meaning associated with diverse agricultural development models. This section discusses how the analysis of farmers' use of digital information services through a social practice perspective contributes to social sustainability, especially the aspects of knowledge generation and the meaning associated with sustainable agriculture in SSA.

The three elements of material, competence and meaning to perform sustainable agriculture lack in diverse ways amongst the participants in the study. The lack of material elements might be the most painful to see of all the constraints. Some participants showed good knowledge about farming but are unable to set up a profitable farm due to the lack of resources. This is extended to all the participants at different levels. Furthermore, the lack of knowledge presents an issue in the context of the study. Without a doubt, many, although not all, of the participants could substantially improve their farming systems with adequate knowledge. Especially knowledge related to ecological processes, such as the interactions among living and non-living systems, including species, nutrients, and energy, that could help to improve the management of soil, water, and pest without requiring the acquisition of inputs. However, lacking material and competence are not the only elements impacting the capability of farmers, but also their motivations and perceptions of the reality around them. The common meaning of farmers is highly influenced by being "smart" and having a profitable agribusiness. This might

employ agricultural techniques that are largely available and seen amongst their neighbours, such as flooding irrigation, fertiliser use, and pesticide use. Hence, the possibilities and capabilities of farmers to improve their farming systems are conditioned by the combination of these three elements, which constitute their farming practices as entities and as performance.

In the context of the study, farmers often lack economic means for pest control, including pesticides. Farmer 1 had the fall armyworm pest in the maize and the only control methods applied were handpicking and some sort of wooden trap with a rope whose effectiveness can be questioned. Since Farmer 1 does not apply any chemical inputs, the production is 100% organic. However, pest management is rather deficient. He could neither access other pest control methods that require economic spending nor did he know other preventive methods such as planting in the long rain season in March and avoiding late planting or practicing the push-pull technology. Here the inability of the farmer to acquire pesticides due to economic constraints is not offset by the adoption of pest management knowledge. This means that, generally, digital information services are not directing farmers to integrate other pest management techniques that could help them to reduce their dependence on pesticides. Hence the increased diversity of knowledges is still limited and conditions the social sustainability of farming systems.

In such situations, digital information services such as iShamba have the potential to contribute with locally applicable innovations just using the materiality that is available to farmers. For example, Farmer 2 has a neem tree on his farm which he considers a medicinal tree, used to heal malaria and other diseases. However, he did not know that it can be used as a biopesticide to treat the fruit fly pest that he had in his mangos by extracting a solution that is applied with spray. This type of practices that are accessible to farmers in terms of material, competence and meaning could stimulate African agriculture and put smallholder farmers on the front line of safe and sustainable food producers. Nevertheless, some farmers are sceptical about traditional knowledge and miss the integration of scientific elements with more traditional knowledge that can be beneficial for managing their farms. They have complained about the inefficacy of pesticides, but they claim better or stronger pesticides that solve their problems. However, how helpful can it be to apply a better pesticide if you do not integrate it with other methods of pest control? Therefore, part of the limitations of competence and meaning in farming is understanding what to do, how to do it and why. It would be interesting to further study how educating farmers in plant biology digitally might contribute to the social sustainability of farming systems in resource-poor contexts. This might include content about the life cycle of pests, the impact of different practices on the soil microbiome, or what is and how to change the pH of the soil.

The social sustainability in agriculture is strongly affected by the generation of practical knowledge and skills, which can be complemented by the acquisition of discursive knowledge. For example, Farmer 2 was grafting indigenous trees with modern varieties that are more productive. He found the idea and knowledge on a guide to best practices in commercial production of mango and passion fruit. The guide was part of a pilot programme implemented by TechnoServe and funded by Coca-Cola and the Bill & Melinda Gates Foundation, which aimed at enabling 54.000 participating growers in Kenya and Uganda to increase their productivity and double their fruit income. This is a living proof that farmers can effect a change through education if there is interest. Nonetheless, grafting is a practice that the farmer can implement, as he gets the indigenous trees from the surroundings and the seedlings from the Oxfam nursery at a price that he can afford. This shows evidence of the potential of information dissemination, which can be also done digitally, that relates to the socio-economic circumstances of farmers.

This thesis found that the two farmers (2, 10) more knowledgeable about plant biology and ecological processes were both equally interested in digital information and carrying out a high level of experimentation on their farm. For Farmer 10 "farming is experimental." For two years, he has started using acacia trees to support the passion fruit plants. This was his own idea, and he explains that "the acacia tree fruits are very nutritious, and the animals like them. This way, as the animals are eating, I am eating as well." This shows that practical knowledge and skills are generated in processes of experimentation in which the integration of new practices is tested. However, Farmer 10 added that "if you make a mistake that year, you are lost, you will not recover. This is why it is better mechanical work than farming work that involves biology." However, farming involves biological elements that must be considered in agroecosystem management and embodied in the tacit knowledge of farmers. Another important source of information has resulted to be the internet, which some farmers use to complement their farming practices. Learning digitally presents an opportunity to increase the learning capacity of rural farmers, but it needs to complement, not replace practical learning. Farmer 10 did not only show to be very skilful learning digitally and using the internet, but he also showed to be very active on his farm. Consequently, discursive knowledge can be experienced and learnt in the practical activity of farming when the required elements that constitute such practice are available.

Farming is a process in which farmers integrate new practices into the system when the required elements are in place. Hence agricultural development has a tempo that depends on the circumstances of each farmer and their ability to introduce new elements. Farmer 10 stated that knowledge without money is useless, referring to the importance of considering the materiality involved in the implementation of agricultural practices. Thereby, the cruciality of accounting for the circumstances

of each farmer and their ability to introduce new elements into the system. Taking into account that some of the material constraints faced by farmers are out of the scope and capacities of digital information services, other organisational and institutional structures such as the role of the government must be considered. The potential of digital information services is to provide diverse information in accordance with the different circumstances of farmers that can be easily adopted into the farmers' knowledge. This implies that in resource-poor contexts, digital information services must promote pro-poor innovations. This study suggests that biological-based innovations that are less dependent on input application can be more effective in such contexts. In this way, digital information services could communicate, facilitate, and articulate agricultural research to the need of farmers.

Overall, farmers have shown to be pragmatic and learn about what is of interest to their projects, meaning that their interpretations and use of knowledge are highly influenced by the ability of practices around them. The coevolution of values that legitimise the diverse models of agricultural development depends on the common meaning that is constructed in the social context of farmers. Hence, a key point to sustainability transition is how to transform societal structures to have an impact on the farmers' management skills. Sustainability transitions theory argues that a profound transformation implies interventions in changing physical infrastructures, the rules and legislations prevailing in food value chains, the dominant cultural assumptions and discourses, and so on (Grin et al. 2010:2). Therefore, the social sustainability of farming systems does not only depend on digital information services but also the availability of biodiversity-based innovations in terms of material, competence and meaning. While digital information services have limited capacity to influence the material world around farmers, they can still play a decisive role in co-generating competence and co-constructing meaning together with farmers. However, both must be framed within the material possibilities of resource-poor contexts that characterised SSA if they aspire to have a larger impact.

7. Conclusion

7.1. Outline of findings and future research

This thesis intends to contribute to the literature on ICT to educate smallholder farmers in resource-poor contexts and the ICT trajectories for social sustainability in SSA agriculture. For this purpose, this thesis has focused on the local context of farmers to analyse their use of mobile phone-enabled services by answering *how digital information merges, coexists or competes with diverse bodies of local knowledge.* This thesis considers knowledge as a social process in which the ability of farmers to make informed decisions is produced and reproduced within the large social structures of *material, competence* and *meaning* in which farmers act and practise.

One of the main findings which are repeatedly enunciated throughout this thesis is that effective innovations must consider the contextual realities of farmers. This argument is supported by the observation that digital information which relates to the socio-economic circumstances of farmers is easily adopted. Not forgetting that in resource-poor contexts, the lack of material resources is a reality, also hindering the use of digital information. Therefore, digital service providers must carefully pay attention to these contextual realities to provide innovations that can be employed by and extended to these potential users, the poor smallholder farmers. This study found that biological-based innovations are more adequate considering both the cost of implementation and the accessible materials. It is also discussed here that digital services are offering several options to farmers which contributes to social sustainability in agriculture by increasing the diversity of knowledges. However, it is not well-defined how the multiplicity of values in digital information corresponds to different models of agricultural development.

This study brings a more actualised vision into the work of Sulaiman V. et al. (2012) who argued that ICTs do not generally contribute to putting new knowledge into use. However, while ICTs might put new knowledge into use by increasing the diversity of knowledge, they might not encourage innovation that leads to a sustainability transition. Probably the biggest difference between the study of

Sulaiman V. et al. (2012) and this thesis is that Sulaiman V. et al. (2012) focus on all types of ICTs including radio, TV, and media, and this thesis focuses only on the use of digital information services through the mobile phone. This study found that digital information services, despite taking a top-down approach to information dissemination, facilitate farmer-to-farmer interactions throughout WhatsApp and Facebook groups. Even though agricultural experts still rule over the type of solution in assisting farmers' issues, farmers are engaged in the discussions and co-construction of meaning associated with agricultural development. However, it is not clear if ICTs, as intermediaries, direct innovation and research towards attending to the demands of poor rural farmers, which would require further research. Nonetheless, this thesis found that farmers are provided with similar innovations that the ones available at the Agrovet stores, although farmers reported trusting the digital services more. Digital services also provide farmers with additional information that is not available at the Agrovet stores, and which is diverse as far as it attends to different realities of farmers. However, it seems apparent that the level of participation is limited to the availability of innovations in the context of the study, rather than encouraging the generation of innovations.

Digital services have proved to involve different types of innovations, niche and regime, according to the needs of farmers. Therefore, the fate of sustainability depends on the development policy paradigm fostered at the landscape level. Accounting for the social context of farmers would imply that digital information not only considers the competence element of social practices but also the material and meaning elements. The material element has appeared as a persisting constraint in the implementation of new agricultural practices. The participants of the study showed little knowledge about biological-based innovations, meaning that the increased diversity of knowledge is also limited. And the meaning associated with agricultural development is constructed in accordance with the social context. This indicates that innovation does not necessarily come by itself, but it requires that the institutional arrangements shield, nurture, and empower it by adjusting the structural landscape. Farmers showed to adapt the digital information to their contexts and combine it with other sources of information. Sometimes, coexisting both chemical and biological input-based innovations as part of the same local knowledge. While digital information is adapted to the different needs of farmers, it is not completely customised. Customised information would imply that, for example, it considers the appropriate dose of fertiliser for a particular plot according to a soil test. In addition, generating site-specific agricultural knowledge would imply that it also considers the socio-economic circumstances of farmers so that farmers adopt it, such as farmers' accessibility to soil test in this case. However, changing the trajectory of agricultural development to a biological-based approach would mean that it considers other factors, such as crop rotation, green manure, cover crops, bio-fertilisers use, etc. to gradually enhance soil health.

This thesis also found that the perception of agriculture, traditional knowledge, and modernity conditions the use of digital information. For instance, discursive scientific knowledge that is already present in the local knowledge of farmers did not present resistance to being adopted. Traditional knowledge and science showed to be decisive not only in the use of digital information but also in the agricultural model performed by the farmer. However, digital services proved to be effective in the dissemination of information about chemical use and management and influenced practices among farmers in the context of the study. Digital services have been useful in creating awareness about health-related issues and as a result, farmers have changed their practices associated with such issues. For example, farmers have understood the importance of PHI indications and thereby changed their perception and meaning of chemical use concerning health. This shows evidence of the potential of digital information services for the co-construction of meanings and values associated with diverse models of agricultural development.

The role of human intermediation appeared to be fundamental in educating or assisting farmers, either through field advisory visits or training courses that can complement digital information. Digital information presents limitations in both the amount and the complexity of information. When digital services have shown to be effective to disseminate information about the minimum space between plants, the appropriate dose of fertiliser, or the recommended PHI time, digital learning through SMS might be limited to educating farmers about more complex practices such as intercropping or poultry farming. Some farmers also reported finding difficulties accessing the information on their phones, who considered field advisory visits and training courses important aspects that could complement the digital services. While providing field advisory visits or training courses would likely account for some of the current limitations of digital information, the increased cost of the service requires studying its feasibility further. Therefore, digital services could facilitate farmers with access to training courses and veterinary or field advisory visits at an affordable price. Not being clear if digital services might also facilitate the payment exercising similar effects to cooperative unions that are highly valued and trusted among the farmer members. Neither is clear how the public governments and international agents could support such services, also considering that there exists already an infrastructure of ineffective public agricultural extension services.

This thesis has left some aspects underexplored. The first is the impact of digital services on the learning capacity of farmers through increased connectivity on social networks. The second is the impact of digital services on the market participation of farmers. Digital services that offer farmer-to-farmer connectivity could present a niche innovation in terms that they could enable farmers to directly sell their products digitally. This is considered a niche innovation because farmers

are allowed to participate in the market without the need of the middlemen who often take benefits from them. The third is the impact of digital services on farm workers, a perspective that was not covered in this thesis. This would be an interesting way to investigate how digital information impacts the poorest and most marginalised farmers.

Another finding is that the farmers' perception of digital services determines the use of digital information. Farmers showed to not make "good" use of digital information when they lack the motivation to learn either due to ignorance of digital services or reliance on other sources of information. This reflects an issue of trust in digital services that might be influenced by the limitations of creating trust just by calling or sending an SMS. Mistrust in digital services might be partly reversed by informing farmers about the possibilities within the services, however, another part will undoubtedly come by making the farmers believe that the services can solve their problems. This includes attending to the material constraints by, for example, providing solutions that are accessible to farmers in material terms. This thesis has found examples of both, in which digital information is, and is not, effective. This is a task for the digital platforms that aim to improve their impact to scrutinise further how to complement their services where they are not so effective.

This study found that digital information services are generally perceived as qualified experts in comparison with the Agrovet dependents who sell agricultural products. Digital information services are also perceived as the only alternative to the non-existent public agricultural extension, and could consequently, represent an important advance in providing science-based agricultural advice and services. However, farmers must know what to expect from digital services, they must believe that digital services can help them, and they must be satisfied with the proposed solution in terms of integrity with their agricultural development model. Farmers do not present opposition to being assisted, always that it helps them to improve their situations, that is the sustainability of their farming system.

While appearing beneficial to farmers in certain cases, this thesis found that digital information services present some limitations. First, diagnosing and treating diseases that require a physical examination. In such cases, digital services could complement their services by helping farmers to access veterinary and field advisory services. Second, engaging farmers with poor management and inadequate local knowledge in the formulation of questions that fits their own interest and necessities. This aspect has been vaguely explored and requires further investigation to understand how different skills, including digital ones, might affect the learning capacity of different farmers. Third, digital information that is inaccurate might lead to wrong decisions. It is important to acknowledge that technology is designed to serve humans and not the way around. Therefore, when

technology might help the farmer, the latter must consciously take the decisions. And fourth, the level of participation showed to be limited on the digital information services in the case of the free subscribers who are allowed to ask questions, but the answers only allow for one-way communication. Not for the premium subscribers who participate in the WhatsApp group, being said that the impacts are underexplored in this study.

7.2. Implications for policy and practice

This thesis found that the reach of private agricultural extension through digital services is limited in the poorest and most marginal areas. Most of the study participants did not have access to agricultural extension and did not know other neighbouring farmers using digital services. This was more pronounced in Igembe which is the most marginalised region in the study. Additionally, services such as the Agri tips that are used by free subscribers have been cut due to being financially unsustainable. Let's assume that the free subscribers are the poorest users, at least these services are directed to them, although it might also attract other farmers who are not in such category. There must be also taken into consideration that the poorest farmers do not probably use digital services and are not represented by this study. This correlates with the study of Muyanga and Jayne (2008) who found that private agricultural extension does generally not attend to farmers in remote areas due to the lack of profitability. This thesis found that digital information services rather than extending to areas where agricultural extension and advisory services were non-existent, as expected in the literature, public agricultural advisory services have been diminished or worsened as private initiatives came in. Therefore, Muyanga and Jayne (2008) suggest that private initiatives, digital or not, must, rather than compete, complement the public agricultural extension.

ICT presents a lot of possibilities for sustainability, but its design must align with the interest of end-users and the large society. Private initiatives are thought to be more effective in providing agricultural advice that works for the interest of the end-user (Muyanga & Jayne 2008), however, their contributions to the large society are undiscovered. This study found that digital information services integrate diverse models of agricultural development. Here is where policy that works for the benefit of society must foster models of agricultural development and practices that not only work for the benefit of individual farmers and households but the whole society. Such as, for example, promoting practices that enhance soil health as a strategy to increase the agricultural productivity of the country in the long run, in opposition to the application of fertilisers. This might also involve supporting companies and research institutions that are developing technologies that work for such propose, including the production of charcoal, biofertilizers and alike;

informing farmers through campaigns about which products to use according to the different soil conditions; and providing farmers with access to soil test. This thesis found that digital information services represent a landscape innovation that is articulated to replace public agricultural extension services with limited availability. However, the emerging institutional arrangement compound of private initiatives, public governments, and international agents do not shield, nurture, or empower innovation that works for the benefit of poor smallholder farmers.

Within the field of business and management studies, which generally emphasises the role of private providers to generate innovation through competition, few scholars have put attention to the role of universities for research and development and the role of the government in providing financial and regulatory support (Marchant 2015:7–8). Nowadays, science acknowledges the importance of both natural and social processes in the production and reproduction of agricultural knowledge that accounts for the sustainability of farming systems. This means that reducing the technology and the management gaps, between those who have access to science and those who have not, do not imply the transfer of information but the sharing of research capabilities to co-produce knowledge and meaning that accounts for both ecological and social processes. This thesis found that there is a lack of knowledge about biological-based agriculture among smallholder farmers in Meru County, and digital information services make limited efforts to reduce this knowledge gap. It might be that the latest technologies, such as pheromone traps and semiochemicals are not circulating in those regions due to marketing constraints in a global economy, however, there could be promoted other practices that optimise water, soil, and pest management and that are poorly practised.

It is unprovable that digital information services achieve Bill Gates' (2018) vision of making ICT work for the poor by serving mobile phone-enabled services for agricultural development. This vision expects that technology affects positive adjustments in market constraints without human intervention. So far, farmers' participation in generating contextualised agricultural knowledge is still limited throughout the digital services, and the trajectories of agricultural development are undefined in the context of the study. Therefore, to prevent innovation from following the same patterns of dominant innovation processes while being directed to tackle the needs of poor and marginalised communities in a sustainable manner, the role of the government and international agents to organise this transition is unquestionable in several ways. The dysfunction of the social system does not come only from a lack of institutional trust but also from the disconnection from public support for rural farmers. When private initiatives are promoted to solve inefficiency issues in public extension services, digital information services also show to be dependent on donor agents and limited in providing certain services that require field visits or in-person training.

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Appendix 1: Example of Field Notes

Farmer 2 is halfway through the process of setting up a fruit tree farm, a project that he started 6 years ago. “When I bought the land there were mainly miraa trees, but I never liked the idea of cultivating only miraa, so I cut most of them and started planting different fruit trees.” Farmer 2 is planting different trees on his farm and observing, and testing, which ones work well according to the environmental conditions. For example, the orange tree did well last year, but this year it is struggling because of the drought, however, the lemon tree is doing well. He does not water them; he relies on rain-fed water to manage the farm as he uses the available water for human consumption.

Farmer 2 is very interested in indigenous trees. He came to pick me up from the matatu stop on the main road and we walked to his farm for 20 minutes. On the way, we talked about the (indigenous) trees that we found, and he proved to be knowledgeable about them. He believes that indigenous trees are better adapted and provide more nutrients to the soil (he also talked about the acidity of the soil). “Eucalyptus and pines are good for timber but not for the soil. Conversely, indigenous trees are more sustainable, even though they are not very productive, they are more resilient to climate change.”

As he showed me on his farm later, he is grafting the indigenous trees with modern varieties that are more productive. He gets the indigenous trees from neighbours and buys seedlings from the nursery (Oxfam). The idea and knowledge come from a guide to best practices in the commercial production of mango and passion fruit that he showed to me. The guide was part of a pilot programme implemented by TechnoServe and funded by Coca-Cola and Bill & Melinda Gates Foundation, that aimed at enabling 54.000 participating growers in Kenya and Uganda to increase their productivity and double their fruit income. He also mentioned that some knowledge comes from iShamba. So, he tests the trees that work better on his farm, grafts the more productive and healthy ones with local varieties and distributes them between his neighbours for free. He argues that in this way his neighbours will not come to steal from him. It can be understood that in African cultures social ties are very important and economic or material exchange is an important part of it (Maranz 2001). Therefore, if his neighbours are doing good, they will not come to ask for favours or money from him.

Appendix 2: Codebook

DOCUMENT 1:

(Indexing and organising the data in the first main categories)

A. Constraints, Strategies & Suggestions
B. Improvements due to iShamba.
C. Uses of iShamba services & Complaints.
D. Knowledge management & Social capital.

DOCUMENT 2:

(Coding and reorganising the data in relation to the research question)

A. Knowledge processes due to digital information services:
    a. Obtain information about a particular crop or livestock.
    b. Adoption of new crops and varieties according to different agro-climatic zones and the weather forecast.
    c. Diversification and crop-livestock integration.
    d. Soil health management: minimum tillage, crop rotation, intercropping.
    e. Which chemicals to use for controlling pests and weeding and how to manage them?
    f. Learning from other farmers' challenges and interacting with different types of farmers and ideas.
    g. To know where to buy or find something and where to sell.
B. The integration with other types of knowledge
    a. Cultural pest control methods (physical control, handpicking, wooden trap, spaying a solution with detergent, burning brushwood or cow dung, biological control with chameleons, push-pull system).
    b. Knowledge about biology (indigenous trees, own experimentation to plant crops adapted to semi-arid areas, push-pull system).
    c. Agriculture class at primary school - basic agriculture techniques: apply manure and tillage on the soil, maize intercropped with beans, crop rotation and plant beans, collect his own seeds, make terraces.

d. Agronomists, agricultural extension services and other Ministry of Agriculture training or agricultural expert training as, for example, within the church or the cooperatives.

DOCUMENT 3:

(Coding for themes and rewrite the text in an organised manner)

A. The use of digital information (the adoption of new practices).
    a. Digital information is easily adopted in contexts in which it relates to the socio-economic reality of farmers.
    b. The lack of resources constraints the use of digital information.
    c. Digital information not only put new knowledge into use but also integrate different trajectories of agricultural development.
    d. Social relations and social capital (networks, trust, and common meaning) are important factors in the use of digital information in poor-resource context.
    e. The use of digital information depends on the farmers' perception of digital services.
    f. The limitations of digital information.
    g. Digital information is validated and reconstructed in the social context of farmers
    h. The use of digital information is conditioned by the farmers' perception of modernity (science and traditional knowledge).
B. The impact of digital information services for the social sustainability of the farming system and the wider societal context.

Appendix 3: Fact sheet

How can digital information services contribute to a more transformational change for (poor) smallholder farmers in SSA?

- ◊ Less is more. Digital services to be effective should not overscale their service so that they do not reach more farmers than those who can provide customised and locally relevant advice with the number of available agricultural experts.

- ◊ Generating site-specific content. Digital services can develop instructions about biological-based innovations that have shown to be locally applicable in terms of the materials available to farmers. Some examples are charcoal production, neem biopesticide production, chicken shelter construction with recycled materials, push-pull technology, etc.

- ◊ Promoting farmer-to-farmer knowledge exchange. Digital services can identify niche innovations that work for farmers and promote them throughout the digital network.

- ◊ Connecting local farmers with research institutions. Digital services might present difficulties in generating site-specific content. However, they could exchange knowledge with other digital services, public agricultural extension, and research institutions. Directing research to practice would unavoidably require that digital services, as intermediaries, enable two-way communication among local farmers and researchers.

- ◊ Generating trust with users. A fundamental aspect is complementing digital information with different educational formats that meet different needs, such as field advisory visits and training courses.

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