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Agroecological development in Nigeria

the challenges to its improvement and the potential for mobile-enabled applications to enhance transitioning

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Agroecological Development in Nigeria: The Challenges to its Improvement and the Potential for Mobile-Enabled Applications to Enhance Transitioning

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Ezinne Emeana

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Can Mobile Phone Applications Improve the Adoption of Agroecological Farming Systems in Nigeria?

This is to certify that the above named applicant has completed the Coventry University Ethical Approval process and their project has been confirmed and approved as Medium Risk

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Research declaration

The work presented in this thesis is, to the best of my knowledge entirely my own, any use of materials from others is appropriately acknowledged as reference in-text citations and compiled accordingly in the bibliography. I also declare that all the activities carried out to complete this project complied with the Coventry University research ethics policy.

Signature

Date 11/06/2021

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"*And, when you want something, all the universe conspires in helping you to achieve it*." Paulo Coelho, the Alchemist

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Abstract

Nigeria is still predominantly an agrarian society; the agricultural sector employs around 40% of the entire labour force. Over the last four decades in a bid to enhance agricultural production, various agricultural policies and programmes have been introduced by the government. Based on conventional agricultural techniques these policies have done little to support smallholder farmers and have resulted in negative environmental impacts. Despite all these efforts, Nigeria remains a food deficit nation and a net importer of agricultural produce. Increasing global food and environmental crises, particularly in Africa, have created renewed interest in the viability of alternative approaches to agriculture and food systems such as agroecology for ameliorating these issues. This study had three broad aims: 1) to understand how agroecology is practised and understood in Nigeria; 2) to evaluate the opportunities for wider adoption of agroecological techniques; and 3) to understand the challenges to transitioning from the current conventional farming system to a more agroecological approach. From these aims, five objectives were developed, and these were addressed using a variety of qualitative methods. This study adopted an inductive approach which incorporates participatory action and design science research. A theoretical framework provides the rationale for the study and justification for the methods chosen as this project intersects at different research fields. Qualitative methods were successfully utilised for data collection and analysis, these included focus groups, semi-structured interviews and thematic analysis. The fieldwork research activities took place in Imo and Abia states, in south-east Nigeria. In total, 70 participants took part in the study, this comprised of 40 farmers, 20 extension personnel and 10 agricultural university lecturers, purposively and randomly selected. The farmers interviewed in this study were not familiar with the term agroecology although they understood what organic agriculture was and were concerned about the impact of conventional practices on their environment. Further work is needed to determine if this is replicated in other regions of Nigeria. The examination of the existing agricultural knowledge exchange systems (AKIS) in Nigeria identified two clear strands, a top-down formal system determined by government policy and facilitated by the extension services and a bottom-up, informal system of peer-to-peer knowledge exchange between farmers. Currently, information on agricultural techniques and innovation is provided to farmers through the extension services. A key organisation is the National Extension and Advisory Liaison Service [NEARLS]. Interviews with NEARLS personnel revealed that government agricultural policy was based solely on intensive or conventional farming techniques and there was no expertise within the organisation on agroecology. As the top-down information AKIS is driven by government policy, this is difficult to influence and change in the short-term. Therefore, this study explored potential options to facilitate a bottom-up approach to agroecological transition. Peer-to-peer knowledge exchange is a key aspect of this approach and mobile applications (m-apps) could be used to facilitate this. A scoping review of currently available m-apps in Nigeria, revealed none which support agroecology. The SmartAgroeocology m-app was developed and demonstrated to farmers and extension agents, feedback from participants was positive. In conclusion, this study found that farmers are concerned about the negative impacts of the conventional techniques they use, and they are interested in adopting agroecological practices although they need support to do this. Currently formal support is provided by the extension services, but this is based on government policy which does not include agroecology. This top-down approach therefore does not currently support transition towards agroecological systems. Encouraging farmers to support each other and facilitate peer-to-peer knowledge exchange using mobile technology could instead facilitate a bottom-up approach to agroecological transition. In this study in southeast Nigeria, the potential of this was demonstrated by the SmartAgroecology app. The farmers in this study were very positive about its potential but further work is needed to determine whether these findings are representative of farmers in Nigeria.

Keywords: agroecological systems, transition challenges and opportunities, interactive knowledge exchange.

List of papers and author's contribution

This thesis consists of published and unpublished artefacts. The thesis candidate was solely responsible for the concepts, planning, development and writing of all the manuscripts, as well as undertaking the necessary revisions in response to reviewers' comments prior to publication. More so, the thesis candidate is exclusively responsible for compiling and reporting the entire thesis. All the activities were done under the supervision and incorporation of the feedback from the co-authors.

Peer-reviewed publications

Emeana, E. M., Trenchard, L., Dehnen-Schmutz, K., and Shaikh, S. (2019). Evaluating the role of public agricultural extension and advisory services in promoting agroecology transition in Southeast Nigeria. *Agroecology and Sustainable Food Systems*, *43*(2), 123-144.

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Published conference proceedings

Emeana, E. M., Trenchard, L., and Dehnen-Schmutz, K. (2017). The Current State of Agroecology in Sub-Saharan Africa: A Systematic Review of Research. In *OrgaTrop 2017: International Conference on Organic Agriculture in the Tropics: State of the Art, Challenges and Opportunities* [*in press*], 20-24 August 2017 in Yogyakarta, Indonesia

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Acronyms

ADP	Agriculture Development Programme
AGRA	Alliance for a Green Revolution in Africa
AFSA	Alliance for Food Sovereignty in Africa
AFDB	African Development Bank
AIS	Agricultural Innovation System
AKIS	Agricultural Knowledge and Information (Innovation) System
ATA	Agricultural Transformational Agenda
AVS	Adopted Village Scheme
CIA	Central Intelligence Agency
CTA	Technical Centre for Agricultural and Rural Cooperation
DFID	Department for International Development, UK
ECOWAS	Economic Community of West African States
FAO	Food and Agricultural Organisation
FCT	Federal Capital Territory
FMARD	Federal Ministry of Agriculture and Rural Development, Nigeria
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
GSMA	Groupe Special Mobile Association
HCI	Human Computer Interaction
HLPE	High-Level Panel of Experts
ICT	Information and Communication Technology
ICT4D	Information and Communication Technology for Development
ITU	International Telecommunication Union
IFAD	International Fund for Agricultural Development
NAERLS	National Agricultural Extension and Research Liaison Services, Nigeria
NARIs	National Agricultural Research Institutes
NBS	National Bureau of Statistics
NGO	Non-Governmental Organisation
PAR	Participatory Action Research
REFILS	Research-Extension-Farmer-Input Linkage System
SDGs	Sustainable Development Goals
SFSA	Syngenta Foundation for Sustainable Agriculture
SMS	Short Message Service
TOT	Transfer of Technology

USAID	United States Agency for International Development
UN	United Nations
UNEP	United Nations Environment Programme
UNSDGs	United Nations Sustainable Development Goals
WHO	World Health Organisation

List of appendixes

Chapter 1: Introduction, study background and research aims

This chapter begins with a brief introduction to the challenges facing Africa's agriculture and the renewed interest in sustainable agricultural practices globally. The chapter further describes smallholder farming and the issues that affect smallholder farmers in Nigeria especially in the area of agricultural production and access to agricultural information. It reviews the improvements made by Nigeria's government to promote the extension and advisory system and highlights the challenges to working with the existing top-down approach to agricultural information delivery. Additionally, the chapter explores options for dealing with this top-down approach by understanding the current exchange of agricultural information and methods that can enhance interactive exchange. The chapter evaluates the role of mobile phone-enabled applications in agriculture popularly known in this present study as 'm-apps' – these are mobile phone-enabled applications used for agricultural development that aid farmers' access to agricultural services and information (GSMA 2015). It further explores important factors to consider when embarking on any information communication and technology-assisted initiative such as m-apps that involve smallholder farmers. Furthermore, the potential of m-apps to facilitate collaborative agroecological information generation is outlined.

The chapter concludes by highlighting the importance of the study, aims and objectives, as well as the scope and structure of this thesis with evidence of how each of the objectives was achieved.

1.1 Introduction

Increasing global food and environmental crises, particularly in Africa, have created renewed interest in the viability of alternative approaches to agriculture for ameliorating these issues (Altieri 2017; Food and Agricultural Organisation of the United Nations [FAO] 2015, 2018a; High Level Panel of Experts [HLPE] 2017; Lampkin et al. 2015). Alongside these crises, smallholder farmers[1] face several challenges both in terms of production and in access to available agricultural information (Niang et al. 2014). The general concept of agricultural policies is to assist farmers to improve farm production without damaging the natural resources on which they depend. However, this has not been realistic as global agricultural food systems have continued to be influenced by powerful agri-business corporations that dominate the pattern of agricultural production to the tune of conventional[2] agriculture even in Africa (Clapp 2018; Therond et al. 2017). While aiming to address the food crisis and improve natural resources, the conventional farming systems have increased the problems to the extent of marginalising smallholder farmers and exacerbating climate change (International Panel of Experts on Sustainable Food Systems [IPES-Food] 2016, 2017). Moreover, these systems are characterised by a top-down agricultural information delivery approach which ignores smallholder farmers in agricultural information generation (Cuéllar-Padilla and Calle-Collado 2011). This paradigm involves the agricultural information and/or innovation being developed in the controlled environment of research institutions, agricultural universities and colleges, and passed on to agricultural extension and extension advisory services and then to farmers, who receive the information and implement it (Chambers 1997). The structure is known as Transfer of Technology[3] (Davis 2008). This process is mainly linear and one-way and has long been associated with various shortcomings (Rivera and Gustafson 1991; Röling and Engel 1990). Some critics have argued that this approach reduces farmers to ordinary users of technology and the transfer is mostly aimed at isolated individual farms (Moschitz et al. 2015). As such, various schools of thought have proposed different types of agricultural practices and reforms, as well as promoted ecological knowledge systems

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[1] Smallholders are small-scale farmers, pastoralists, forest keepers, fisherfolks who manage areas varying from less than one hectare to two hectares. Smallholders are characterised by family-focused motives such as using family labour for production and using part of the produce for family consumption (Eastwood et al. 2010; Lowder et al. 2016).

[2] Conventional systems of agriculture also known as industrialised systems depend on intensive use of agrochemicals such as fertilisers, pesticides, herbicides, genetically modified organisms, concentrated animal feed operation and other continual inputs to maximise yield (Seufert et al. 2012). The extent to which these various inputs are used is often regulated by national or regional policies.

[3] In the context of this study, agricultural technologies refer to farming methods (Rogers 2003).

in the bid to sustain food and agricultural systems (International Assessment of Agricultural Knowledge, Science and Technology for Development [IAASTD] 2009; Jayne et al. 2010; Pretty et al. 2011; Röling and Jiggins 1998; The Montpellier Panel 2013). As a result, several different approaches collectively known as sustainable agriculture practices[4] have been promoted (e.g., Carolan 2006; Godfray et al. 2010; Pretty 2008). Of these various approaches, agroecology has (see Chapter 2 for the definition of agroecology and various approaches) continued to gain traction as an approach that is sustainable, viable and compatible with smallholder farmers' traditional or indigenous farm knowledge[5] (e.g., Altieri and Nicholls 2017; Nyantakyi-Frimpong et al. 2016). Agroecology also supports action-oriented agricultural context solutions that involve smallholder farmers' traditional knowledge and promotes co-production of agricultural knowledge (Pimbert 2009; Uphoff 2013; Warner 2008). The increasing interest in agroecology has resulted in various countries especially in Latin America, Europe and a few in Africa to begin to adopt[6] and/or transition (see transition concept in Chapter 2) towards agroecological practices and a few have begun institutionalising and integrating them into their agriculture and food policy frameworks (Ajates Gonzalez et al. 2018; La Via Campesina 2015; Meek and Anderson 2020; Nyeleni 2015; PAN International 2015; Watts and Williamson 2015). In the case of African countries such as Uganda, Tanzania, Tunisia and Malawi, the driving forces for adoption are the government, strong local non-governmental organisations and support from international development agencies (Adebiyi 2014; Bakewell-Stone 2006; UNEP-UNCTAD 2008). Although the progress of adopting and/or transitioning towards agroecological approaches has continued to gradually increase in other African regions (IPES-Food

[4] Sustainable agriculture practices are those practices that aim to produce more output from the same land area, while reducing the negative environmental impacts as well as contributing to natural capital, enhancing farmers' quality of life and promoting the flow of agroecosystems using certain agricultural principles (Kleemann 2012; Pretty et al. 2011).

[5] Knowledge is an organised set of ideas or understanding of skills which is acquired through experience by perceiving or learning and are socially determined, which farmers use in adapting to their farming conditions (Paul 2007). The term traditional knowledge can also be known as local or indigenous knowledge which could be defined as a cumulative body of knowledge, practice, and belief, evolving by adapting processes transferred or exchanged down through generations by cultural transmission about farmers and their environments (Berkes et al. 2000; Colding et al. 2003; Gómez-Baggethun et al. 2012).

[6] Adoption is the integration of new and/or existing agricultural practices and is usually continued by a period of trying and degree of adaptation (Loevinsohn et al. 2013). Also, adoption is a mental process a person undergoes from first hearing about a practice to final utilisation of such practice. This can be rate of adoption and intensity of adoption (Bonabana-Wabbi 2002).

2018; 2020; Nyantakyi-Frimpong et al. 2016; Nyeleni 2015), Nigeria remains a country where agroecological approaches are yet to receive full attention (Olaito 2014).

1.2 The agricultural sector in Nigeria

Nigeria is a populous developing nation situated in Sub-Saharan Africa with huge agricultural potential. The country is situated in the wet and dry climate of West Africa with an estimated 78% agricultural land cover (arable land 37.3%, permanent crops 7.4% and permanent pasture 33.3%), forest 9.5% and other 12.5%. The climate generally varies from equatorial in the south to tropical in the centre, and arid in the north (Central Intelligence Agency [CIA] 2014). Nigeria is a federal constitutional republic made up of 36 states and the Federal Capital Territory [FCT], Abuja. This includes 774 Local Government Areas with a total land area of 923,768 km^2 (CIA 2021). In the post-colonial era (from 1960 onwards), Nigeria has relied heavily on crude oil production for income generation, however, the country is still predominantly an agrarian society with the agricultural sector employing over 36% of the entire labour force (FAO 2017b; Osita-Njoku 2016). More recently, the reduction in oil generated revenue led to the reconsideration of agriculture development (Federal Ministry of Agriculture and Rural Development [FMARD] 2016). Over the last four decades in a bid to enhance agricultural production, various agricultural policies and programmes have been introduced by the government these include National Accelerated Food Production, Fertiliser Subsidy Scheme, Operation Feed the Nation, National Agricultural Land Development, Green Revolution, Agricultural Transformation Agenda etc. (FAO and ECOWAS Commission 2018). Although some of these policies have faded out, the most enduring are the Fertiliser Subsidy Scheme, Green Revolution and Agricultural Transformation Agenda. Also, in operation are the recent National Agriculture Investment Plan and Agribusiness Partnership Framework (FAO and ECOWAS Commission 2018; FMARD 2016). Various studies have argued that the reforms in Nigeria's agricultural sector have had an effect on the procurement of agrochemical inputs aimed at the development of smallholder agricultural production (Alabi and Adams 2020; Uduji et al. 2019), resulting in the shift to more conventional agricultural practices (Medugu and Skudai 2006). Despite all these efforts, Nigeria remains a food deficit nation and a net importer of agricultural produce (Abutu 2014; Kolade 2016).

The aforementioned agricultural strategies are focused on increasing agricultural output through expanding the aggregate area under cultivation, using more agrochemicals, improved seed varieties and using more irrigation (Medugu and Skudai 2006). Often, these techniques derive their sustenance from the agroecosystem and in turn negatively affect the chemical, physical, environmental, and socio-economic structure of the system. Different ideologies have insisted that natural resources should be managed in such a way that they provide a basis for sustained development (Altieri and Nicholls 2017; Brown 2001; FAO 2018). In discussing the relationship between agroecosystem weakening and economic decline, Brown et al. (2000) earlier concluded that sustained overuse of biological systems may aggravate changes that are self-reinforcing and where each stage of the deterioration quickens the onset of the next. In the end, however, agroecosystem production is destined to deteriorate leading to a reduction in food production and economic and social impacts on smallholder farmers (Brown 2001). Moreover, the consequence of these unsustainable practices is already being experienced in the present-day agricultural situation in Nigeria (Medugu and Skudai 2006; Mgbenka et al. 2016). This has resulted in studies calling for more sustainable approaches to farming that are agroecological and exchange of information and experiences based on such approaches (Adebisi et al. 2010; Adebayo 2004; Mgbenka et al. 2016; Nwankpa 2017). Accordingly, Oyekanmi et al. (2008) insisted that the poor performance of smallholder farms is attributed to the lack of use of sustainable practices and farmers' lack of awareness. Attah (2012) argued that for sustainable agricultural approaches to be considered in Nigeria, smallholder farmers must be encouraged by the government and agencies. Similarly, Adebiyi et al. (2020) conclude that exposing farmers to information about the economic and health viability of such approaches can motivate farmers. This, therefore, draws attention to understanding the agricultural knowledge and information system [AKIS[7]] and/or agricultural innovation system [AIS[8]] to clarify who contributes which kind of knowledge and information to decision-making in agriculture and the relationship between them.

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[7] AKIS is a system that links people and institutions to promote mutual learning and generate, share, and utilise agriculture-related technology, knowledge, and information. The system integrates all actors such as farmers, agricultural educators, researchers and extensionists to harness knowledge and information from various sources for better farming and improved livelihoods (FAO and World Bank 2000)

[8] AIS is the network of the agricultural actors involved in bringing about new products, new processes as well as new forms of organisations into social and economic use, including the institutions and policies that influence their innovative behaviour as well as performance (Sulaiman 2015).

1.2.1 Overview of the agricultural extension and advisory service in Nigeria

In African countries such as Nigeria, the primary representatives of agricultural policies at the farm level are the agricultural extension and advisory service agents and they are responsible for the delivery of agricultural information[9] (Apantaku and Oyegunle 2016; Obidike 2011; Sani et al. 2014). In Nigeria, this sector consists of an international agricultural research centre, 17 commodity-based research institutes, the National Agricultural Extension Institute [NAEI], three specialised agricultural universities and agriculture departments in 18 national universities (FMARD 2016b). It is not clear yet what the role of the private sector in agricultural extension entails, because presently in Nigeria, the extension and advisory service is run and controlled by the federal and state government (FMARD 2013). Although various studies have argued the importance of private sector participation in agricultural extension and advisory services as there are only a few private extension organisation present in Nigeria, there is still a need for their explicit functions and policy guidelines (Anchaver 2015; Ayansina et al. 2015; Isife 2010; Sodiya et al. 2007). The federal government provides the most funds for extension, while the state governments execute most of the extension activities. Up until 2001, agricultural extension and advisory services in Nigeria suffered many constraints which include poor funding, inadequate coordination, and disjointed agricultural extension policies affecting their dealings with the smallholder farmers (Anaeto et al. 2014; Chikerenma 2015; Oyelami et al. 2018). However, the last two decades have witnessed dramatic reforms especially in policies and in improving direct linkages with farmers (Naswem and Ejembi 2017). Examples of such improvements include the Adopted Village Scheme [AVS], Research-Extension-Farmers-Input-Linkage System [REFILS], National Agricultural Policy [NAP], and the Agricultural Extension Transformation Agenda [AETA] (Naswem and Ejembi 2017; Oyelami et al. 2018). These reforms aimed at improving the efficiency of the operations of extension services as well as more effectively promoting the delivery of agricultural information (Sani et al. 2015). NAP assigned the various states in Nigeria with the responsibilities of training and capacity building of the extension agents (Federal Ministry of Agriculture and Rural Development [FMARD] 2013; Issa and Issa 2013). The AVS scheme facilitated more effective face-to-face contact between extension agents and farmers (see further details in Chapter 5) and REFILS promoted research and extension activities, as well as linking farmers to suppliers (Sani et al. 2015). Additionally,

[9] Agricultural information is a codified knowledge designed to improve existing agricultural production practices, soil, crop, and livestock management as well as marketing and processing activities (Zezza 2002).

the AETA created a structure to transform the extension system into a demand-responsive, market-oriented and information and communication technology (ICT) driven service (Babu et al. 2020). Given these improvements and the need to promote agroecological approaches (Groundswell International 2019; IPES-Food 2018), the extension and advisory services seem ideally positioned to facilitate collaboration with smallholder farmers which could foster agroecological development and transition.

1.2.2 The challenges facing smallholder farming in Nigeria

Many organisations such as the World Bank in their rural development strategy, use the size of landholding to characterise smallholder farmers (World Bank 2014). The most common definition of a smallholder farm is one that is less than two hectares in area (Conway 2011; Lowder et al. 2016; Salami et al. 2010). The farming methods used by smallholder farmers range from traditional, indigenous growers using no external inputs to those with a heavy dependency on modern or improved seed varieties and agrochemicals such as fertilisers, herbicides, and pesticides (Altieri and Toledo 2011). These smallholder farmers engage in crop and livestock production, forestry, and artisanal fisheries (FAO 2013; Graeub et al. 2016). Recent policy debates at the international and regional levels have highlighted how smallholder farmers are central to addressing food security crises (HLPE 2013; Silva 2014). It is documented that almost 70% of the farmers in Nigeria are smallholders. They contribute to the country's gross domestic product and are the major producer of about 80% of all food consumed (Mgbenka et al. 2015). Over the years, efforts have been made by successive Nigerian governments and some international organisations to enhance agricultural production. Consequently, the country has considerably increased the production land area by reducing the fallow periods, adopting mono-cropping, and embracing conventional food production in order to keep up with the increasing population's demand for food (Akinwumi 2013; Oguamanam 2015). However, these commitments have not yielded the expected results such as food security and improved smallholders' livelihoods (Akinsuyi 2011; Dambatta 2012). The failures have been attributed to constraints such as political, economic, and financial limitations (Mgbenka et al. 2015). But most importantly, the development approach to agriculture (e.g., the Green Revolution Programme) that is characterised by the introduction and promotion of a conventional or largescale system[10]

[10] Farmers are encouraged to adopt one-crop system, apply more agrochemicals such as fertilisers, pesticides etc. and use improved seeds over native ones.

of production has continued to have adverse effects on the farm agroecosystem and has been in forefront of debates (Adomako and Ampadu 2015; FAO 2016; Oguamanam 2015). As a result, smallholder farmers have continued to suffer from various social, economic, and environmental crises (Adeyolanu et al. 2018; Aikhionbare 2015; Nwaiwu et al. 2013; Nzeh and Eboh 2011), beckoning for a more sustainable approach to farming.

Another key problem affecting smallholder farming in Nigeria is the smallholder farmers' inaccessibility to agricultural information when needed. Information and knowledge are essential in the agricultural development of communities and if poorly driven, the farmers may be at risk of underdevelopment (Agbamu 2007; Fidelugwuowo 2020; Obidike 2011). Oladele (2011) observed that limited access to agricultural information is a major factor that has adversely affected agricultural development in developing countries, including Nigeria. According to Arokoyo (2005), the public extension to farmer ratio is very low meaning that extension agents are stretched, and the provision of information is ineffective. In Nigeria, this ratio is estimated at 1:5,000-10,000, much lower than the World Bank approved target of 1:500 (Huber et al. 2017; Ogbe 2016). Agbamu (2006) and Omotayo (2011) found that the disproportionate extension agent to farmer ratio in Nigeria directly affects smallholders' access to information and has resulted in many smallholder farmers not benefiting from extension services. Similarly, Adomi et al. (2003) argue that for farmers to achieve improved agricultural production, they need to access relevant agricultural information. Although agricultural information per se may not enhance productivity unless the farmers are provided with the right type of information and at the right time, using the best medium and with all other vital mechanisms in place, such as ICT facilities or digital technologies that can enhance the process (Sani et al. 2014). Enhanced information and knowledge flow to, from and within the agricultural sector is a major aspect in developing smallholder farming production and linking increased production to compensable markets (Lwoga et al. 2011). Therefore, smallholder farmers' frequent access to useful information (e.g., agroecological information) can help drive sustainable productivity, improve livelihoods, and enhance agroecosystem restoration.

There are other factors affecting smallholder farmers' access to agricultural information. Key amongst them are remote farm locations and poor access roads which also have a direct influence on access to the market (Obidike 2011; World Bank 2014). According to Obidike (2011), smallholder farmers in Nigeria are often faced with various constraints.

A study carried out in Enugu, Nigeria reported that lack of access roads for easy extension agents' community visits affects smallholder farmers' regular access to agricultural information (Obidike 2011). According to the World Bank (2014), the majority of the smallholder farmers and their farm holdings in Nigeria are situated in remote areas. Oyegbami (2018) explored the implication of location and distance of farmers on access to extension service in Oyo State, Nigeria and observed that bad road networks affected available agricultural information to the farmers. Olorunfemi et al. (2020) also claim that the extension of climate-smart agricultural initiatives in southwest Nigeria is limited to a few farm communities due to extension agents' inability to access the communities as a result of dilapidated roads. Their findings provide more reason for an alternative approach to extension services that can ameliorate these challenges.

Having access to agricultural information may not necessarily be complete for these smallholder farmers if there is no medium for feedback. According to Arokoyo (2010), one of the key challenges of agricultural development in Nigeria is poor information dissemination and inadequate feedback between farmers and other relevant agricultural actors. The agricultural extension system in Nigeria is known to be top-down in approach and mainly depends on the use of mass media (e.g., radio and television) and face-to-face contact (e.g., farmer to extension agent) for information dissemination (Nwachukwu 2014). These approaches have been marred by challenges, especially in the area of 'timeliness' and 'feedback' (Bolarinwa and Oyeyinka 2011; Yahaya and Badiru 2002). Moreover, the lack of feedback process means that the farmers are unable to contribute their own or traditional knowledge to enhance situation-specific and farmer-centred agricultural research and information development (Gliessman 2018).

1.3 ICTs/ digital technologies can facilitate interactive communication with smallholder farmers in Nigeria

Information and communication technologies [ICTs] also known as digital technologies are comprised of various technologies used that aid communication and information exchange. These technologies include hardware such as computers and mobile phones, and software such as internet facilities and media for information transmission (Kaware and Sain 2015). ICTs especially mobile phones can connect more people even in remote areas and foster effective information sharing. Mobile phones' efficiency in this aspect has also been demonstrated in Africa (Graham et al. 2012; GSM Association [GSMA] 2017). The use of mobile phones allows farmers to communicate with extension agents, marketing agents and their fellow farmers as well as in learning about new agricultural information (Evans 2018; Fu and Akter 2016). Mobile phones can facilitate more frequent interactive communication and learning amongst the agricultural actors (Yonazi et al. 2012). The many advantages of mobile phones such as affordability, instant two-way communication and user convenience enabled by the increasing penetration and use of internet facilities, motivates international and local companies/developers and vendors to develop various mobile applications popularly known as m-apps[11] to promote agricultural development and learning (International Telecommunication Union [ITU] 2015; Qiang et al. 2012). M-apps are the software applications made for mobile phone operating systems that increase the efficiency of feature or smartphones. These features allow users of such phones to carry out specific tasks which may include audio recording, sharing of graphics, locations, texts messaging, social networking on platforms, and sharing of photos (Asenso-Okyere and Mekonnen 2012; Qiang et al. 2012). Different operating systems such as Google's Android and Apple's iOS play stores, enable third-party providers to create and sell or offer for free apps for customers and allow individuals to download such apps (Apple.com 2018; Qiang 2012). The mobile phone-enabled applications (as in the case of feature or smartphones) can aid feedback and/or interaction in communication and some have been used to facilitate smallholder farmers' access to agricultural information such as credit facilities, market prices, weather conditions etc. (Baumüller 2013; Qiang et al. 2012). Thus, facilitating an interactive platform[12] where farmers and extension agents, as well as other agricultural actors such as the researchers and policymakers, can engage with each other and also enable farmers to contribute their knowledge.

ICT initiatives can sometimes be faced with challenges. As such, studies have argued that various factors should be considered when thinking about using ICT-assisted initiatives[13] to solve perceived problems that concern smallholder farmers (Aker et al. 2016; Dormon et al. 2004; Owusu et al. 2018; Stuiver et al. 2004). Looking more closely into the arguments, it is vital to acknowledge the social processes and power relations that are inherently part of any development or social change (Etzo and Collender 2010;

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[11] M-apps are inbuilt and/or external application(s) that are supported by smart or feature phones (Matteo 2018)

[12] Mobile application platform or platform for short – is a pre-packaged ICT solution that delivers content and services on a mobile phone, manages the content, and may or may not include hosting as well as other services related to managing and operating the platform (U.S Agency for International Development [USAID] 2011).

[13] ICT-based products that are aimed at solving agricultural related problems (Aker et al. 2016).

Chiumbu 2012). Accordingly, Chepkwony et al. (2018) noted the importance of critically evaluating the environment of the potential users of the initiative so as not to exacerbate any existing inequalities that may foster negative consequences. For instance, if the m-apps are not free, require high and expensive data usage or do not running on older systems, this may result in target users abandoning such m-apps. Addressing the capacity needs of the users is also important. Hence, it is imperative to put out a context-specific initiative and to conceptualise its utility in relation to the social structure, as merely providing the initiative may not automatically create a need for it, nor will it foster a culture of use (Avgerou 2010; Hosman 2010). Thus, a participatory approach in the design and development of the initiative could avail the understanding of the intended users' context (e.g., see Bilandzic and Venable 2011; Iivari 2003).

Nigeria's population is estimated at 201 million people of which 172 million are active mobile phone subscribers with over 64 million owning smart and feature phones (Jumia Mobile Report 2019; Statista 2020; Worldometers 2019). The internet penetration stood at 42% in the year 2020 with over 120 million Nigerians having access to the internet and the mobile 3G and 4G internet subscribers amounted to over 86 million (Datareportal 2020). It has also been noted that many farmers in Nigeria have access to mobile phones and a considerable number are connected to the internet (Ogbeide and Ele 2020; Ogunniyi and Ojebuyi 2016; Techpoint 2021). According to Haruna et al. (2013), 66% of the 120 farmers sampled in selected communities in Kaduna State, Nigeria, found mobile phones very efficient for sourcing and sending information concerning their farming business, thus, making it practically possible to attempt the challenge of bridging the top-down agricultural information gap.

The feasibility of using m-apps to address the challenges faced by agriculture was demonstrated in 2011 by Nigeria's Federal Ministry of Agriculture and Rural Development. Under the FMARD's Growth Enhancement Support Scheme [GESS], 20 million smallholder farmers across Nigeria were registered. The e-Wallet component of the GESS scheme rectified the bottlenecks in the fertiliser supply and subsidised improved seed supply (Alabi and Adams 2020; Uduji et al. 2019). E-Wallet allows the farmers to contact agro-dealers directly via the GESS platform using their phones with their requirements (Uduji et al. 2019). Although there may be barriers that still exist for employing ICTs for agriculture development, especially with marginalised communities in the rural areas, m-apps are becoming increasingly important to close the gap in lack of knowledge exchange in agriculture (Aker and Mbiti 2010; Baumüller 2018; Eitzinger et al. 2019).

The use of m-apps in supporting interactive messaging amongst agricultural actors in other countries like India, Kenya and some countries in Latin America has been demonstrated (Eitzinger et al. 2019; Palmer 2012). Sharing experiences and information is essential as farmers prefer to make their decisions based on interactions and their own experiences (Ingram 2008; Wellard et al. 2013). Farmers' preference for taking part in the decision-making process can change the role of the extension agents to facilitators and promoters of knowledge generation as well as strengthen collective production of knowledge (Kiptot and Franzel 2015). Though not all the actors involved will see this type of initiative as beneficial, as some might oppose any such venture, the platform can enhance dialogue and knowledge sharing, and the generation of important agricultural information.

1.4 Linking the efficiency of m-apps for interactive communication to agroecology development and transition in Nigeria

Agroecological approaches are centred on smallholder farmers' knowledge with an emphasis on strengthening horizontal networks of grassroots innovation[14] and farmers' oversight over knowledge production (Pimbert 2017b). The m-apps (e.g., open access) have been credited with supporting the democratisation of agricultural information where communities collaborate and share knowledge (World Bank 2017). Vast quantities of the information held by institutions and individuals are being made visible, publicly accessible and reusable through m-app platforms (FAO 2017; World Bank 2017). Moreover, many governments and organisations such as the FAO, World Bank, Consultative Group on International Agricultural Research etc. are beginning to provide publicly available information using m-apps. These actions have not only enhanced transparency and accountability but have also allowed other private (e.g., farmers) and public research sectors to participate in solving agricultural problems (World Bank 2017). Thus, the use of m-app may create an opportunity for collaborative research and solutions to farming issues based on agroecological knowledge with smallholder

[14] Grassroots innovation is the smallholder farmers' experimentation of their agelong experience (Altieri 2017).

farmers. For instance, the m-app platforms can provide a space for demand-driven innovation where traditional and external sources of knowledge are made available.

In Nigeria particularly, the use of m-apps for agriculture information sharing is still developing and existing m-apps are focused on input supplies (Okoroji 2019). An example is the Hello Tractor m-app which helps farmers to access tractors and other farming equipment, as well as enabling them to send their request to the input suppliers through the m-app (Hello Tractor 2018). Some farmers also use WhatsApp and Telegram to create informal groups where they share information (Okoroji 2019), however, there is no established m-app targeted to facilitate the interactive exchange of knowledge on sustainable agricultural practices such as agroecology amongst smallholder farmers in Nigeria.

There have been other initiatives in Europe to digitise agroecological knowledge, such example includes; the open-source agricultural technology initiatives – Farmhac.net; collaborative project innovation spearheaded by farmers – L'Atelieirpaysan; and research projects using data technologies in promoting biodiversity – Capsella; as well as a platform for documentation and sharing of traditional ecological knowledge and practice – CONECT-e platform, which focus on agroecology-based approaches (Calvet-Mir et al. 2018; Capsella.eu 2018; Farmhack.org 2018; Latelierpaysan.org 2018). Indeed, these emerging initiatives enhance expectations that m-apps are fit for agroecological knowledge exchange and development. Although the use of m-app for agroecology development and knowledge sharing is yet to be explored, the need for strategies that can enhance the transition to agroecological approaches especially in Nigeria is timely called for. To date, no research has explored a framework for creating an innovative interactive platform that allows users to download, access, create, share and dialogue agroecological knowledge in Nigeria. To this effect, exploring this framework is fundamental in laying the foundation and in determining the potential for m-apps to enhance the transition to agroecological approaches to facilitate a transformed agricultural food system in Nigeria. Hence, the aims and objectives of this thesis are detailed below.

1.5 The study aims and objectives

This study contributes to the knowledge about how technology innovations such as m-apps can be incorporated into the agroecological transition process and reshape smallholder farmers' agricultural activities, as well as expose the hegemonic nature of the agricultural information and decision-making processes in Nigeria. Driven on this basis, the three broad aims, and five objectives are outlined as follows:

Aims:

1. To understand how agroecology is practised and understood in Nigeria;
2. To evaluate the opportunities for wider adoption of agroecological techniques;
3. To understand the challenges to transitioning from the current conventional farming to a more agroecological approach.

Objectives:

1. Contextualise the importance of the study by exploring the current state of agroecology in Africa and ascertain the opportunities and challenges in the region;
2. Investigate the role of public agricultural extension and advisory services in enhancing agroecological knowledge and farmers' transition towards agroecological practice in Nigeria;
3. Evaluate farmers' knowledge of agroecology and understand their information needs and sources of information;
4. Evaluate the landscape of mobile phone-enabled services in Africa and ascertain the challenges for sustainability;
5. Develop, demonstrate and evaluate the potential of interactive methods, principally a mobile phone-enabled application '*SmartAgroecology*' for enhancing agroecological transition.

1.6 The outline and scope of the thesis

This thesis is organised into 10 chapters with each chapter starting with an overview and concluding with a summary and further signpost to the succeeding chapter. **Chapter 1** sets the background to the study by outlining the state of agriculture and challenges facing smallholder farming and farmers in Nigeria. It highlights some of the country's agricultural development intervention programmes as well as the need for improvements of the extension services. The chapter further addresses the significance of this study by justifying the need for agroecological transition and identifies the challenges of working with the existing top-down agricultural information delivery approach. After exploring the opportunities of mobile phone application to facilitate interactive exchange of knowledge amongst agricultural actors, the chapter details the need to digitalise agroecological knowledge and why Nigeria makes for an interesting context to situate this study. Finally, the chapter outlines the study's aims and objectives and summarises the chapters that included peer-reviewed articles, conference and unpublished papers produced based on this study's aims and objectives to align with their contribution to knowledge.

Chapter 2 provides a comprehensive literature review on the importance, context, and concepts of agroecology. It highlights the different agricultural practices or approaches that are compatible with agroecology and further explains its specific relationship with smallholder traditional practices and organic agriculture. The chapter also outlines the political economy of agroecological transition and how collaborative sharing of smallholders' ecological knowledge with other relevant agricultural actors can foster transition.

Chapter 3 is based on a **peer-reviewed conference Paper** which situates and justifies the study agenda by detailing the state and need for agroecology in Africa, the benefits of improving smallholder farmers' livelihoods, as well as the drivers of agroecological transition and the challenges hindering the development. This chapter aims to address the first objective of this study which allows it to shed light on the positive impacts of agroecology in helping to achieve the United Nation's Sustainable Development Goals in Africa. This is fundamental and timely for agroecology transition debates in the African context, as the Chapter provides detailed literature about the increasing impact of agroecology on smallholder farmers' livelihood as well as the circumstances that can limit smallholders' transition to agroecology, hence important for future similar research.

Chapter 4 provides the conceptual and theoretical framework upon which the overall study is based on. This chapter details the transition and sustainability theories and more especially the concept of agroecological transition that underpinned this study (i.e. the Gliessman's five-level transition). It further explains that this study is informed by the first three levels of transition that are focused on smallholders' transitioning at the farm level. The chapter also explores some of the behavioural theories that contributes to individual's decision-making and conceptualises the factors that can influence the farmers' and other agricultural actors' behaviour towards agroecology adoption and/or transition. It then unveils the information and communication technology for development [ICT4D] theoretical concepts and how they have shaped agricultural development over the last decade, as well as the theoretical foundations of technology acceptance. The chapter presents the ICT4D value chain and its proposed integration in the development of agroecology and further outlines the methodological approaches that informed this study. This chapter then concludes by presenting a diagrammatic representation of the theoretical framework of this study.

Chapter 5 explains the logical and methodological processes used to actualise the aims and objectives of this study. It describes the study area and justifies the reasons for choosing the selected study locations in Nigeria. The chapter further presents the research design process and details the fieldwork activities with some visual presentations and outlines the analytical process, as well as the strategies that were applied in ensuring a reliable study.

Chapter 6 is an **empirical published peer-reviewed article** which evaluates the study aims and situates them into Nigeria's context. The chapter explores the knowledge about agroecology and the role of agricultural extension and advisory services in this regard. Moreover, it examines the implications of the agricultural policies and extension agents' activities on smallholders' farming decisions. This chapter is directly linked to answer the second and third objectives of this study. It unveils how the smallholder farmers and extension agents in this survey perceived agroecology as well as their knowledge in upholding agroecological practices. The insights gained from this chapter gave rise to the concepts explored in the succeeding chapter.

Chapter 7 is an **empirical unpublished manuscript** which examines the information needs of the smallholders and the major sources of agricultural information. It analyses the AKIS in the study area and classifies the sources of agricultural knowledge into two different categories. The two categories are formal and informal, where the former is from the organised sources and the latter is from and within the local communities. The chapter establishes that the informal sources create opportunities for sharing traditional ecologically based knowledge which are agroecological and highlights the motivational factors that facilitate smallholders' share of such revered knowledge. It further identifies that although face-to-face meetings remain important in knowledge sharing, mobile phones are facilitating access to and sourcing of agricultural knowledge. The chapter then presents a mobile interactive framework that can encourage interactive exchange of knowledge.

Chapter 8 is a **published peer-reviewed article** which explores the landscape of mobile phone technologies used for agriculture in Africa. It identifies the contributions of such mobile phone-enabled application (m-apps) or initiatives towards the improvement of smallholders' livelihoods, as well as agricultural development in Africa. The chapter identifies the reasons why some of such initiatives do not stand the test of time and further outlines the strategies that are relevant in helping to ameliorate the challenges identified to be affecting their long-term impact. It then describes some of the various m-apps, their location and uses. The chapter further provides insights into the role of the policymakers in making sure that agricultural development initiatives aimed at improving smallholder farmers' livelihoods achieve the desired goals. The highlights of this review are important because it shaped the process involved in achieving the fifth critical objective of this study which is recorded in the succeeding chapter 9.

Chapter 9 is an **empirical conference paper** which evaluates the potential of mobile phone-enabled applications to facilitate interactive exchange of knowledge such as agroecological knowledge. It presents the processes of design, development, and demonstration of a mobile phone application known as SmartAgroecology and outlines the identified social, economic, and environmental factors that can affect the wider use of the application across Nigeria. Most significantly, this chapter discovered the importance of the interactive approach and continuous engagement with agricultural stakeholders with a focus on knowledge co-creation and co-learning to enhance agroecological transition. The aim of changing the dominant farming activities of all the smallholder farmers in all regions of Nigeria is ambitious, however this thesis focuses its inquiry within the south-eastern region states of Imo and Abia.

The scoping review and empirical papers described above attempt to answer the overall study's aims and objectives and their individual direct contribution to each objective is illustrated in Figure 1.1 below.

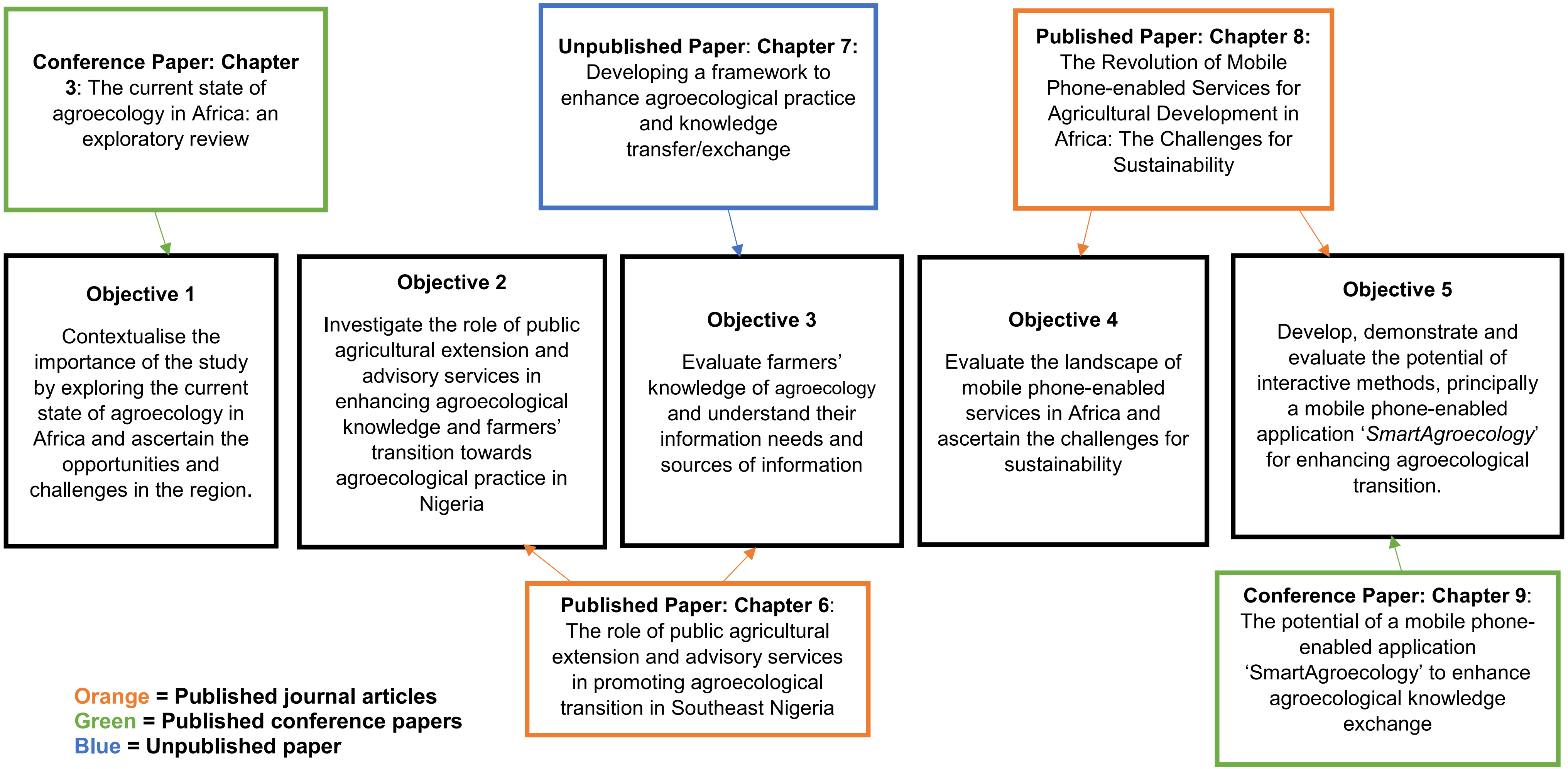

Figure 1.1: Each paper's contribution/relationship to this study's objectives and their respective chapter in the thesis

Chapters 1 – 9 explored different facets of this study and Chapter 10, therefore, critically discusses the implications of the chapter findings and their relationship to extant literature. This chapter justifies the theoretical framings and methods used to actualise this study and further appraises the research process and limitations. It highlights the key findings, recommendations and suggested future research ideas that can advance the scholarship of this field of study. Finally, the chapter presents the researcher's reflection and evaluates the achievement of the overall aims and objectives of the study and a general conclusion.

Chapter summary

This chapter highlighted the importance of this study by detailing the challenges facing smallholders' agriculture and described the various strategies used to improve agricultural production and extension in Nigeria. It explained that the existing agricultural extension delivery system in the country is top-down and there is need for an alternative approach both in agricultural practices and extension systems. It finally outlined the aims and objectives of this study and detailed the scope of the chapters of this thesis. Given an understanding of where the focus of this thesis is situated, the following chapter (Chapter 2), explores the concept and context of agroecology and how agroecological knowledge can be promoted and transition achieved.

Chapter 2: Detailing the importance of agroecology, context, and concepts and the need for transition

This chapter begins with an introduction to the need for the transition to agroecological approaches. It reviews the challenges linked to dominant industrialised agricultural systems and highlights some of the institutions and organisations that are campaigning for agroecology and agroecological approaches. Additionally, the chapter presents some of the policies and activities that are in favour of promoting agroecological development globally and further outlines the concepts of agroecology. Moreover, the chapter details the implication of political-economic structures that could hamper agroecological transition and highlights the role collective efforts might play in facilitating the transition. The chapter highlights the importance of promoting agroecology in Nigeria and Africa as a whole.

2.1 Introduction

'*Every place in the world must build its own agroecology*' Janaina Stronzake

2.1.1 Why is the transition towards agroecology important?

The global demand to increase food production to match the needs of the additional two billion people expected by the year 2050 has resulted in various suggestions for technological changes to agricultural production systems as well as manipulations and counter suggestions (HLPE 2019, 2020; La Via Campesina 2015). An estimate of about 30% more food is needed at the global level, disregarding allocation issues, overproduction, and food waste in some regions of the world (Wezel et al. 2020). Global agriculture is therefore facing major challenges in meeting this demand. Additionally, there has been an increasing demand in the last three decades to not only produce larger quantities of food, but to also achieve improvement towards sustainable agriculture where production is simultaneously environmental-friendly, economically beneficial, and socially fair (Altieri 2017; De Schutter 2010; La Via Campesina 2015).

Significantly, a strong contrasting debate has been ongoing regarding the most appropriate agricultural production practices with which to reach the goal of increased, and also sustainable production of food (e.g., Borlaug 2000; Médiène et al. 2011; McNeely and Scherr 2003; Tilman et al. 2002). Agricultural practices range from high-technology-based, often referred to as conventional or industrialised[15] practices to more sustainable, ecology-based practices. Conventional practices are largely dependent on the intensive use of agrochemicals, hybrid seeds, and a one-crop farming approach. The conventional system is also often characterised by short crop rotations and, where legally allowed, genetically engineered crops and livestock and the routine use of rapid growth hormones and antibiotics in livestock production. These practices have impacted negatively on human health with reports of food-related health risks associated with nitrate contaminated food, high oestrogen levels in milk and rising antibiotic resistance (European Centre for Disease Prevention and Control [ECDC] 2017; Grout et al. 2020; Sharma et al. 2018). There are also negative impacts on the environment; industrialised agriculture has been linked to soil degradation, loss of biodiversity, water pollution and

[15] Industrialised and conventional agriculture will be used interchangeably in this thesis to refer to unsustainable agricultural practices such as intensive use of agrochemicals, improved seeds etc.

shortages (Kremen et al. 2012; Tilman et al. 2002). Nevertheless, industrialised agriculture contributes to increased food production by enhancing the yield of specific crop varieties (mainly cereals) in specific climatic zones (Ejeta 2010; Evenson and Gollin 2003; James et al. 2013). These conventional practices have continued to impact negatively on the social and economic livelihoods of the smallholder farm families by segregating them from the consumers as well as assigning commodity pricing powers to agribusiness companies (Friends of the Earth International 2016; Hendrickson and James 2005). Recognition of these environmental, economic, health, and social issues, has resulted in calls for a transition to more sustainable agricultural practices. Of the many sustainable approaches, agroecology as a holistic approach to the global food system and the use of agroecological practices at the farm level have emerged as the most viable system to tackle these crises (Alliance for Food Sovereignty in Africa [AFSA] 2017; FAO 2018; Wezel et al. 2014; Wezel et al. 2020). Other sustainable agricultural practices that have been suggested as possible options to increase food production are precision farming, sustainable land management, low input sustainable agriculture, conservation agriculture, climate-smart agriculture, ecological agriculture etc. (Gurr et al. 2004; Huang et al. 2002; Lipper et al. 2017; Srinivasan 2006; World Bank 2020). Some of these concepts overlap and some are nested in each other, while they share related principles, they support monoculture, use agrochemicals, and do little to promote productive redesign[16] of agricultural systems (Altieri et al. 2017; Lampkin et al. 2015). Some of these concepts are used by agrochemical corporations to represent their interpretation of the call for more environmental-friendly practices to meet the future demand for food (Pimbert 2017). However, their motives represent a continuation of the existing dominant industrial approach where farmers are increasingly dependent on agrochemical industries for external inputs such as improved seeds and animal feeds. In addition to the farmers running the risk of extinction of their indigenous varieties. As such, many of these concepts have been viewed as contrasting with agroecological principles (see agroecology principles in section 2.1.3 and Table 2.2) and the campaign for transitioning towards agroecology continues (Pimbert 2015; 2017).

[16] Redesign refers to the change of the farming practice using ecology-based processes (Wezel et al. 2020).

2.1.2 Why the support for agroecology?

The need for the transition to agroecology has continued to gain notable recognition and is increasingly promoted by farmer-led social movements (La Via Campesina 2015), scientists (Nicholls and Altieri 2018; Silici 2014), international organisations (FAO 2018b) and non-governmental organisations (AFSA 2016; Oxfam 2014). Although there are several scepticisms about shifting to ecology-based agricultural processes in the present-day challenges of climate change, many studies have confirmed the positive impacts of agroecology and agroecological approaches on smallholder farms and farm families (Barnes et al. 2016; De Nooy van Tol 2016; Franzluebbers et al. 2020). Most of the reports emanate from Latin America with increasing interest from parts of Europe, Asia and Africa (Altieri and Toledo 2011; Anderson et al. 2019; Gliessman 2017; La Via Campesina 2015). The best agroecological systems balance the three essential dimensions of sustainability (i.e., social, economic, and environmental), and ensure that all aspects are included to enhance the livelihoods of both the producer and consumer (Herren et al. 2015). Within this backdrop of increasing evidence of the viability of agroecological systems, the campaign for the transitioning towards agroecological approaches has continued to intensify (De Schutter 2010; FAO 2015; Padel et al. 2018; Rosset and Martinez-Torres 2012). The expectations that agroecological approaches can sustainably feed the growing world population have drawn attention towards strategies that can facilitate the process (FAO 2015; Padel et al. 2018; Rosset and Martinez-Torres 2012). With the support of the United Nations, the FAO has continued to lobby for integrating agroecology into the global policy agenda. They have hosted a series of International Symposia on Agroecology (FAO 2018; Treakle 2018). Furthermore, a consultative study with stakeholders from 34 countries across the globe highlighted agroecological farming practices as part of the post-2015 development agenda (Oldekop et al. 2016), with the examples from Rudel et al. (2009) and Weiner et al. (2014) stressing that the negative environmental and social impacts of industrialised agriculture are increasingly clear.

Similarly, the International Assessment of Agricultural Knowledge, Science and Technology for Development [IAASTD] (2008) reported the need for countries to adopt agroecological approaches to help cope with present and future agricultural production challenges (IAASTD 2008). In 2009, IAASTD established the need for the agroecological transformation of agriculture, food production and consumption and further positioned the idea of agroecology in the global food policy debate (IAASTD 2009). Although not legally binding on the 58 signatory states that accepted the report, the IAASTD report identified policy options that can contribute towards the achievement of people's right to food, improved health and nutrition as well as a sustainable environment (see Beck et al. 2016 and excerpts from IAASTD 2009 in Appendix 1). However, only a few countries including some that were not signatory to the report (see Table 2.1), have so far made any changes to policies, to support agroecological research, to improve farmers' access to/and security over land or support access to markets which empowers agroecological farmers (Copeland 2018; Gonzalez et al. 2018; Kepkiewicz et al. 2018; McCune et al. 2017; Mottershead and Maréchal 2017; Sabourin et al. 2018; Whittman and Blesh 2017). While the support for the global recognition of agroecology as a system for agricultural transformation continues to increase, most countries are yet to implement any form of agroecological policy. While these countries particularly African countries are lagging in the implementation of agroecological policy, the urgency for the transition in Africa has become evident (AFSA 2016; De Schutter 2010; FAO 2015). Thus, despite the campaign for agroecological transition and policy support, strategies for mainstreaming and/or exchanging agroecological knowledge to facilitate the transitioning are yet to be fully explored.

Table 2.1: List of countries that accepted the IAASTD report, ones that made changes and ones that did not approve it

Signatory countries that accepted the report	Countries that have made changes to their policies	Countries that recognised the value of the report but did not fully approve it
Armenia, Azerbaijan, Bahrain, Bangladesh, Belize, Benin, Bhutan, Botswana, Brazil, Cameroon, People's Republic of China, Costa Rica, Cuba, Democratic Republic of Congo, Dominican Republic, El Salvador, Ethiopia, Finland, France, Gambia, Ghana, Honduras, India, Iran, Ireland, Kenya, Kyrgyzstan, Lao People's Democratic Republic, Lebanon, Libyan Arab Jamahiriya, Maldives, Moldova, Mozambique, Namibia, Nigeria, Pakistan, Panama, Paraguay, Philippines, Poland, Palau, Romania, Saudi Arabia, Senegal, Solomon Islands, Swaziland, Sweden, Switzerland, United Republic of Tanzania, Timor-Leste, Togo, Tunisia, Turkey, Uganda, United Kingdom, Uruguay, Viet Nam, Zambia.	Argentina, Brazil, Bhutan, Chile, Costa Rica, Cuba, El Salvador, France, Germany, Mexico, Nicaragua, United Kingdom	United States, Canada and Australia

Source (adapted from Beck et al. 2016; Copeland 2018; Gonzalez et al. 2018; IAASTD 2009; Kepkiewicz et al. 2018; McCune et al. 2017; Mottershead and Maréchal 2017; Sabourin 2018; Whittman and Blesh 2017

2.1.3 What is agroecology, and agroecological practices?

The term 'agroecology' first appeared in a scientific publication written by Basil Bensin, a Russian agronomist in the 1930s (Bensin 1930). In that publication, Bensin used 'agroecology' to describe the use of ecological methods in the research on crop plants (Bensin 1930; Silici 2014; Wezel et al. 2009). In 1965, German ecologist Tischler also wrote a book titled 'agroecology'. In an approach that combined ecology and agronomy, the book analysed the interaction between plants, soils, animals, and climate within an agroecosystem, and the impact of human agricultural management on them (Parmentier 2014; Wezel et al. 2009; Wezel and Jauneau 2011). The scientific research on agroecology increased significantly in the 1970s/80s and as the influence of agroecology grew, it contributed to the concept of sustainability in agriculture at the farm level. Altieri (1995) further expanded the science of combining ecology and agronomy. In a bid to understand the global scale of agroecology, INRA the French National Institute for Agricultural Research compiled a list of scientific publications from 1975 to 2012 and found 2,500 publications that contain the keywords “agroecology” and more than 33,000 international publications that contain related words from 2011 to 2012, since then, agroecology has continued to gain prominence in current literature (Schaller 2013; Wezel et al. 2020).

Today, the concept of agroecology has developed and is often used more broadly to encompass a scientific discipline, a set of practices or approaches and as a political or social movement (Francis et al. 2003; Silici 2014; Wezel et al. 2009; Wibblemann et al. 2013). Agroecology once dealt primarily with aspects of crop production and protection, however, in recent times new dimensions such as environmental, economic, social, ethical and developmental issues are gaining importance (Anderson et al. 2019; Wezel et al. 2009). As a science, agroecology involves a holistic study of agroecosystems, including human and environmental elements (Silici 2014). Agroecology as a movement focuses on the integration of ecological principles into agricultural research and practice, and to approaches that uses ecological processes throughout agricultural food chain (Wezel et al. 2015). Agroecology is embedded in many smallholder, sovereign, resilient and efficient farming systems that respect human rights of all ages and diversity, local cultures, food traditions and social participation of agricultural stakeholders and local knowledge systems (Altieri 1995; Boafo et al. 2016; Dalgaard et al. 2003; FAO 2015; Francis et al. 2003; Méndez et al. 2015; La Via Campesina 2015; Wezel et al. 2015). At the farm level, agroecology favours farming practices based on multi-functionality and biodiversity to enhance the ecological process and reduce the dependence on external inputs (Bonaudo et al. 2014; Duru et al. 2015; Wezel et al. 2014b). For the various dimensions of agroecology, see Figure 2.1 below.

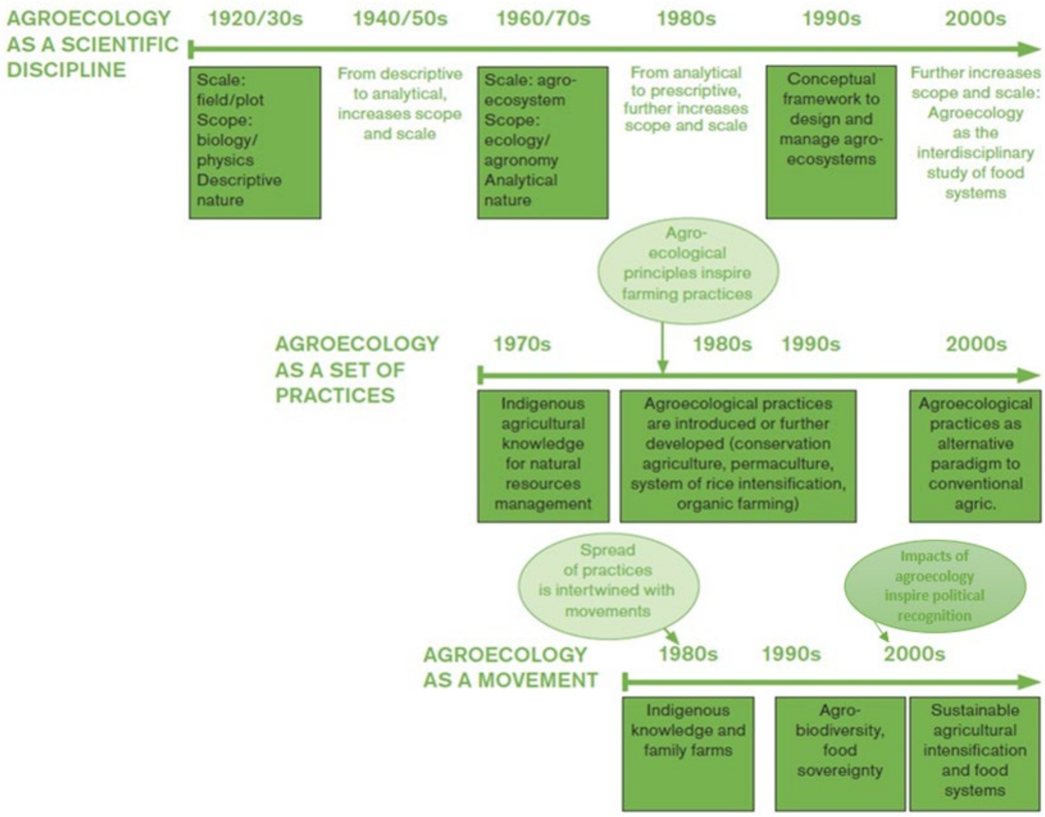

Figure 2.1: The evolving context of agroecology as a scientific discipline (from scientists), a set of practices (from farmers) and a movement (from society) (adapted from Silici 2014; Wezel et al. 2009; Wezel et al. 2014b; Wezel et al. 2018).

In recent years, significant debates regarding how to define, interpret and pursue agroecology have emerged from different schools of thought. Whilst civil societies link agroecology to food sovereignty, national representatives often have a contrasting view of agroecology and consider it as being compatible with sustainable intensification that is focused on approaches to enhance agricultural production per unit of land to achieve food security (Wezel et al. 2020). Although these definitions reflect articulations in line with the three-component manifestations of agroecology (i.e., a science, a set of practices and a social movement), there are interlinkages between and a co-evolution amongst these three manifestations that together form a holistic approach (Agroecology Europe 2017; Gliessman 2018). Thus, conforming with agroecology being increasingly described as a transdisciplinary, participatory, and action-oriented approach across agricultural, ecological, food, nutritional and social sciences (Gliessman 2018; Méndez et al. 2013; Wezel et al. 2020). Several different knowledgeable practitioners have summarised agroecology to simplify its meaning in their own understanding (Altieri 2017; De Schutter 2010; FAO 2018; Gliessman 2007; Wezel et al. 2014; Wezel et al. 2018). For instance:

> De Schutter (2010) explained agroecology as both '*a science and a set of practices. As a science, agroecology is the application of ecological science to the study, design and management of sustainable agroecosystems. As a set of agricultural practices, agroecology seeks ways to enhance agricultural systems by mimicking natural processes, thus creating beneficial biological interactions and synergies among the components of the agroecosystem. It provides the most favourable soil conditions for plant growth, particularly by managing the organic matter and by raising soil biotic activity. The core principles of agroecology include recycling nutrients and energy on the farm, rather than introducing external inputs; integrating crops and livestock; diversifying species and genetic resources in agroecosystems over time and space; and focusing on interactions and productivity across the agricultural system, rather than focusing on individual species. Agroecology is highly knowledge-intensive, based on techniques that are not delivered top-down, but developed based on farmers' knowledge and experimentation* (De Schutter 2010).

Even though some interpretations have been subject to debate (Wezel and Jauneau 2011), other stakeholders have continued to explain what agroecology means in their own terms. Another example is Altieri (2017) who emphasised that agroecology is:

> '*deeply rooted in the ecological rationale of traditional small-scale agriculture, representing long-established examples of successful agricultural systems characterised by a tremendous diversity of domesticated crop and animal species maintained and enhanced by ingenious soil, water and biodiversity management regimes, nourished by complex traditional knowledge systems* (Altieri 2017).

These two definitions both strongly highlight the importance of smallholder farming in sustainable agricultural production. This present study focusses on agroecology as a set of practices supported with ecological science that is governed by smallholders' traditional knowledge and defines agroecology as:

> '*ecological practices devoid of agrochemical inputs and genetically modified organisms in the management of crop, livestock, and agroecosystem restoration aiming to produce significant variety and amount of food, while ensuring sustainable agroecosystems* (author's compilation).

Although agroecological practices are knowledge-intensive these are tailored to local ecological conditions and cultural knowledge, and so they allow farmers to be active participants with nature and knowledge co-creators (Cardoso et al. 2001; Van den Berg et al. 2018). Gliessman (2007) noted that agroecology helped smallholder farmers to improve their indigenous farming practices as an alternative to the high input, agrochemical intensive agriculture promoted by international corporations. Farmers have for centuries used some traditional or indigenous practices that could actually be considered to be agroecological (Silici 2014; Wezel and Soldat 2009; Wezel et al. 2009; Wezel et al. 2014). Although some of the widely accepted agroecological practices, principles[17], and elements (see Table 2.2 below and Appendixes 2 and 3) are being applied in the form of organic agriculture (certified and noncertified), permaculture, and agroforestry, these approaches are different from conventional agriculture (Altieri 2017; Wezel et al. 2009; Wezel and Jauneau 2011; Wezel et al. 2014). Debates exist about total conformity of these systems of agriculture (i.e., organic, permaculture and agroforestry) with agroecology, as all can occasionally use agrochemicals and improved seeds as a management alternative and to enhance diversity (Nair and Graetz 2004; Szott and Kass 1993). Although organic regulations can vary, organic agriculture has strict rules against the use of external inputs and promotes the use of natural fertiliser (including farm wastes). In most markets, to be legally sold as organic, produce needs to be certified and this often results in higher prices and an organic premium. In many food systems worldwide, agroecologically produced crops are often referred to as organically based produce (Freyer and Bingen 2014; Valenzuela 2016; Wezel and Soldat

[17] The fundamentals for the design of agroecologically-based farming systems (Altieri 2017, 2018; Chappell et al. 2018)

2009). See also, the interwoven relationship between traditional, agroecological, organic, agroforestry and permaculture practices in Figure 2.2 below.

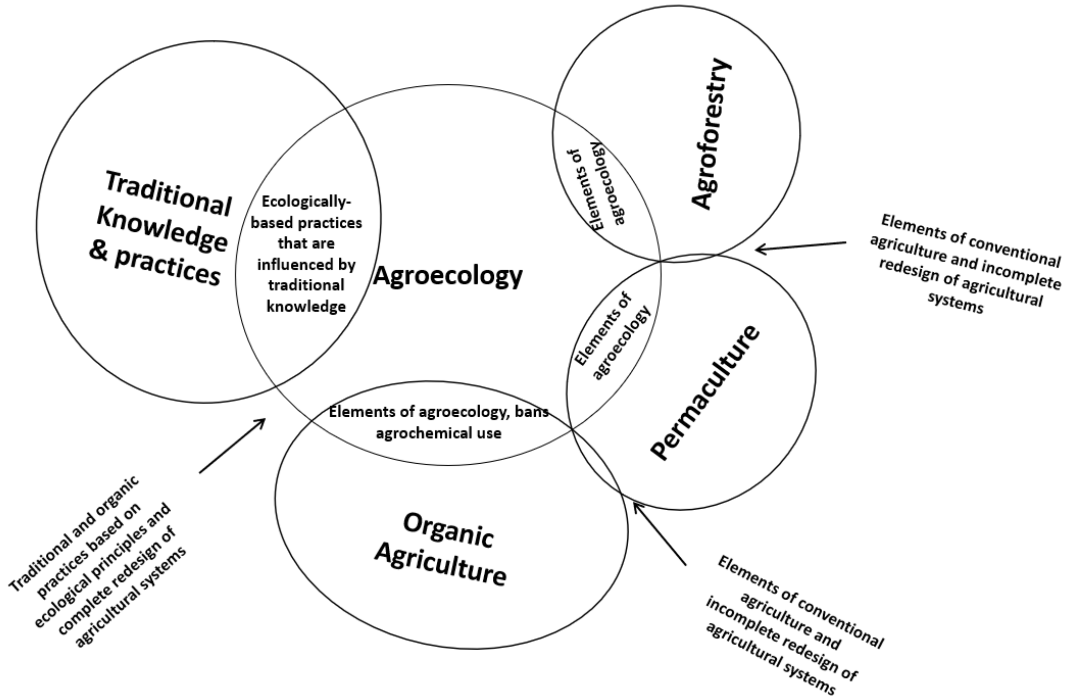

Figure 2.2: The relationship between agroecology, traditional, organic, agroforestry and permaculture practices. The figure illustrates that agroecology is built on traditional ecological knowledge and practices, and amongst other approaches, certified organic agriculture is more closely related to agroecology. Although permaculture can also be organically certified, the three approaches can occasionally support the use of some external inputs and agroecology conforms to the complete redesign of the agroecosystems (Author's insight).

Given this understanding, Table 2.1 below further illustrates the various widely accepted agroecological practices and the 10 FAO elements formed on the basics of agroecological principles.

Table 2.2: Agroecological farm practices on the left (the list is illustrative and not exhaustive) and the fundamental principles and elements of agroecology on the right

<table>
<tr><th>Agroecological farm practices</th><th>The 10 Principles and Elements of Agroecology (FAO 2018)</th></tr>
<tr><td>Intercropping and polycultures</td><td rowspan="10">Diversity – Diversification ensures food security and nutrition while conserving, protecting, and improving natural resources. Intercropping combines harmonising crop species to increase spatial diversity. Moreover, crop rotations, often including legumes and nitrogen-fixing plants, increase temporal diversity and enrich the soil. Integrated crop-livestock systems rely on the diversity of local breeds adapted to a specific environment. Diversification increases productivity and resource-use efficiency by enhancing biomass and water harvesting. Mixed grazing from different species of ruminants decreases health risks from parasitism, while diverse local varieties have a better capacity to survive, produce and maintain reproduction levels in harsh environments.

Co-creation and sharing of knowledge – Agricultural innovations[18] respond better to local challenges when they are co-created through participatory processes. The co-creation and sharing of knowledge play a key role in the process of developing and implementing agroecological innovations. Using the co-creation process, agroecology combines farmers’ traditional knowledge, traders’ practical knowledge and global scientific knowledge. Farmers’ knowledge of agricultural biodiversity and management experience for a specific environment and their knowledge about markets and institutions are at the centre of the process. Both formal and informal education play a key role in sharing agroecological innovations resulting from co-creation processes.

Synergies – Building synergies improves fundamental functions across food systems, supporting production and multiple agroecosystem services. Synergies resulting from crop-animal integration helps crops to absorb nitrogen from livestock manure.

Efficiency – Innovative agroecological practices produce more using fewer external resources or energy. Agroecological systems enhance the use of natural resources, especially those that are abundant and free such as carbon and nitrogen. By improving biological processes and recycling biomass, water and nutrients, farmers are able use fewer external inputs, thereby reducing costs and negative impacts on the environment.

Recycling – More recycling means agricultural production with lower environmental and economic costs. Recycling takes place at farm level and within the landscape, through diversification and synergy building between various components and activities.</td></tr>
<tr><td>Crop rotation and shifting cultivation</td></tr>
<tr><td>Passive biological pests, insects, and disease control</td></tr>
<tr><td>Cover cropping and mulching</td></tr>
<tr><td>Integrated crop-animal farming</td></tr>
<tr><td>Use of compost or green manuring</td></tr>
<tr><td>Reliance on soil biota for soil structure and formation</td></tr>
<tr><td>The utilisation of grassland by multiple livestock species</td></tr>
<tr><td>Use of legumes and symbiotic nitrogen-fixing plants to enhance production and conserve resources.</td></tr>
<tr><td>Efficient water harvesting and on-farm surface water control</td></tr>
</table>

[18] Development and processes geared towards providing strategies to solve identified situation-specific agricultural issues (Letty et al. 2012).

	Resilience – Improved resilience of people, communities and agroecosystems is fundamental to agricultural system. Agroecological practices recover the biological complexity of agricultural systems and enhance the essential community of interacting organisms to self-regulate pest or disease outbreak. **Human and social values** – Protecting and enhancing rural livelihoods, equity and social well-being is necessary for sustainable agricultural systems. As a bottom-up grassroots paradigm, agroecology empowers people to become their own agents of change. **Culture and food traditions** – By supporting healthy, diversified and culturally appropriate diets, agroecology contributes to food security nutrition while maintaining healthy agroecosystems. **Responsible governance** – Sustainable agriculture requires responsible, effective, and efficient governance structures at different scales from the local to national and to global scale. **Circular and solidarity economy** – Circular and solidarity economies that reconnect farmers and consumers make innovative solution for living at the local level while ensuring the social foundation for inclusive and sustainable development. Agroecological approaches promote fair solution based on local needs, resources, and capacities, creating more sustainable and equitable markets. Promoting local supplies increases farmers' income while maintaining fair price for consumers.

Source (Adapted from Altieri 1995, 2002; Barrios et al. 2020; FAO 2018; Hoffmann et al. 2014; Lampkin et al. 2015; Wezel et al. 2014; Wezel et al. 2020; Wojtkowski 2006).

2.1.4 The relationship between indigenous or traditional practices, organic agriculture, and agroecological practices

Traditional farming practices have nourished the world's populations for centuries and continue to feed people in many regions (Koohafkan and Altieri 2011). Moreover, traditional farming practices have played a significant role in the development and establishment of scientific knowledge in agriculture (Sandor and Furbee 1996; Singh et al. 1997). Farmers throughout the globe particularly in developing regions use traditional or indigenous practices for minor and major crops, as well as for livestock management (Jackson et al. 2007). Although technology-based agriculture has been adopted by farmers in every corner of the world, almost 2.6 billion people still use traditional agricultural practices (Dixon et al. 2001; Kremen et al. 2012). Smallholder farmers are stewards of traditional agricultural practices and they adjust to environmental changes using their indigenous knowledge and experience (Lasco et al. 2014). According to Altieri (2004), for centuries, traditional farmers have developed diverse and locally adapted agricultural systems, managing them with ingenious practices that often result in both community food security and the conservation of agrobiodiversity. They preserve genotypes through unique and valuable traits within their traditional livestock and crop varieties that tolerate environmental stresses including climate change (Gonzalez 2011; Johns et al. 2013). In Africa, smallholder farmers cultivate about 80% of all farms and their traditionally managed fields have frequently been confirmed to be equally productive and more resilient to farming shocks than conventional managed farms (Altieri 2004; Kuivanen et al. 2016). High vegetational diversity and a multifaceted system of indigenous knowledge are the important features of the traditional farming system in the region (Altieri et al. 2015; Boyce 2006). Mixed cropping and crop rotation which are traditional practices not only decreases the risk of crop failure, pest and disease but also diversifies the food supply and enhances the soil organic matter (Sauerborn et al. 2000). Thus, many ecologically-based traditional agricultural practices can be considered to be agroecological practices (Altieri 2002; Gliessman et al. 1998; Wezel et al. 2014; Wojtkowski 2006).

For organic agriculture, the understanding of the overlapping relationship with agroecology is quite variable in the literature. This can be either: 1) they are considered as synonyms – that is, organic agriculture being perceived as the technical translation of agroecology; or 2) as completely different approaches; or 3) as different strategies for marketing (Barberi et al. 2017). Thus, the relationship between both concepts can be somewhat unclear in the sense that some see agroecological systems as a stricter version or interpretation of organic agriculture, while others see it as a more relaxed or more lenient implementation of organic principles (International Federation of Organic Agriculture Movement [IFOAM] EU Group 2018; Rosset and Altieri 1997; Wezel et al. 2009).

Undeniably, millions of smallholder farmers around the world use organic practices which are also in tandem with the widely accepted agroecological practices without being certified as organic producers (Wezel et al. 2014). These farmers may avoid the use of synthetic inputs that are banned in organic agriculture. Altieri (1999, 2000) referred to these traditional farmers as 'pioneers of the agroecological movement' a phrase that denotes the overall sustainability of their farming practices. In general terms, 'organic agriculture' is often described as 'farming with no agrochemical or synthetic fertilisers', 'certified organic agriculture for export' or 'traditional farming' (Barret et al. 2002; Vaarst 2010). In this context, it is imperative to clarify the difference between organic by design or certification as contrasted to organic by default, where the latter is characterised by a situation where there is no access to synthetic or external inputs. Such situations could be caused by the unavailability or high financial costs of agrochemicals. The former – that is, certified organic, is a legal distinction where the certified products are confirmed to have been produced according to specified standards as codified in national law. As such, the International Federation of Organic Agriculture Movements [IFOAM – Organics International] considers organic as a well-defined subset of agroecology and the certification as a tool, not a criterion. It is, therefore, the practice and not certification that defines whether a production system is or is not organic (IFOAM EU 2018). It is also pertinent to note that at present, compared to Europe, Oceania, Asia and America, Africa has the lowest production of certified organic products (with an estimated 2.1 million hectares) for national and export markets, but with higher potential for organic by default farms based on traditional practices (Tung 2018; Willer et al. 2021). IFOAM regulates organic agriculture with specific guidelines for international standards regarding the production and marketing of organically produced foods (Willer et al. 2021). IFOAM is an umbrella organisation that oversees the work of national organic movements, each nation develops her own organic standards based on those of IFOAM. The East African Organic Product Standards [EAOPS] represents the first multi-country organic standards in Africa which harmonises existing organic standards and practices for five African countries – Burundi, Kenya, Rwanda, Tanzania, and Uganda (Tung 2018). There is an African Organic Agriculture Training manual established by the IFOAM and African Organic Movements which aims to deliver best farming practices to farmers and related stakeholders. However, Pan-African organic standards are yet to be developed. Although different private standards regulate alternative certification for some smallholder farmers, not all African countries have national organic standards, resulting in poor regulation of organic products in the African continent (De Bon et al. 2018; Tung 2018). But the principles of organic agriculture are maintained through the support of IFOAM for farmers by building local markets and promoting participatory guarantee systems (IFOAM 2021). In Nigeria, there are national umbrella organisations such as the Nigerian Organic Agriculture Network [NOAN] and other smaller organisations mainly established in the western part of the country (Olaito 2014). Generally, in Nigeria, organic agriculture (i.e. certified and destined for export markets) is still developing (Mgbenka et al. 2015). The area of certified organic land, including land in conversion, continues to increase, from an estimated 5,021 hectares in 2015 to 55,047 in 2019 (Willer and Lernoud 2017; Willer et al. 2021). Despite numerous activities such as organised programmes, seminars, creation of a national organic agriculture movements and associations geared towards enhancing organic agriculture awareness and practice (Olaito 2014). These activities are yet to transform the organic sector, the proportion of organic farm holdings remains low and certified organic products are still poorly marketed. Most of these activities take place in the western part of Nigeria (Willer and Lernoud 2017). The few certified organic products include honey and lemongrass tea with only 310 producers of certified products recorded in 2017 (Willer et al. 2021). There are other non-certified organic products produced in Nigeria which include turmeric, a local rice cultivar known as ofada, black soap produced from wood ash and herbs, red hibiscus for local soft drinks, tropical fruits, mushrooms, and cashew nuts (AdeOluwa 2010; Kazeem 2010). These products are sold in the local markets (AdeOluwa 2010). For livestock production, a certification system was reported to be in the development in 2010 (Kazeem 2010), however, no recent advances have been made (Oguamanam 2015; Amudavi et al. 2021).

Although some of the principles may vary, there is clearly an overlap between agroecological and organic agriculture practices. Both support a closed system, prioritise soil fertility and maintain biodiversity, promote transition pathways to sustainable food systems and fairness, as well as optimise performance by building upon natural systems rather than increasing external inputs (Arbenz 2018; Niggli 2015). Accordingly, the IFOAM EU (2018) reaffirm that agroecology and organic should not be considered in opposition to each other, rather should be considered through their common practices, synergies, and drivers.

In this thesis, however, agroecology refers to the redesign and management of farming at the farm level in accordance with the practices of agroecology as outlined in Table 2.2, a concept which unlike organic farming does not necessarily mean certification. The principles of agroecology in practice improve soil health, farm productivity and biodiversity, while directly and/or indirectly minimising the effects of the use of agrochemicals on humans and the environment. Additionally, they also aim to enhance farmers' economic viability and income, food and nutritional security as well as promote social change and women empowerment (FAO 2019). In this thesis, therefore, the use of the term 'agroecological practices or approaches' (as in Table 2.2 and Figure 2.2) is used in relation to the type of practical methods which contribute to agroecological systems. Thus, agroecology as a science and movement provides a coherent framework that conceptualises the ecological benefits of the techniques and the need to reinstate them into the agricultural system whilst exposing their socio-cultural and economic impacts on food producers, consumers and the entire agri-food system. Although science informs the practice of agroecology, the full exploration of agroecology as a science and a movement is beyond the remit of this study as it does not take into account the market, food systems and consumer interest. The study expects that the practices will inform the benefits of a sustainable food system. As such, the agroecological practice draws upon and affirms the importance of smallholder farmers' knowledge and is better understood not only as a set of techniques, but rather as principles applied in accordance with the unique context and reality of each farmer (Gliessman 2015; Rosset and Altieri 2017).

2.2 Agroecology and the political economy, can co-creation and sharing of knowledge play a role in the transitioning?

Agroecology as a political movement has the clear aim of transforming agri-food systems and making them more sustainable (Gliessman 2014; La Via Campesina 2015). Agroecology also focuses on people and the agroecosystems and recognises that it is not enough to correct practices on farms; rather it is important to change the underlying political structure; resist corporate control over land, seed and food in bringing about people's right to food sovereignty (Alliance for Food Sovereignty in Africa [AFSA] 2016; Altieri et al. 2017; FAO 2018). These strategies centre on the transformational change in the way food is produced and consumed to improve economic, social, and environmental sustainability, as well as protect the identity and culture of the farming families and respect for all stakeholders. Although agroecology is not a one size fits all approach, it does involve a process of continuous transition based on ecological principles that are adapted to place, as well as social, cultural and political dimensions which are important for its development (Anderson et al. 2019; CIDSE 2018; Chappell et al. 2018). Various studies have illustrated the different strategies that might facilitate agroecological transition (e.g., see Duru et al. 2015; Farla et al. 2012; Gliessman 2016; Magrini et al. 2019). Accordingly, Gliessman's (2016) five-level framework emphasised that agroecological transition should start at the farm level by reducing the use of all types of external inputs across the farm to complex agroecological management that involves fundamental redesigning of farming and food systems. The first three levels describe the farming practice steps farmers can take to convert from conventional agroecosystems, whilst the fourth and fifth levels go beyond the farm to the wider food systems and the societies in which they are rooted, as well as point towards food sovereignty for everybody involved (Gliessman 2016). On the other hand, Duru et al. (2015) described the transition to agroecology as the systemic transformation involving the ecologisation[19] of agriculture and food, which concerns multiple actors such as farmers and supply chain managers and which is marked with a wilful political intention to establish change. Similarly, Magrini et al. (2019) adopted Kremen et al. (2012) concept and outlined that agroecological transition should involve the route of strong ecological modernisation which is based on a more radical redesign and substantial biological diversification of agricultural systems. Magrini et al. (2019) further highlighted the importance of engaging farmers and their advisers in building agroecological knowledge within the farmers' context to strengthen their capacities to change and to adapt. Although these ideas of agroecological transition are focused on the entire food system transformation, they highlight the importance of ecologically based transformation of agricultural systems at the farm level. In this context, agroecological transitions require interrelated fundamental changes in approaches towards production and consumption, knowledge generation and dissemination, social and economic relations as well as institutional frames (Gliessman 2018). This, therefore, makes agroecological transitions multi-faceted and could take place at multiple scales (e.g., farm, geographic, institutional, etc.) as well as involving diverse actors (Farla et al. 2012; Magrini 2019). The various dimensions of agroecological transition make it a complex process, however, the start from the farm

[19] Ecologisation means shaping human interaction with the environment in an intellectual, material, spatial, social, and emotional sense to achieve a sustainable quality of life for all (Duru and Therond 2015; Magrini et al. 2019; Toillier et al. 2019).

level which requires the smallholders' engagement could form a trajectory for change. Thus, this thesis adopts the concept of agroecological transition as a process of strong ecological modernisation – a farmer shifts from managing a farming system with high reliance on agrochemical inputs, improved crop species and low species diversity, to a system managed with agroecological practices and principles. This concept is informed by Gliessman's framework for transition level 1, 2 and 3 (Gliessman 2016) (see Chapter 4 for the characteristics of the transition levels). The notion of agroecology at the farm level can influence the smallholder farmers to embrace their traditional farming values and practices and improve their relationship with others (e.g., knowledge and traditional seed exchange) which may be developed within farming communities at the local, national or international levels as well as contribute to their autonomy in food production (Gliessman 2016; Guzmán et al. 2013; Rosset and Martínez-Torres 2012; Teixeira et al. 2018; Tomich et al. 2011). On this note, this study defines agroecological transition as:

> *The step by step shift from the dependence on agrochemical inputs and institutionalised view of agricultural systems that are based on yield maximisation to an ecologically based redesign of agricultural systems at the farming level that is based on traditional knowledge and practices. This type of transition supports the collaboration of smallholders and other actors in the development, teaching and exchange of knowledge, management of natural resources and cost-effective market linkages at the community through to the national and international level* (Author's definition).

This definition recognises the importance of revitalising existing traditional knowledge of smallholder farmers which has proven effective in the redesign of agricultural systems (Nicholls and Altieri 2018). The shift and adaptation towards agroecological practices by relevant stakeholders (e.g., farmers, extension personnel, etc.) in the context where agroecology is still not widely recognised or practised, should be the central focus in agroecological transition. This implies translating agroecological principles into practical strategies for biodiversity, soil, and water management to optimise production and resilience as in the case of Latin America in the 1980s (Altieri 1999). Accordingly, FAO (2018) in their report on the important elements of agroecology (see Table 2.2) highlighted that agroecological transition will respond better when there is co-creation and knowledge sharing amongst the relevant stakeholders (e.g., educationalists, extension agents, farmers etc.). Nevertheless, as with any structural change, the stakeholders driving such transitions are more than likely to be faced with the entrenchment of the existing policies or models (Magrini et al. 2019; Meynard et al. 2018). Hence, it is important to understand the structural bureaucracies that can prevent or slow transitions towards agroecology which underlies the political-economic control of food systems. These may be in the form of development funding, lobbying, technologies, agricultural media, seed vendors and even research agendas in the public or private national and international research systems as well as the global value-chains controlled by corporations (Holt-Gimenez 2017; IPES 2016; McMichael 2016).

From the perspective of political economy, the dominant food regime is always supported by powerful capitalist and neoliberal configuration that limit alternatives in the agri-food systems (Bernstein 2009, 2016; McMichael 2005). However, through the perspective of political ecology, Giraldo and Rosset (2018) elucidate the campaign for agroecology as 'territories in dispute', which characterises the relationship between institutional structures in the incumbent or existing regime and social movements pushing for agroecology as a political struggle with material and immaterial dimensions. Anderson et al. (2019) term such a situation as the overriding economic and political power of corporate food actors that shape the activities of agri-food systems. Agroecological transition is characterised as a shift from the dominant agricultural system, where the actors holding power within the dominant regime have vested interests in the existing system and may not welcome or may actively resist agroecology or may try to appropriate the benefits of change (Anderson et al. 2020; Geels 2014). As such, the situation is no different in Africa even in Nigeria where although agroecology is developing, large-scale investment in the dominant agriculture (i.e., conventional agriculture) continues to increase (Adesina 2012; New Alliance for Food Security and Nutrition [NAFSN] 2013; Serdeczny et al. 2017). An example of such ventures is the Government of Nigeria's collaboration with the G8 members' commitment to increasing private investment in the agricultural sector (NAFSN 2013). Although understanding the political dynamics is important given the fundamental political dimension of agroecology and its aspirations towards community self-organisation for transition (Anderson et al. 2019; De Molina 2013), a detailed analysis of the power and politics that could influence or hinder the transition is beyond the scope of this study.

2.3 How can agroecological knowledge be mainstreamed and transitioning achieved especially in Nigeria?

The rapid population growth rate in Nigeria raises a concern about the availability, accessibility, and affordability of food to meet the population's demands sustainably. With the increasing records of hunger, environmental degradation, economic and social problems which directly affect the quality of livelihoods of smallholder farmers, scholars have begun to explore other sustainable ways of agricultural production (Nwankpa 2017; Medugu and Skudai 2006; Mgbenka et al. 2016). Fortunately, agroecology has been confirmed as a viable alternative in ameliorating such challenges, and Nigeria is listed among the signatories to the report presented by IAASTD in 2009 which promotes agroecology (IAASTD 2009). While the transition towards agroecological practices has already begun in a few African countries, Nigeria remains one of the countries where agroecological systems are still underdeveloped and not widely spread or practised (Mgbenka et al. 2015; Namululi 2011; Nyantakyi-Frimpong et al. 2016; Nyeleni 2015; Olaito 2014). Thus, developing knowledge and understanding about how to achieve agroecological transition using various strategies within diverse context is crucial. This thesis, therefore, aims to contribute to filling the gap on how the transition towards agroecology can be achieved particularly in Nigeria.

Following Gliessman's transition framework, the thesis engages the smallholder farmers at the farm level to understand their agricultural practices as well as the existing agricultural knowledge and information system [AKIS] and agricultural innovation system [AIS] in the area. This approach aims to facilitate the understanding of the viability and state of any ecologically-based agricultural practices of the smallholders. It further explores the various behavioural theories such as the theory of planned behaviour, social cognitive theory, as well as other factors that can influence smallholders' decision-making towards adopting agroecological practices and initiatives that can facilitate the process. The thesis assesses the use of information and communication technologies [ICTs] especially mobile phone and its enabled applications (m-apps) in agricultural development. Moreover, it deepens the understanding about how m-apps are playing a key role in the development of agriculture generally and ascertains that they can facilitate the interactive sharing or exchange of agroecological knowledge amongst the relevant stakeholders (e.g., farmers, extension personnel, researchers) to enhance transition. In doing this, the theories that underpin the use of ICTs for development and the strategies that can improve the sustainability of such initiatives are discussed. Additionally, it explores the potential to co-create and share agroecological knowledge using a multilateral framework with other formal agricultural actors in the context of increasing complex agroecosystems and weak top-down extension systems. The thesis aims to contribute to the knowledge of transforming the top-down approach to an interactive exchange of knowledge system. Investigating the strategies for changing the entire agricultural system is fundamental, however, the topic is far too broad to engage with within the manageable time frame of this research programme.

Chapter summary

In summary, this chapter has identified the three components of agroecology (i.e., a set of practices, science, and movement) but focused on agroecology as a set of practices and discussed the impact of the other two components, as well as recognised that these aspects are vital in the development of agroecology. It highlighted what agroecological transition depends on and critically emphasised the importance of knowledge co-creation in the agroecological transition discourse. The strategies for interactive knowledge exchange will be further explored and developed in Chapter 7. Moreover, this chapter recognised the importance of political economy and the implication of its influence on agroecological transition. Although the political dimension of agroecology is crucial, its analysis is beyond the scope of this study. What is fundamental in Nigeria’s context and may be Africa generally for agroecological development is facilitating agroecological farming practices at the farm level and enhancing the co-creation of knowledge amongst the actors, hence, the following chapter explores how agroecology is understood and practised in Africa.

Chapter 3: Understanding the state of agroecology, the benefits and challenges, and the need for its development in Africa

At the outset, this thesis aimed to understand how agroecology is practised and understood in Nigeria. However, as the project progressed, the researcher realised a dearth of literature in the area of agroecology generally in Nigeria, therefore, it was necessary to search for and unveil the agroecological activities in other African regions to inform the challenges for transitioning. Hence, this chapter utilised a scoping review method, to explore the current state of agroecology and agroecological practices in Africa. A scoping review is less restrictive than a systematic review and therefore allowed a more flexible approach to literature search. This chapter documents the impacts of agroecological practices on smallholder farmers' livelihoods, detailing how the approaches are contributing to the United Nations Sustainable Development Goals' agenda. Additionally, the study discusses the drivers and motivations for the transition as well as the challenges hindering the transitioning within the smallholder farm context. Based on the findings, conclusions and recommendations are made. This chapter is based on a paper that was peer-reviewed and presented at the International Conference on Organic Agriculture in the Tropics in Jakarta, Indonesia from 20th August to 24th August 2017 as:

Emeana, E. M., Trenchard, L., and Dehnen-Schmutz, K. (2017). The Current State of Agroecology in Africa: A Systematic Review. In OrgaTrop 2017: International Conference on Organic Agriculture in the Tropics: State of the Art, Challenges and Opportunities. The abstract of this paper can be found in Appendix 4.

3.1 Introduction

Agriculture faces enormous challenges due to climate change, the increasing world population, water shortages and environmental issues. Africa's population is set to double to 1.3 billion by 2050 (United Nations Department of Economic and Social Affairs [UNDESA] 2019; United Nations 2017b). The projected population increase is expected to lead to an increase in demand for food production. The increasing demand for food continues to rise with record levels of hunger in the poorer nations of Africa. Rising with the increasing population is the demand for fuel and feed for animals (FAO 2017a).

The COVID-19 pandemic has also, remarkably exposed how vulnerable the current food systems are to shocks and disruptions. Food insecurity is expected to be exacerbated by the consequences of the pandemic and increasing climate change in areas that are vulnerable to hunger (Leippert et al. 2020; HLPE 2020b; Wheeler and Von Braun 2013). Areas such as the West African Sahel and dry savannah that are characterised by climatic variations and irregular rainfall that make crop yield uncertain could be hard hit (Hengsdijk and van Keulen 2002; Hirvonen et al. 2020; Hulme et al. 2005). Alongside these predictions, large-scale food production activities brought about by the green revolution or industrialised model have continued to rise more than any time in history (Farrelly 2016; Wise 2020). Although the green revolution model brought about increased cereal production, these practices could not ultimately provide solutions to poverty, food insecurity and nutrition problems, instead, they harmed the environment and affected human health (Farrelly 2016; Wise 2020). Additionally, over-reliance on irrigation has meant that agriculture has become the major user of 70% of water and cause of deforestation (FAO 2012; Organisation for Economic Co-operation and Development [OECD] 2020; Wakeford et al. 2015). Associated with these practices is the increased vulnerability of crops to pest, disease and insect infestation, decline or loss of aquatic animals and resources.

In response to the inadequacy and negative impacts of the green revolution and conventional agriculture as well as to promote a transformative change in how food is grown, produced, processed, distributed and consumed in Africa, new alternative approaches to agriculture and food systems are gaining acceptance (Boafo and Lyons 2021; De Schutter 2010; FAO 2018a). Amongst these is agroecology and its principles. Although agroecology has been in existence for several decades, it is only fairly recently that the potential of agroecology to transform agriculture and improve food security and sustainability has been recognised (Baker et al. 2019; FAO 2014, 2016a; 2018a).

Agroecology offers a means of achieving the much-needed increase in food production by applying ecological science to agriculture and developing integrated agroecosystems with minimal or zero dependence on off-farm inputs (Oakland Institute 2017). The farming practice includes a wide range of practices such as crop rotation, shifting cultivation, and natural or biological control of pests and diseases. Additionally, short food supply chain systems and other culturally inclined sustainable ways of producing food and managing the soil, crops, animals and the ecosystem are also classified as agroecological. Agroecological approaches empower smallholder farmers because the techniques are developed by farmer-led experimentation and are knowledge-intensive involving highly diversified farms rather than capital intensive (Altieri and Toledo 2011; Gliessman, 2011; Holt-Giménez and Altieri 2013). Agroecology recognises that it is fundamental to bring about food security sustainably (AFSA 2016; Altieri et al. 2017). As such, agroecology is highly suited for Africa's agriculture and is being promoted as a viable farming practice that can enhance the health and socioeconomic wellbeing of smallholder farm families (De Schutter 2010; FAO 2016a). Many studies have argued that agroecological approaches have the potential to improve the resilience of rural communities to climate change, fix the broken food systems and repair damaged landscapes in Africa (De Schutter 2010; Farrelly 2016; Nyéléni 2015; Third World Network 2017).

In this regard, many mainstream international institutions (e.g., FAO 2016) and civil societies (e.g., AFSA 2016; Nyéléni 2015 etc.) have, in fact, relentlessly been campaigning for the mainstreaming of the widely accepted agroecological approaches as well as rejuvenating the existing traditional methods inherent within smallholder farmers' knowledge in Africa. Although there is a body of knowledge that includes documented African case studies that showcase some of the benefits of agroecology and agroecological approaches in Africa (AFSA 2016; 2017), there is limited information about the drivers of agroecological practices and challenges that affect smallholder farmers' transition towards the practice. It has been argued that agroecology and agroecological practices are developing in Africa and however, the uptake of the approaches by smallholder farmers is slow (Biovision Foundation for Ecological Development [BFED] and IPES-Food 2020; Isgren 2016). Therefore, more study is required to understand the current state of agroecology and agroecological approaches within the smallholder farm setting in Africa, hence the aim of this review. Using a scoping review method as postulated by Arksey and O'Malley (2005), this review attempted to answer the questions below:

- What is the effect of agroecological practice in Africa?
- What are the drivers and challenges to the transition towards agroecology?
- Are there opportunities for policy contribution towards agroecological development?

Building on the precise aim and objectives of this review, the following sections detail the methods used for searching databases and identifying the relevant materials used for this study. The summary of the major findings from the literature are then discussed and conclusions drawn with recommendations for further actions that can ameliorate the challenges hindering agroecology transition in Africa.

3.2 Methodology

A scoping review of scientific and grey literature formed the basis of this study. The scoping method allowed the researcher to redefine the literature search criteria as the retrieval of relevant materials progressed. The searches were performed in relevant academic and non-academic databases and websites (see Table 3.1).

Table 3.1: List of data source and their URL links

Databases and Websites	URL Links
UNESDOC	https://unesdoc.unesco.org/
AGRICOLA	https://agricola.nal.usda.gov/
AGRIS	https://agris.fao.org/agris-search/index.do
AFSA	https://afsafrica.org/case-studies-agroecology/
Groundswell International	https://www.groundswellinternational.org/blog/agroecology-a-ground-up-solution-empowering-marginalized-communities-to-address-climate-change-and-forced-migration/
FAO of the United Nations	http://www.fao.org/home/en/
Oakland Institute	https://www.oaklandinstitute.org/
Jstor	https://www.jstor.org/action/showAdvancedSearch
Science Direct	https://www.sciencedirect.com/
Springer Link	https://link.springer.com/
ISI Web of Science	https://wok.mimas.ac.uk/
Scopus	https://www.scopus.com/home.uri
Google Scholar	https://scholar.google.co.uk/

Survey from May to June 2017 and March to September 2020

This study used the term ‘agroecology’ synonymously with other terms associated with agroecology and agroecological approaches. Examples of such terms include ‘organic agriculture’, ‘agroforestry’, ‘crop rotation’, ‘composting’ and other sustainable techniques whose main benefits supersede the profits of conventional practices. As such, the outcome of the techniques described in the references obtained was examined to be within the principles of agroecology as outlined by Sinclair et al. (2019). The searches for data were completed between May to June 2017 and March to September 2020 respectively. There were no time and date limitations applied to the searches due to the assumption that agroecology has existed for some decades since at least the 1930s (Silici 2014). The searches occasionally included Boolean search strings such as ‘agroecology’ AND ‘Africa’, ‘agroecology drivers’ OR ‘motivations’ OR ‘benefits’ AND ‘Africa’, ‘agroecology’ AND ‘challenges’ OR ‘limitations’. The searches were repeated several times to generate more outcome.

The selected studies were restricted to African and single and multiple year studies were considered, provided they fitted the scope of the review questions. A snowball method and critical assessment of the publication references were applied to identify other relevant literature. Studies were primarily selected on the basis that they reported evidence of the impact of agroecology and agroecological practices as well as their contribution to improving smallholder farmers' livelihoods in Africa. After reviewing the published titles and their abstracts, relevant readable texts or data published in English were selected. The limitation of this sole language selection is acknowledged as there may be bias against studies conducted in African countries where the official language or publication language of institutions is not English. Therefore, the researcher suggests further studies to cover this limitation. However, a similar sole language criterion was adopted by some previous studies such as Thorn et al. (2016).

The results of the searches included were national policy documents, conference proceedings, international donors' reports, newspaper articles, reports from research centres, non-governmental organisations and civil society organisations reports. In addition to peer-reviewed articles on agroecology and agroecological approaches in Africa, in all amounting to 66 included publications included.

3.2.1 Analysis

This study does not intend to provide an exhaustive list of materials that explored the impacts and factors influencing smallholder farmers' decision to transition towards agroecology, rather it highlights evidence of the importance of agroecology and issues affecting the development in Africa. By so doing, the analysis of the literature addressed three aspects that are in consonance with the study's overarching research questions. The selected literature was characterised by 1) impacts of agroecology on smallholder farmers' livelihoods which covered the social, economic and environmental aspects as in the outlined United Nations' Sustainable Development Goals (SDGs) (see Table 3.3); 2) the drivers of agroecological adoption or transition which highlights productivity, profitability and affordability as major drivers; and 3) the challenges affecting agroecological development. For the first two, however, the study did not adopt any livelihood impact assessment framework nor any pre-determined concept but synthesised the findings according to context. Although the review reported studies conducted in Africa as in Table 3.2 below, the general recommendations for agroecology improvement in this review are occasionally drawn from studies outside Africa, as the region is still in infancy in agroecological development (IPES-Food 2020).

Table 3.2: List of papers that answered the research questions

Area of emphasis	List of papers
Impacts of agroecology on the social, economic, and environmental aspect	AFSA 2016*, 2017*; Akinnifesi et al. 2010; Auerbach 2005, 2013, 2020, 2019; Bayala et al. 2012; Bayala et al. 2019; Christian Aid and ZimPro 2010; Edwards et al. 2007; FAO 2018; Farrelly 2016; Garrity et al. 2010; Gonçalves et al. 2017; Kassie et al. 2009; Mbow et al. 2014; Mburu et al. 2016; Mentz-Lagrange and Gubbels 2019; Millennium Institute 2018; Oakland Institute 2015; Pretty et al. 2011; Pye-Smith 2010; Soil, Foods and Healthy Communities 2015; The Conversation 2015; Thorlakson and Neufeldt 2012; Traoré et al. 2020; Umar 2014; UN 2017b.
Drivers of agroecology adoption	AFSA 2016*, 2017*; Fitzpatrick 2015; Harrison et al. 2019; Johansson 2012; Khan and Pickett 2004; Khan et al. 2011; Midega et al. 2018; Nyantakyi-Frimpong et al. 2016; Owenya et al. 2011; Pretty et al. 2014; Pschorn-Strauss 2013; Reij and Smaling 2008; Settle and Garba 2011; Silberg et al. 2019; Swiderska et al. 2011.
Barriers	Beintema and Stads 2011, 2017; Biovision Foundation for Ecological Development [BFED] and IPES-Food 2020; Bullock et al. 2013; Business and Human Rights Resource Centre 2015; DeLonge et al. 2016; European Commission 2013; FAMRD 2016; FAO 2016a, 2016b; Friends of the Earth International 2016; Gadzikwa et al. 2006; Isgren 2016; Jerneck and Olsson 2014; Johansson 2012; Kiyani et al. 2017; Meijer et al. 2015; Mekoya et al. 2008; Ndayambaje et al. 2012; Nyantakyi-Frimpong et al. 2016*; Oluwasusi 2014; Shikuku et al. 2017; Tsion and Steven 2019; Tully et al. 2015.

*Publications that appeared in more than one aspect.

3.3 Results and discussion

This review analysed the current state of agroecology and agroecological approaches within smallholder farm setting in Africa. In this section, the findings that corresponded to the important questions that arose from the aim and objectives of the study are outlined into three major themes and subthemes and discussed accordingly.

3.3.1 Agroecology impacts positively on the United Nations' Sustainable Development Goals (SDGs)

SDGs are a set of goals (also known as global goals) that were adopted by nations that are signatory to the programme to end poverty, protect the environment, and foster prosperity as part of a novel sustainable development agenda with specific targets to be achieved by 2030 (UN 2017). Table 3.3 below shows how agroecological practices are helping to improve smallholder farmers' livelihood as well as ecosystems and thereby contributing to the UN agenda.

Table 3.3: Examples of how agroecological practices meet the UN SDG agenda

Sustainable Development Goals	**Agroecology activities that showed a positive impact on the goal**
SDG 1: Eradicate poverty	Agroecological practices such as zero or lower use of external inputs and diversification help improve farmers' income through the sale of the farm produce and less or zero spending on agrochemicals.
SDG 2: Eradicate hunger, achieve food security and improved nutrition and promote sustainable agriculture	Agroecological practices such as mixed cropping, use of cover crops and mulching enhance crop yield and access to diversified food varieties as well as improving soil health and fertility.
SDG 3: Ensure healthy lives and promote well-being for all ages	The zero or lower dependency on external inputs such as synthetic fertilisers and pesticides invariably reduces food-related health risks linked to nitrate food contamination. Agroecological practices promote improved access to diversified food varieties and income. The community cohesion brought by the agroecology movements such as the La Via Campesina, Urgenci, Nyéléni, AFSA etc. enhances social relationship as well as improving the mental wellbeing of members.
SDG 4: Ensure inclusive and quality education for all and promote lifelong learning	Integrated training in agroecological techniques, how to improve health and nutrition for women farmers who disproportionately experience exclusion and poverty, contributes to bridging this gap as well as improving the livelihoods of women and their communities. For example, the Development Institute of Rural Women in Kenya is providing agroecological training for rural women, which makes the women responsible for their individual family's nutrition and income. This also contributes to achieving SDG 5.
SDG 5: Achieve gender equality and empower all women and girls	The integrated training on agroecology contributes to addressing gender inequality and helps to empower women. An example is where the elite group dominated the natural resources in Casamance, Senegal, the women received training in agroecological approaches to enhance their food production. Hence, enabling them to organise themselves, improve their monthly income and access to land, which contributed to reducing inequality.
SDG 6: Ensure availability and sustainable management of water and sanitation for all	The decreased use of water for irrigation enhanced by agroecological practices such as rainwater harvesting, drip irrigation, mulching and the use of cover crops as well as reduced or zero use of synthetic fertilisers and pesticides, reduce surface and groundwater contamination, halt degrading water-related ecosystem and promote efficient water use. The use of biodegradable materials also contributes to sanitation and helps to combat climate change, contributing to achieving SDG 13.
SDG 7: Ensure access to affordable, reliable, sustainable and modern energy for all	Agroecological practices such as reduced, or no-tillage systems and short food supply chains help to reduce energy consumption and consequently decrease carbon dioxide emissions. Agroecology-based initiatives such as reducing

	food losses and waste and locally sourcing for materials and inputs as well as the use of biomass energy help to enhance efficient use of and reliable energy.
SDG 8: Promote inclusive and sustainable economic growth, employment and decent work for all	Agroecological production and support for market models that emphasise local and regional products as well as promote direct link from farm to table, contributes to fostering local economies.
SDG 9: Build resilient infrastructure, promote inclusive and sustainable industrialisation and foster innovation	Agroecology promotes farmer-to-farmer intergenerational knowledge exchange and generates and sustains employment in rural areas. Agroecology adapts to the realities of African agriculture by fostering local knowledge and innovation. Agroecological practices are well adapted to the small plots of the smallholder farmers, the practices do not require major land restructuring or upscaling. Agroecology requires moderate financial investment at the outset and enhances cost savings over time through the use of reproducible seeds, lower or zero reliance on external inputs and the use of nitrogen-fixing plants.
SDG 10: Reduce inequality within and among countries	Agroecological systems support equal access to food, water, ecosystem and Fairtrade. Agroecological practices boost farmer's income, help to reduce poverty, improve food security and nutrition and enhance sustainable agriculture. Agroecology principles prohibit discrimination (e.g., ensuring farmers get fair share and consumers know the source of their food) and promote equality as well as giving priority to the most marginalised (e.g., rural women, indigenous people etc.). Agroecology fosters climate-resilient activities and protects the environment as well as enhances biodiversity.
SDG 11: Make cities inclusive, safe, resilient, and sustainable	Agroecological practices are helping farming communities to become resilient to food and environmental crises as farmers can have access to a variety of healthy food while enhancing crop diversity which contributes to ecosystem restoration. It also encourages a territorial approach to development.
SDG 12: Ensure sustainable consumption and production patterns	Inadequate diets result in micronutrient deficiencies; however, agroecology is playing a vital role as farmers who adopt agroecological practices reported having access to fresh and varied local food varieties as well as an increase in soil fertility and health. By shortening the food supply chain and encouraging local markets, agroecology contributes to a reduction in food losses and waste.
SDG 13: Take urgent action to combat climate change and its impacts	Agroecological practices are helping farmers to be adapting to climate change and related shocks. For example, agroecological practices such as mulching, mixed cropping, agroforestry and crop rotation, help smallholder farm communities in Malawi to adapt.

SDG 14: Conserve and sustainably use the oceans, seas and marine resources for sustainable development	Agroecology supports artisanal fishing and the practices such as reduced or zero reliance on synthetic agrochemicals contribute to a reduction in surface and underground water contamination. The short food supply chain contributes to the reduction in carbon dioxide emission which helps to combat climate change and ocean acidification.
SDG 15: Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, halt and reverse land degradation, halt biodiversity loss	The diverse and heterogeneous agroecological practices contribute to preserving and increasing wild and domesticated biodiversity. Agroecological practices contribute to restoring degraded landscape and enhance underground ecosystem health and soil fertility.
SDG 16: Promote just, peaceful and inclusive societies	The agroecological social movements' action in creating more awareness for smallholder farmers' rights is helping to promote inclusive public policies that are instrumental for supporting farmers willing to transition towards agroecology. Agroecology principles advocate Fairtrade, co-creation of knowledge and local innovation. Agroecology movements fight against land grabbing, injustices and exploitation against smallholder farmers.
SDG 17: Strengthen the means of implementation and revitalise the global partnership for sustainable development	The common goal to promote agroecological practices across Africa has united many individuals, communities, social movements, institutions as well as scientists. The belief in the principles and viability of agroecology brings together different people in partnership to support sustainable development. Agroecology promotes Fairtrade, social justice and food sovereignty to deliver a real impact for local food producers globally.

Adapted from (AFSA 2016, 2017; Auerbach 2013; FAO 2018; Farrelly 2016; Millennium Institute 2018; Mburu et al. 2016; Nyantakyi-Frimpong et al. 2016; UN 2017b)

The review result showed that agroecological approaches are contributing to achieving the elements of UNSDGs (e.g., AFSA 2017; Auerbach 2013; FAO 2018; Farrelly, 2016; Nyantakyi-Frimpong et al. 2016; Mburu et al. 2016; Millennium Institute 2018; Pretty et al. 2011). Because of the positive effect of agroecology, institutions and researchers have continued to stress the need to scale up agroecological initiatives in Africa (AFSA 2016; FAO 2018; De Schutter 2011; Nierenberg et al. 2011; Mentz-Lagrange and Gubbels 2019). Having identified how agroecology maps across to all the UNSDGs as highlighted in Table 3.3, the following sections further detail the outcomes of agroecological practices in smallholder farms.

3.3.2 Agroecology generates income, improves livelihoods and reduces rural poverty

The evidence reviewed illustrated how agroecology helps to improve farm family's household income and has especially helped to enhance the livelihoods of the poor farm families living in places where there are famines, drought and lack of government support (Edwards et al. 2007; Mentz-Lagrange and Gubbels 2019). A meta-analysis involving 63 studies on the impacts of agroecological approaches on the yield of cereal crops across the Sahel area, revealed that practices such as crop rotation, green manuring, intercropping, parkland trees and mulching increased cereal yields (Bayala et al. 2012). AFSA (2017) detailed case studies which showcase the capability of agroecology to enhance food security, improve nutrient intake and health of poor communities. Agroecological approaches ensure diversified and healthy nutrition which is rooted in the traditional food cultures of the rural peasant farm families that practice agroecology. For example, practices such as polyculture (i.e., crops and animals cultivated on the same farm) ensured that major nutrients required are available year-round and help farm families maintain a balanced diet during hunger periods (AFSA 2017). AFSA also reported that the livelihoods of smallholder farmers in some African communities were improved through projects which facilitated training and implementation of agroecological principles (AFSA 2017). For example, Kotoba Sustainable Livelihoods Project in Ethiopia was a 5-year project which promoted agroecological practices. These practices included soil fertility enhancement through composting, intercropping and crop rotation, organic pest management, post-harvest management, and improved animal management. The outcomes included increased crop yields, transfer of skills, capacity building and improved livelihoods for participants (AFSA 2017). According to a report by

FAO (2018), farmers share their experiences with one another and plant seed varieties that are resilient to harsh conditions as well as adopt practices that enable them to farm without agrochemicals and save costs. Mburu et al. (2016) observed that farm production systems with high agrobiodiversity contributed more towards food security among smallholder farmers than conventional-based practices, hence, highlighting the synergy between biodiversity and food security. Another recent study by Traoré et al. (2020) confirmed that diversified cropping systems helped smallholder farmers in Burkina Faso to enhance their farm productivity and economic resilience. In Zimbabwe, family farmers reported increased availability of balanced diets to eat and sell as well as escaping from poverty as a result of implementing crop diversification and livestock production in their farm, which also enhanced efficient use of water and other natural resources (Christian Aid and ZimPro 2010). Likewise, Garrity et al. (2010) and Akinnifesi et al. (2010) reported that rainfed smallholder farmers in Burkina Faso, Malawi, Zambia and Niger are using agroecological practices to enhance their food crop yield, income and household food security.

Furthermore, agroecology can provide new income opportunities for those farmers who lack capital and incentives to start new ventures (AFSA 2017). For example, in Zimbabwe, some farmers were able to enter into new ventures due to agroecological techniques which provided opportunities for them; such as fish farming through water harvesting and bee-keeping through varieties of crops planted which served as sources of food for bees (AFSA 2017). Agroecological practices can also help to create jobs and have multiplier effects on rural livelihood development. A study by Pretty et al. (2011) reported that in Burkina Faso, workgroups of young men found employment by gainfully engaging in the land rehabilitation process by digging tassa and zai planting pits for farmers and there were reports about some of the farmers buying degraded land for improvement by these workgroups for improved fertility and crop yield.

3.3.3 Agroecology helps in land restoration, mitigates against impacts of climate change and enhances biodiversity

Agroecological practices can enhance the restoration of degraded land caused by drought and intensive agriculture (Wade et al. 2008) as well as contributing to the enhancement of biodiversity and ecosystem services (FAO 2014). A study in eastern and southern Zambia confirmed the effect of nitrogen-fixing plants such as *Faidherbia albida* on improving soil fertility and yields (Umar et al. 2013). Thorlakson and Neufeldt

(2012) concluded that agroecological approaches such as intercropping can be used as an efficient strategy to reduce vulnerability to climate-related problems within smallholder farms. The diversification of crops can play an important role in assisting rural communities to improve soil fertility and biodiversity (Mbow et al. 2014; The Conversation 2015; Soil, Foods and Healthy Communities 2015). In Malawi, agroecological farming techniques such as growing varieties of soil-enriching legumes and crop rotation gave rise to improved soil quality, hence allowing for the cultivation of wider diversity of crops at minimum risk (Oakland Institute 2015). Similarly, in western Tanzania, the diversification of crops contributed to the restoration of degraded land (Pye-Smith 2010). Bayala et al. (2019) observed that nitrogen-fixing plants in farmers' fields improved organic matter in the soil and enhanced carbon sequestration across the Sahel region. Recycling organic matter from various fields is an important agroecological strategy for managing and enhancing agricultural landscapes (Altieri et al. 2017). Improvement in soil fertility and quality of the product was observed in Kenya due to the application of compost and farmyard manure by farmers in parts of the country experiencing land degradation and poor fertility (Gonçalves et al. 2017). Gonçalves et al. (2017) further recounted that smallholder farmers in Ethiopia and Uganda have been using agroecological approaches such as mulching to deal with the challenges of climate change and soil degradation. Additionally, a study conducted between 1993 and 2005 in South Africa, detailed how rainwater harvesting techniques helped to reduce crop failure risk by enhancing infiltration of plant available water and irrigation needs by 50% as well as evaporation by 40% (Auerbach 2005; 2019). The combination of rainwater harvesting with other agroecological techniques improved biodiversity (Auerbach 2020).

Undoubtedly agroecology in Africa is receiving a boost in the rate of adoption by farmers, however, pushing boundaries to enhance the bold transition requires a clear understanding of the drivers for transitioning or adoption of the practices. Therefore, some of the identified drivers of agroecology adoption in Africa are listed and discussed accordingly.

3.3.4 Drivers of agroecology in Africa

Improving the transition towards agroecology requires a detailed understanding of the viability of agroecology to highlight its potential. Articles examined in the scoping review acknowledged the potential benefits of agroecology as the motivating factors to adopt agroecology (AFSA 2017; Fitzpatrick 2015; Oakland Institute 2017). Thus, this study grouped such benefits into subthemes namely; productivity, profitability and affordability.

Productivity

In Africa, smallholder farmers constitute the main agricultural producers and run about 80% of all farms (AGRA 2014). Increased productivity means more food to eat, store and sell and hence, productivity is a major driving force for farmers' adoption of any agricultural technique or process. Evidence of an increase in yield attributed to novel techniques or inputs, which is seen and shared with other farmers is vital to the adoption of such techniques. In Zambia and Malawi, demonstrations of the increased productivity of maize enhanced with agroecological practices, resulted in over half a million farmers adopting such practices (Garrity et al. 2010). AFSA (2017) showed that agroecology delivered improved yields even from soils that were known to be degraded before agroecological restorative techniques were implemented. Moreover, agroecological approaches contribute to helping smallholder farmers produce enough quality food whilst also supporting a healthy environment (AFSA 2016). Research on the use of compost and local seed varieties in Ethiopia revealed that there were increased yields from composted crops as well as soil fertility restoration (Edwards et al. 2007). As such, many farmers started to make and use compost to enhance their productivity, while the use of synthetic fertiliser dropped by 40% (Edwards et al. 2007). In another study in Mali, farmers used cost-effective approaches such as integrated pest management techniques which increased their income by 41%, and this also resulted in the reduction of pesticide use by 94% (Settle and Garba 2011). Under a holistic agroecological management system, agroecological practices can match the yield of large-scale industrial systems. As such, if adequately supported, agroecology can double agricultural productivity in the entire region by revitalising soil health and improving biodiversity, argued De Schutter (2010). Kassie et al. (2009) in their study on the impact of agroecology in high and low rainfed areas, recommended that resource-constrained farmers should adopt agroecology since it reduces production costs, enhances crop productivity and provides environmental benefits in the low-rainfed area. Although, they argue that in high-rainfall region agroecological practices seemed less productive than inorganic fertiliser application (Kassie et al. 2009). Thus, the viability of agroecological approaches in enhancing the productivity and diet for smallholder farmers as well as improving soil fertility, appear to be the major drivers for transitioning.

Profitability

Agroecology is profitable especially to the small farm holder in local communities (Pretty et al. 2011). Profitability is indicated both in the yield relative to input and capacity building which improves the livelihoods of the farmers. In Africa, women are estimated to constitute about 70% of smallholder farmers in sub-Saharan Africa (AGRA 2014). Agroecological practices are helping to empower women to manage their harvesting and post-harvesting activities in saving, selecting and breeding their local seeds (Pschorn-Strauss 2013). Agroecological practices such as beekeeping and crop diversity enable smallholder farmers to improve their income and livelihoods. For example, it was observed that agroecological practices taught and implemented as part of the 'Malawi Farmer-to-Farmer Agroecology project' improved soil fertility and encouraged the planting of crops such as peanuts, beans and pigeon-peas, which provided a food source as well as other benefits such as income and livestock feed (AFSA 2016; The Conversation 2015). In their respective studies, both Harrison et al. (2019) and Midega et al. (2018) observed that species' diversity mitigates the infestation of weeds, pests and diseases which allows the farmers to gain more from their farms. Similarly, Silberg et al. (2019) in their review, identified that intercropping cereal crops with legumes, improved weed management in smallholder farms which made farmers spend less on labour. The integration of nitrogen-fixing plants such as *Faidherbia albida* was reported to improve soil health as well as provide fodder for livestock, as such, helping farmers to save costs (Midega et al. 2018). A study in East Africa on the use of a push-pull system (i.e. an agroecological pest-management technique) in the control of stem borer and Striga weed, showed that over 30,000 smallholder farmers adopted the technique due to its effect on improving biodiversity and conserving soil resources as well as crop yields, as maize yields increased by 1 to 3.5t/ha on average (Khan et al. 2011). The techniques contributed to increasing farmers' income and empowered women as the previous study reported that they made profits from the maize production (Khan and Pickett 2004). Another case study in Malawi showcased how permaculture allows farmers to save money and reduce inputs as well as creating opportunities for diversified income generation, which resulted in many farmers adopting the practice (AFSA 2016).

Affordability

One of the main highlights of agroecology is its affordability because the inputs and methods are relatively cheap and locally available compared to those of conventional agriculture (Fitzpatrick 2015). The affordability of agroecological approaches makes it easier for the poor farmers in Africa to carry out trials and adopt the principles as it comes at a little or no cost at all. Silici (2015), concluded at a workshop on five ways to sustainably intensify agriculture in Mozambique that affordable new methods and tools encourage farmers to test them to the local conditions through participatory research. Johansson (2012) observed that availability and affordability of both synthetic and organic inputs, and of labour, significantly influenced the type of methods the farmers used in Uganda. The study further noted that farmers preferred to utilise organic inputs because of their affordability. In Malawi, the farm communities used permaculture-based principles such as local farm waste which they interpreted as care for the earth, care for people and a fair share of resources to revitalise year-round food production, evidencing the affordability of agroecological practices which emphasises the use of on-farm inputs (AFSA 2016). A number of studies have consistently shown that traditional or indigenous practices are more affordable than conventional farming because the majority of the farm resources are sourced on-farm or locally, saving money for the farmers. For instance, case studies in Kenya found that local crop diversity has been the major strategy the farmers use in adapting to worsening pests' infestation (Swiderska et al. 2011), thereby averting the need to buy costly pesticides for their farm management. In Karatu-Tanzania, the implementation of agroecological practices such as using cover crops to suppress weeds, intercropping, direct seeding etc., contributed to a reduction in labour and time required in the farm operation and over 3,600 farmers adopted the techniques due to the benefits (Owenya et al. 2011). In the Maradi and Zinder area of Niger, Reij and Smaling (2008) reported that there was 4.8 million ha of *Faidherbia*-dominated agroecosystems due to increased adoption. The farmers claimed that the trees shield their crops from dry winds and land from water erosion as well as improve their crop yields. Additionally, the foliage and pods provided much-required fodder for their ruminants during long dry seasons (Reij and Smaling 2008). The experience led to the promotion of several programmes that support farmer-managed natural regeneration of *Faidherbia* and other related woody species. About 500,000 smallholder cereal crop farms in the highlands of Tanzania and Malawi successfully implement this technique (Reij and Smaling 2008).

Most importantly, many studies confirmed that agroecology and agroecological practices are having positive impacts on the smallholder farmers' livelihoods in Africa (AFSA 2017; Fitzpatrick 2015; Harrison et al. 2019; Nyantakyi-Frimpong et al. 2016; Owenya et al. 2011; Pschorn-Strauss 2013; Pye-Smith 2010). The farming system helped smallholder farmers in northern Malawi to improve their farm productivity, nutrition and income, as well as revitalise their soil fertility and landscape regeneration (Nyantakyi-Frimpong et al. 2016). Farmers' enthusiasm towards the affordability and profitability of agroecological approaches as well as the farming system's ability to improve yield, facilitated their (farmers) transitioning (AFSA 2016, 2017; FAO 2018). Although there are criticisms regarding the affordability and profitability of agroecological production mostly due to the perceived need for more land, as well as increased labour and farm production costs (Rausser et al. 2019). These issues can be alleviated by enhanced or premium market prices which can then improve smallholder farmers' income and alleviate food insecurity (Taheri et al. 2017). Furthermore, the viability of agroecological approaches to increase crop yield, improve biodiversity, enhance soil health etc., compensates these contentions. A requirement for increased labour can reduce unemployment, for example, in Kenya, women employed local people to work on their vegetable farms and in marketing (Pretty et al. 2014). Nonetheless, to unlock the transformative power of agroecology and agroecological approaches and advance towards achieving food sovereignty in Africa, requires the knowledge of the barriers and challenges that are hindering the transition or that which could hinder the progress, as well as ways to improve the situation.

3.3.5 Barriers and challenges of upscaling agroecology in Africa

The materials reviewed illustrated the various challenges threatening the upscaling and transitioning towards agroecology and agroecological practices in Africa as listed below.

Policy issues

Political instability in most African States, as well as war and insecurity, affect agriculture generally. In some cases, farmers abandon their farms and villages because of insecurity and war. Changes in government often usher in new policies at the detriment of former ones or modifications to existing policies which are often entirely driven by politics. FAO (2016a) particularly highlighted policy frameworks that favour high external chemical inputs that are expensive over traditional peasant farming which may discourage investment and hinder adoption of relatively inexpensive approaches such as agroecology. Moreover, the rapid globalisation of food chains and liberalisation of agriculture through the World Trade Organisation Agreement 1995, influences the dominion of agri-business corporations throughout the entire food chain. This; has resulted in the privatisation and commodification of natural resources, as well as the use of industrial seeds and genetically modified organisms. Beintema and Stads (2011) observed that Kenya maintained and supported a marketing environment that strongly favoured private agricultural companies and the establishment of markets based on external inputs. The favouritism shown to agri-business companies by governments in many African countries contributes to agroecology constantly being regarded as less competitive than conventional systems (Friends of the Earth International 2016).

Land ownership and access to land are one of the major factors to consider in Africa (Toulmin 2009). In a study in Ethiopia, Mekoya et al. (2008) concluded that the adoption of sustainable soil conservation practice was constrained because of restricted access to land. Bullock et al. (2013) examined the influence of tenure security on the adoption of agroecological approaches in Tanzania and their logistic regression analysis showed that tenure security significantly affected adoption. Some of the agricultural policies commonly promote large seed companies' operations as well as support commercial-oriented farmers to easily access and acquire land triggering domestic seed losses and land grabbing in many parts of the continent. For example, many smallholder farmers in Taraba, Plateau and other states in Nigeria were compelled by the government to relinquish their land to the US's multinational companies such as Dominion Farms to establish 30,000 hectares of improved rice plantation which is being supported by the Nigerian government and the G8's New Alliance for Food Security and Nutrition in Africa (Business and Human Rights Resource Centre 2015; ActionAid 2015; New Alliance for Food Security and Nutrition 2013; FAMRD 2016). Another common problem is the gender bias in land ownership, for instance, Drechsel et al. (2005) reported that under customary land practices in many African countries especially in the Sahel region of West Africa, women do not have title rights to land. Ndayambaje et al. (2012) confirmed that the gender of the head of the household played important role in the decision to adopt nitrogen-fixing trees in Rwanda as female household heads' opinion were less considered. As such, any agroecological extension in that region must consider gender issues in the design and approach to farmers otherwise the new methods may run a high risk of rejection.

Access to natural resources play an important part in for the practice and upscaling of agroecology and therefore, it is necessary to ensure that farmers' in the African region, have access to natural resources, particularly land, water and biodiversity (FAO 2016b; 2016c). Accordingly, De Schutter (2010) emphasised the importance of increasing agroecologically-based cultivated land and creating a working framework for farmers to harness the positive impact of agroecology and agroecological approaches on productivity, ecosystems and farmers' livelihoods. Policies at all levels can strengthen agroecological practices by making sure that farmers remain the sole seed producers locally. Additionally, farmers should be seen as collaborators in the agroecological process, and their involvement, as well as concerns, must be taken into consideration in policy formulation, administration, implementation and dissemination (Blandford and Hassapoyannes 2015). If not, they could be ignored in the design and selection of agroecological technologies which suits their environment and personal circumstance. FAO (2016b) observed that this is one of the main hindrances to the adoption and dissemination of agroecology generally in Africa. There is also the tendency to promote agroecological techniques in such a way that the smallholder farmers find it difficult to adopt, thus the need for proper attention.

Attitude towards change

Attitudes towards a change of agricultural practices which the farmer is familiar with is also a barrier to agroecological transition and adoption in Africa (see behavioural theories and factors that contribute to attitude towards change in Chapter 4). Johansson (2012), observed that attitudes originating from behavioural beliefs about profitability, together with perceived behavioural control i.e. the perception of how easy or difficult it will be to successfully carry out the behaviour, seemed to be important influencers over farmers' intentions whether or not to use or practice agroecological practices. Shikuku et al. (2017) explored smallholder farmers' attitudes towards climate risks management farming techniques and confirmed that farmers' attitudes favoured such techniques because of the perceived benefits. Similarly, Meijer et al. (2015) argued that factors such as knowledge, attitudes and perceptions of the potential adopter towards new farming practice, play a significant role and concluded that smallholder farmers' uptake of agroforestry is influenced by both intrinsic and extrinsic factors. Jerneck and Olsson (2014) also observed that smallholder farmers' perceived uncertainty in crop yield determined their uptake of an agroecological approach. Sometimes fear and suspicion of the intentions of the agents of change or extension and advisory services affect the farmers' choices in Africa, particularly where the agents are coming from abroad in view of colonial history or even within the state but linked to the government. Sometimes, the lack of trust could be because of previous failed promises and abandoned projects (D'angelo 2014). Generally, farmers' ability to perceive agroecology as an act of 'co-creation of knowledge from the existing nature (Gliessman 2017)' will improve their attitude towards agroecology transition.

Lack of required information on agroecology and inputs

Over time, availability of and access to required information have been central to smallholder farmers' decision-making towards adopting and/or not adopting any given farming practice. Generally, it has been argued that raising awareness and sharing information about agroecology helps agroecology to gain higher power, influence and visibility (Friends of the Earth International 2018). Isgren (2016) also highlighted the importance of access to information and background knowledge as conditions for farmers to adopt agroecological approaches. In a study on the effect of access to information on agricultural practices in Kwazulu-Natal province, Gadzikwa et al. (2006) observed that lack of access to appropriate information as one of the major barriers to farmers' adoption and/or transition towards agroecological farming practices. Accordingly, Tsion and Steven (2019) argued that lack of required knowledge and access to the right information influenced farmers' actions and decisions about on-farm inputs. They noted that, although the farmers in Africa are aware of the implications of using synthetic inputs, not having sufficient knowledge about organic inputs made them not consider adopting them (Tsion and Steven 2019). In another perspective, Oluwasusi (2014) revealed that farmers' attitude towards organic techniques in southwest Nigeria, was dependent on the availability of information.

The evidence in these articles suggests that information should be made available to farmers in the clearest and easiest way in order to ensure that the farmers understand the new methods. Interpreters could be hired from amongst the communities to enhance communication with the farmers. The most appropriate methods (see Table 2.2) which suit the area should be employed and could be varied to optimise learning. Acknowledging the nature of agroecological approaches which is knowledge-intensive, farming communities require ecological literacy and decision-making skills (De Shutter 2010). The farmers should be trained to train others and recognised as agents of communication and dissemination of information. Farmers need access to information on the potential benefits of agroecology and why it is important for them and their families to adopt these methods or rejuvenate their existing traditional methods. Information about available local markets, targeted productivity strategies, sources of local on-farm inputs, and experiences of other farmers who already engage in agroecological practices should be disseminated. Sometimes farmers have too much information (information overload) and the new techniques become ambiguous to them or they have too little or irrelevant information which does not help them to make 'informed adoption' decisions. For example, if the farmers lack access to knowledge or information about how to prepare compost that may influence their decision to utilise synthetic fertilizers, such could happen among the farmers that are still new to agroecological approaches.

Support for rural extension activities by the government and or non-governmental organisations in agroecology as well as allowing the farmers control over their own resources, knowledge creation and sharing, will enable the rapid dissemination of agroecological approaches. Agroecological practices are said to be better adopted when shared from farmer to farmer and not imposed top-down. Social networks promote the dissemination of knowledge and transform the way knowledge is shared amongst farmers by allowing them to realise the right to food through co-construction (De Schutter 2010).

Research, incentives and support

Information provided for farmers should be supported by sound research. Research is important in the support for agroecology in Africa as information that gets to the farmer should be supported by sound research. Research can also deliver more information on the benefits of agroecological techniques and help to enhance existing ones. Research helps to tailor techniques to the needs of the farmers taking into consideration their environment, circumstances, climate and region (Maiangwa 2010; Waibel 2006). Currently, agricultural research is mainly funded by large agri-business and food companies which show no interest in agroecology and agroecological approaches as the methods and inputs are not homogeneous and may not show an obvious yield at first, thus hindering research on elements and benefits of agroecology (FAO 2014). Provision of support, supervision and monitoring could enhance the adoption and implementation of agroecological techniques in Africa as some of the farmers felt abandoned due to lack of support for wider adoption and long-term investment (Tully et al. 2015). Furthermore, the field of agroecology is evolving and there is a need to keep pace with advances in agroecological techniques and their benefits as well as to adapt such studies to African conditions and circumstances. In an exploratory study on the role of agricultural research for the development of sustainable agriculture and food security in sub-Saharan Africa, the European Commission (2013) highlighted the need for optimised research in the area of agroecology. A recent joint report by BFED and IPES-Food (2020), shows that agroecology is still marginalised in terms of support, funding for research and incentives. As an example, the report highlighted that the majority (as many as 85%) of the projects funded by the Bill and Melinda Gates Foundation in Africa were in support of industrial agriculture and for enhancing agricultural efficiency through improved pesticides and livestock vaccines (BFED and IPES-Food 2020). Another report indicated earlier that more than 70% of the projects executed by Kenyan agricultural research institutes focussed on conventional practices (Beintema and Stads 2017). Moreover, DeLonge et al. (2016) argued that much of the United States Department of Agriculture research funding is unrelated to agroecological based practices and they highlighted the need for more public funds to be allocated for agroecology development and socioeconomic support for smallholder farmers. Exploring the significant effect of the lack of support for agroecology, Kiyani et al. (2017) noted that the decline in farmers' adoption of agroecological practice in the southern province of Rwanda, was because of a lack of skills support and subsidies for such practice. Transforming our food system and promoting agroecology requires grassroots' supports and targeted schemes for smallholder farmers especially the women because they are the critical agents of change (van Walsum 2015).

3.4 Conclusion and recommendations

This review has identified that agroecology is gaining a foothold in Africa, but there are still challenges to overcome in order to achieve upscaling which would transform Africa's agriculture and food systems and help to achieve food security. There is evidence of the impact of agroecological practices on SDGs, promotion of food security, increased yield, improved income and livelihoods of smallholder farmers. Additionally, agroecological practices are helping farmers to attempt new ventures as well as revisit traditional practices such as beekeeping, intercropping, natural seed conservation, etc. Furthermore, there are indications that agroecology is driving improved nutrition. The three major drivers of agroecological transitioning in Africa identified in this review are enhanced productivity, profitability, and affordability. Of these, productivity is seen by smallholders as the key driver, as poor farmers want to see improvements that will improve their livelihoods and that of their families. Conversely, some of the barriers to the adoption of agroecological practices are policy issues, attitude towards change due to intrinsic and/or extrinsic factors and lack of required information and access to farm resources. As well as poor research support and lack of incentives for would-be and/or transitioning farmers. It was also noted that the negative attitudes to change could be because of culture, norms and values which may influence farmers' adoption of new methods. Unfavourable policies and issues associated with land ownership or access to land are also confirmed as major challenges to agroecological transition in Africa.

Given the issues identified that are affecting the transition to agroecological approaches, this review recommends that farmers should be participants in the co-creation and transfer of knowledge and skills. Moreover, the share of experience between farmers can enhance the adoption or transition towards agroecological approaches in Africa. Furthermore, farmer-led and grassroots experimentations are necessary to enhance awareness of the benefits of agroecology as well as encourage adoption. It is important for the farmers to appreciate the fact that they are participants rather than receivers and that they can pass on the skills to others. It is pertinent to see farmers as collaborators in knowledge generation, and farmer involvement, as well as their concerns, should be considered in policy formulation, administration, implementation and dissemination (Levidow et al. 2014). Research to understand the particular environment under which smallholder farmers live and conduct their farming activities would enhance farmer collaboration. Thus, improve the identification and promotion of agroecological methods that match farmers' circumstances and that which can provide solutions to their problems, challenges and limitations. In addition to the approaches that can improve their crop yields, income and opportunities.

Chapter summary

This chapter identified many positive impacts of agroecological approaches on smallholder farmers' livelihoods in Africa but revealed that agriculture in Africa is largely based on conventional systems, and agroecology is yet to receive full policy support, while smallholder farming receives little or no attention. There is limited information on agroecology and research support, all of which affect farmers' transition to agroecology. The situation, therefore, provides the impetus to investigate approaches that can enhance the transition, especially within the smallholder farm setting. Given the background of this study which is formed on the premise of transition, sustainability, behavioural and information and communication technology development studies, the next chapter outlines the various theories underpinning the concept.

Chapter 4: Unpacking the theoretical framework that underpins this study

This chapter details the theoretical framework that is derived from relevant literature which formed the basis for the contextualisation of the overall study, as well as the conceptual thinking undertaken in different chapters and the theories that informed the discussion. In doing this, the chapter explores the sustainability transitions in agri-food systems and highlights the synergy between the environmental, social, and economic factors and the challenges to sustainable agriculture and food systems. It then details the agroecological transition framework that underpinned this study and further outlines how the main aims and objectives of the study are conceptualised. The chapter then examines what might influence smallholders' decision-making towards or away from agroecology, exploring behavioural change theories. It also unveils the concept of Information and Communication Technology for Development [ICT4D] and the need for ensuring sustainability (here sustainability means long term impact) of ICT for agricultural development [ICT4Ag] initiatives, and how ICT4Ag initiatives can contribute to facilitating interactive agroecological knowledge exchange. The chapter concludes with a diagram representing the framework of the overall study.

4.1 Introduction

The direction and contextualisation of every research study must be informed by one or more different ideologies and based on the existing literature. As for this study, it is situated at the intersection between sustainable transition in agriculture and food systems and ICT4D studies. Thus, in laying the conceptual foundations of these two different fields upon which the empirical research and analyses are formed, the various sections below are important.

4.2 Exploring 'sustainability transition' in food systems

The concept of transition which commonly means "*a fundamental change in structure (e.g. organisations), culture (e.g., norms, behaviour) and practices (e.g., routines, skills)*" and the field of transition has begun to gain attention both in the policy debate and academic literature (Falcone 2014; Loorbach et al. 2017; Markard et al. 2012). Most importantly, the transition concept has continued to gain increasing attention and importance in agricultural research and food systems (e.g. Elzen et al. 2017; Hinrichs 2014).

Concerns for the sustainability of agri-food systems have led to an increasing interest in 'sustainability transition' in agriculture and food systems' discourse (El Bilali 2020; IPES-Food 2018, 2020). Food systems are said to be dominated by globalised conventional agri-food systems controlled by a few, powerful, large corporations and agri-businesses that control much of the processes from production to consumption (Clapp 2014; Holt-Giménez and Shattuck 2011; Ilbery and Maye 2005; McMichael 2009; Sage 2013; van der Ploeg 2010). These corporations are interested in profit maximisation and their fight for market share is largely achieved at the expense of the weakest links in the chain such as the farmers (Agrifood Atlas 2017). Friedmann and McMichael (1989) conceptualised this kind of structure as food regimes. The concept of the food regime exposed the structural issues of agri-food politics and economics (Friedmann 2016; McMichael 2014; Pritchard 2009). Presently across the globe, food systems are in one way or another influenced by an established or existing food regime, which McMichael (2009) referred to as the corporate food regime. The politics and economics of agri-food systems are determined by the corporations and the international patterns of trade that increasingly determine what food producers (farmers) produce and how value-added is distributed (Clapp 2018b; O'Kane 2012; Therond et al. 2017). Evaluating such a situation, Nilsen and Roy (2015) conceptualised Antonio Gramsci's theory of corporate hegemony[20] (Gramsci 1971) and illustrated how food producers endure policy and institutional arrangements or guidelines that are obviously not in their best interests. In this context, food regimes are consolidated and even accepted and embraced by these marginalised groups (Bernstein 2016; Brown 2020; Patel 2013). The corporate food regime is also embedded in the green revolution which is an industrialised approach to food and farming even in Africa (Lang and Heasman 2015; Lowe et al. 1993; Therond et al. 2017). The negative social, economic and environmental impacts of food regimes (e.g., Hinrichs 2014; IPES-Food 2016; O'Kane 2012), have led to calls for an alternative to corporate food systems – one that is ethically appropriate and sustainable (see El Bilali 2018; Brunori et al. 2013; Holt- Giménez and Altieri 2013; Holt- Giménez and Shattuck 2011; Hubeau et al. 2017; Ingram 2015; Meynard et al. 2017; Migliorini et al. 2017), hence, sustainability transition[21].

Sustainability transition is defined by Markard et al. (2012) as "*long-term, multi-dimensional and fundamental transformation processes through which established socio-technical systems shift to more sustainable modes of production and consumption*". These concepts have been widely adopted in agri-food system transition studies (El Bilali 2019; Gaitán-Cremaschi et al. 2019; Medaets et al. 2020). Contextually, the concept of sustainability transition applies to the shift from an agri-food system that has the main goal to increase productivity at all costs, to one that is built around the wider principles of sustainable production and rural development (Brunori et al. 2013; Lamine 2011; Wilson 2008). Accordingly, Spaargaren et al. (2013), noted that agri-food transitions include structural change processes that transform production and consumption modes and to more new sustainable practices. The process of sustainability transition can happen at the local, to regional levels, as well as national or international levels and can take place in the middle to long-term duration (Darnhofer 2015).

[20] Hegemony is the state of being where all sectors of society seem to be in harmony with people in power and control. Hegemony involves a way of seeing or feeling about things and convincing people that such way of seeing or feeling is natural and right (Gramsci 1971).
Corporate hegemony happens when economic interests become the dominant interests in a society and other institutions become means by which to promote such economic interest or agendas (Dugger 1989).

[21] Embracing the aim of transition towards sustainable agriculture and food systems (Geels 2011; Lachman 2013; Markard et al. 2012).

Transitioning to sustainable agri-food systems has become the objective of many initiators in the agri-food field (e.g., UNEP 2019) and a focus of increasing literature on agri-food sustainability transitions in transition studies (Maye and Duncan 2017; Spaargaren et al. 2013). As such, a number of different frameworks have been used to examine the sustainable transition concept and process. Accordingly, Lachman (2013) and El Bilali (2018) detail some of the outstanding ones in research on agri-food sustainability transitions. These are 1) Multi-Level Perspective on Sociotechnical Transitions (Geels 2011); 2) Transition Management (Loorbach et al. 2008; Loorbach 2010); 3) Strategic Niche Management (Raven and Geels 2010); 4) Technological Innovation Systems (Bergek et al. 2008) and 5) Social Practice Approach (El Bilali 2018). Additionally, other studies have explored different issues in and strategies to achieve agri-food system sustainability transitions. Examples of the various narratives include the interaction between innovation networks and the existing food regime, stability of the food regime and challenges, science driven and grassroots transition movements, as well as the agencies responsible for change (see Bui et al. 2016; Diaz et al. 2013; Ingram 2015; Ingram and Maye 2016; Lamine 2011; Levidow et al. 2014; Meynard et al. 2017; Rossi 2017; Vlahos et al. 2017). But, most importantly, these various pathways involve the redesign of the farming practices used by farmers at the farm level (Gliesman 2015, 2016; Lamine 2011b; Meynard et al. 2017) and, agroecological systems have been identified as a viable paradigm for the sustainability transition and transformation in agri-food systems (Altieri 2017; Anderson et al. 2019; IPES-Food 2018; Mier y Terán Giménez et al. 2018). Although transformation is mentioned at some specific points in this study, it refers to an envisaged future of the study area where a broader societal shift emerging from a multifaceted agroecological transition process in the entire food system is attained. That is, that which changes the activities, form, beliefs, nature or values in production, commercialisation, consumption, and waste management (i.e., achieving the three dimensions of agroecology). This study focuses on sustainability transition based on agroecological practices at the farm level as one component of the food system. The conceptual aim is to build long-term soil fertility, a healthy environment and consumption, and fair livelihoods (IPES-Food 2016).

4.3 Situating Gliessman's theory of agroecological transition in the context of this study

As stated in Chapter 2, this study is not directly concerned with analysing the wider power and political context or processes that can determine and shape transitions, rather it focuses on the agroecological transition at the farm level. Different theoretical frameworks have been established to understand the dynamics and explore the multifaceted level of agroecological transitions (e.g., Duru et al. 2015; Falcone 2014; Grin 2012; Lanchman 2013; Markard et al. 2012; Meek 2016; Moraine et al. 2017). Amongst these popularly used frameworks established within the sustainability transition studies is Gliessman's five-level framework (see Figure 4.1). Accordingly, Gliessman (2016) used the framework to classify the levels of food system change and the framework has proven useful in understanding farm level transitions. At the first level, the efficiency of the production system is enhanced by reducing the use of external inputs across all types of farming systems, although, this level does not remove the farmers entirely from using the external inputs and unsustainable practices. The second level involves replacing external synthetic inputs and environmental degrading practices with ecologically based inputs and practices[22]. Although, at this level, the farming system is not fundamentally altered from its simplified form, therefore, the farmers could experience the same issues as in conventional systems. Nevertheless, these first two levels and their characteristics may not necessarily reflect agroecological transition – as they are also co-opted in conventional methods such as climate-smart agriculture, each level will likely be part of the transition process. The third level (i.e., deeply rooted within agroecology expressions) involves the redesign of farming systems based on ecological principles and natural process. At this level, redesign of the system eliminates the root causes of the issues that may continue to persist at the first two levels. The focus is to prevent the problems before they occur, rather than attempting to control them after their occurrence. This is done by creating and/or strengthening independent mechanisms for managing weed and maintaining soil fertility and other resources within the agroecosystem (Gliessman 2015, 2016). The framework goes further to include the fourth level of the transition process, which involves direct connections between food producers and consumers to support a socio-ecological transformation of the food system (this is concerned with people's value to locally grown and processed food to shorten the food chain and patronise local farmers). And finally, the fifth level, which involves a much extended, deeper and wider

[22] The use of nitrogen-fixing cover crops, natural control of pests, insects and diseases infestations, crop rotations, use of manure or compost for enhancing soil fertility and management.

transformation of the existing and/or enabling context, institutions, policies, culture as well as society (this kind of change is more than mere transition, but a transformation of the entire food system) (Gliessman 2015, 2016). Thus, the five-level framework illustrates how changes in practices vary in their complexity and transformative potential as well as building on each other (Gliessman 2015, 2016; Lamine et al. 2014).

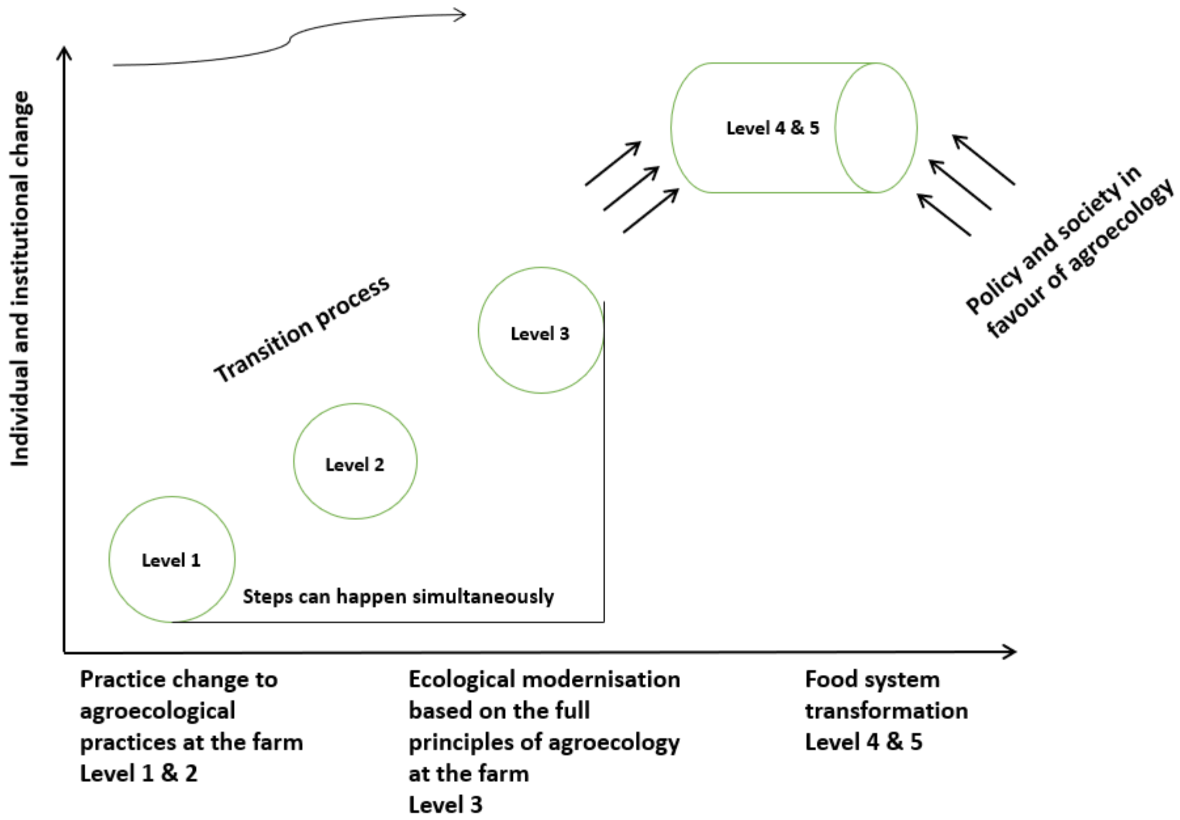

Figure 4.1: Agroecological transition (Adapted from Gliessman 2015, 2016).

Nigeria's agriculture is largely subsistence and her policy and institutions appear to reflect and be more aligned to conventional systems (i.e., the dominant regime) (FAO and ECOWAS Commission 2018; FAMRD 2016). The focus and aims of this dominant regime are demonstrated by current agricultural policy and regulations whose stated aim for agricultural development is to increase food production at all costs (FAMRD 2016). Farming practices promoted by the established institutions such as extension and advisory services, agricultural universities etc. are all based on conventional systems (see further details in Chapters 1 and 6). Therefore, situating agroecological transition in

Nigeria through the lens of Gliessman's transition framework, Figure 4.1 above illustrates the levels of a transition process that involves smallholder farmers at the farm level towards an agroecological system and individual and institutional changes both in knowledge generation and dissemination (e.g., Altieri 1999; Anderson 2015; IPES-Food 2018). At present, there is no study yet on agroecological transitions in Nigeria, however, examples from other places where input substitution for agroecological transition has been successful (e.g. IPES-Food 2018), show that it is important for early adoption of agroecological practices, as it shows relatively fast and visible results that may appeal to farmers. The step-by-step change in farming practices would introduce the smallholder farmers to defined procedures in order to familiarise themselves with the basic concepts of agroecology (IPES-Food 2018). On the national and international level, there would be a need for policy changes to favour agroecology (Meek 2016). This could be possible only if the government becomes convinced of the viability of agroecology and makes necessary legislative changes such as creating incentives for farmers at the farm level and/or the entire food system. Although this could be difficult in a wider historical and political context where vested interests may prevail, and where corporate power and the established regime may attempt to influence the direction and depth of change (Avelino et al. 2016; Gaede and Meadowcroft 2015; Geels 2014; Hauser and Lindtner 2017; Wezel et al. 2016). A transition towards agroecology follows the general principles and steps as highlighted, but each particular farm has a unique way to adopt and adapt practices and management strategies. Hence, transitioning towards agroecology may not be the same for all farmers as they differ in their objectives and values. Moreover, changes in farming practices and in managing new situations require the adaptive capacity of the farmers which depends not only on the state of their agricultural system within which they are embedded but also their personal traits (Edwards-Jones 2006; Moser and Ekstrom 2010; Nazari et al. 2015). As such, supporting agroecological transition in Nigeria may require changes in individuals' (e.g., farmers) perception or behaviour towards agroecological practices as well as products and other initiatives aimed at improving the transition.

4.4 Exploring factors that can influence smallholder farmers' decision-making

Given that agroecological transition is a non-linear process, which may be influenced by many factors, focusing on one particular theory in understanding the decision-making may not provide full clarity of the adoption or transition process. Additionally, this study's intention to explore the use of mobile phone-enabled applications (m-apps) to facilitate interactive exchange of agroecological knowledge, makes it imperative to identify and evaluate key theories that are useful for this study. These theories are important because they consider the interaction of different factors in decision-making and use of a particular practice(s) or technology. Smallholder farmers are unique, individual, and depending on context, different factors can trigger a change in behaviour for one farmer and discourage change in another. Policies and rules for agricultural change can be enacted, however, without support from farmers and their engagement, such changes may end up on the surface with no effect or impact. Hence, in exploring smallholders' behavioural change, it is important to understand the theories that contribute to change in behaviour and adoption and use of practices. There are over 40 theories that support behavioural change (Darnton 2008; Ozmete and Hira 2011), however, the ones that are most relevant and appropriately for the focus of this study are detailed below.

4.4.1 The theory of planned behaviour [TPB]

This is a psychological theory that describes individuals' cognition of intentions to perform a behaviour. This theory has been successfully applied in understanding farmers' decision-making towards the adoption of agricultural practices (Meijer et al. 2015; Moellers et al. 2018; Mutyasira et al. 2018). The theory was first proposed by Ajzen (1985) and it explored why an individual behaves in a certain way, considers available information, and takes into consideration the resultant effect of their actions. The theory highlighted that '*an individual's intention to perform or not to perform a behaviour is the major determinant of the action. The theory predicts an individual's intention*' (Ajzen 2005). It identifies and integrates other determinants of a person's behaviour conceptually to account for attitudes, social influence, and perceptions over control. Accordingly, Fishbein and Ajzen (2010) noted that social attitudes and personal traits play significant roles in predicting and explaining human behaviours towards change. As such, the motivating factors are the subjective norm, attitudes towards the behaviour and perceived behavioural control. Attitudes are defined as human beliefs or behaviour towards something (where something could mean a person, concept, or physical object). The antecedents will manifest into good or bad, negative, or positive attitude about a behaviour. This perception may be based on what the individual perceives to be true about the concept (Ajzen 2005). On the other hand, behaviour is a function of attitudes, habits, norms, and expectations regarding the outcome of intentions, while the subjective norm is referred to as a person's perceived social pressure to perform a certain behaviour. It encompasses beliefs about social expectations and the motivation to comply with such expectations (Fishbein and Ajzen 1975). Two important beliefs are formed to assess subjective norm: normative belief and motivation to comply (where normative belief is the perceived expectation of the referent person to perform behaviour and motivation to comply refers to how people are motivated to comply (Ajzen 1991, 2011). Perceived behavioural control reflects the perceived degree of control individual has regarding their own capacity to perform the behaviour. This has to do with the extent to which all the required intentions necessary to perform the behaviour are met. This means that the stronger the attitude, subjective norm, and perceived behavioural control, the stronger the intention is likely to do the behaviour (Davis et al. 2002).

The TPB is a modification of the theory of reasoned action (TRA) which has also been developed to include the reasoned action approach (RAA). TRA explains the relationship between attitudes and behaviours as well as the subjective norm in behavioural actions of humans (Ajzen and Fishbein 1980). Behavioural actions can be predicted by intentions, whilst the attitude towards behaviour and standard beliefs are the antecedents of intentions (Ajzen 1991; Ajzen et al. 2018). TPB was added because individuals might have incomplete control over their intended behaviour, particularly in an uncontrolled and unstable external context. It, therefore, considers the three major components (i.e., attitude, subjective norm, and perceived behavioural control) to explain human behavioural intentions (see Figure 4.2) (Ajzen et al. 2018). Human behaviour can be influenced by intention, the strength of the intention is proportionate to how the individual performs his/her behaviour. As such, the intention is assumed to be the antecedent of behaviour (Ajzen 1991; 2012). Though TPB disregards the complexity of the relationship between farmers and other actors, it is significant in describing and predicting farmers' adoption behaviours (Darnton 2008). Hence, TPB is applied to allow the understanding of farmers' attitudes and how that could influence their behaviour towards agroecology.

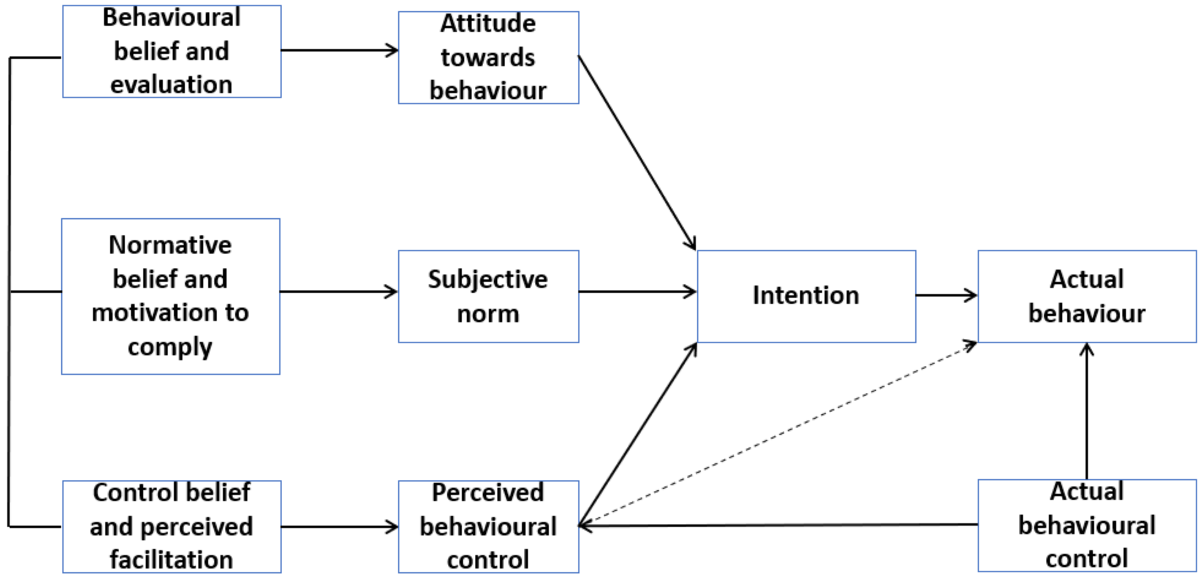

Figure 4.2: The theory of planned behaviour (Adapted from Ajzen 2005)

Additionally, other factors can influence farmers' behavioural change. The RAA incorporates background factors such as the individual, social, informational, and environmental factors that can influence intention and behaviour. These factors may include gender, age, race, personality, personal knowledge and experience, perceived risks, access to information, skills, education level etc. (Fishbein and Ajzen 2010). Given the importance of knowledge sharing to promote agroecology, social contexts and social interaction are also central to farmers' knowledge sharing practices and as such their social networks can influence behaviour, as well as affect information sharing and knowledge exchange practices (Chiu et al. 2006; Kumar 2017; Snowden 1998; Wellman and Wortley 1990). Thus, the concept of social capital theory can play important role in explaining the behaviour of the smallholder farmers, as well as other participants that are involved in this study.

4.4.2 The social capital theory

This theory describes the factors that are fundamental in the behaviour of a person towards adoption and information sharing, which is fundamental to agroecological transition. Social capital theory offers a strong conceptual lens to look beyond the personal, cognitive, and general cultural factors (Kim et al. 2010; Kumar 2017; van Dijk et al. 2016). The theory is defined by Bourdieu (1986) '*as the aggregate of the actual or potential resources embedded within, available through, and derived from the network of relationships possessed by a person or social unit*' (van Dijk et al. 2016). Putnam (2000) suggests that social capital facilitates coordination and cooperation for mutual benefit. Thus, drawing from literature, social capital is defined as a network of relationships or a social network (i.e., between relevant agricultural actors) that can provide opportunities for leveraging resources (e.g., skills, information etc.). This broad understanding of social capital incorporates three different types of social capital namely: bonding social capital, bridging social capital, and linking social capital. Bonding social capital is defined by the connection that exists amongst people that share similar values, backgrounds, identity, or interests such as gender, ethnicity etc. These bonds create a strong link between people with similar characteristics (Flora and Flora 2004). Bridging social capital is the connection and networks between groups and individuals with other external groups. This can include business relationships and similar connections to other people that share similar interests but do not necessarily share a common identity (Szreter and Woolcock 2004). Linking social capital is the connection or network of relationships between groups or individuals in different levels or position of power within the social hierarchy (e.g. relationships with institutions and individuals who have relative power) (Szreter and Woolcock 2004). Therefore, social capital can enhance farmers' willingness to adopt better agricultural practices and may result in fewer efforts needed from policymakers in promoting such practices. For example, households with a greater number of relatives and/or networks of influence[23] are more likely to adopt new technologies due to their ability to gain knowledge easily (Di Falco and Bulte 2011). Hall and Pretty (2008), noted that linking social capital, has a significant influence on farmers' attitudes and their farm management. Olawuyi and Mushunje (2019) found that farmers who belong to a group of diverse members had positive influence to adopt conservation agricultural practices. But, despite the recognised importance of social capital to enhance relationships at different levels (e.g., family, community etc.) as well as leading to increased farmer participation, only a few studies have assessed the influence of trust

[23] Individuals or groups that connect with each other through bonding, bridging, or linking social capital.

and its effects on agricultural-related problems (Mariola 2012). The most important aspect of social capital is the trust that bonds the individuals and the value of the knowledge they share (Burton and Paragahawewa 2011). Facilitating social capital and relationships built on trust can promote efficient multilateral communication between various actors (or stakeholders) involved. Thus, social capital can influence farmers' decision-making as the connections (network of influence) could facilitate farmer-to-farmer knowledge sharing and improve trust in grassroots innovations (e.g., experimenting agroecology on the farm), as well as support agricultural research and information institutions through collaboration (e.g., Thomas et al. 2020; Zhang et al. 2020).

Recognising the importance of social capital could mean that researchers could adopt methodologies that will ensure effective exchange of knowledge as well as build strong linking social capital that can enhance farmers' participation and their attitude to change. As this study explores the potential of an interactive m-app for enhancing the exchange of agroecological knowledge and possible transition, it, therefore, conceptualises social capital at the community through to the national level (see Figures 7.6 and 7.7 in Chapter 7). It is worth acknowledging that the capacity of individual farmers to reap benefits arising from participating in such relationships may vary due to social factors such as age, literacy level, gender etc. For example, a study on formerly displaced farm households' access to agricultural technical assistance in Uganda found that middle-aged and more educated household heads have larger network size and bridging social capital as well as engaging in information seeking than older and less educated household heads (Malual 2014). While this aspect is important, the understanding of the person's initial adoption decision-making behaviour towards practice and use of an initiative such as the m-app is equally important, hence, the unified theory of acceptance and use of technology is utilised.

4.4.3 The unified theory of acceptance and use of technology

The theory was introduced by Venkatesh et al. (2003) and it considers the four behavioural factors of effort expectancy, performance expectancy, facilitating conditions and social influence. These factors are influential in determining user acceptance and usage behaviour towards an initiative. Effort expectancy is described as the degree of convenience connected with acceptance and the use of any initiative. This factor has an influence on behavioural intention in both compulsory and voluntary use environments, although the influence of effort expectancy can become insignificant in long-term and continuous use. Performance expectancy has a significant impact on an individual's intention to use a system. It refers to the degree of believing that a given agricultural practice or initiative such as agroecology or use of the m-app will help in knowledge exchange and improving smallholders' livelihoods. But theoretically, performance expectancy may differ according to age and gender (Venkatesh et al. 2003). Then facilitating condition such as the person's experience, gender and age can also influence the usage of an initiative (Venkatesh et al. 2003; Samaradiwakara and Gunawardena 2014). Social influence is the degree to which other individuals who are important to the person involved believes that he/she should use the new initiative. Social influence is determined by personal variables such as gender, the volunteer act of use, age and experience (Venkatesh et al. 2003). This factor is also dependent on other factors such as friends' opinions (Afonso et al. 2012). Additionally, the theory provides a refined view of how the determining factors of intention and behaviour change over time, although, majority of the relationships are moderated by the variables (Venkatesh 2015). See Figure 4.3 for more details.

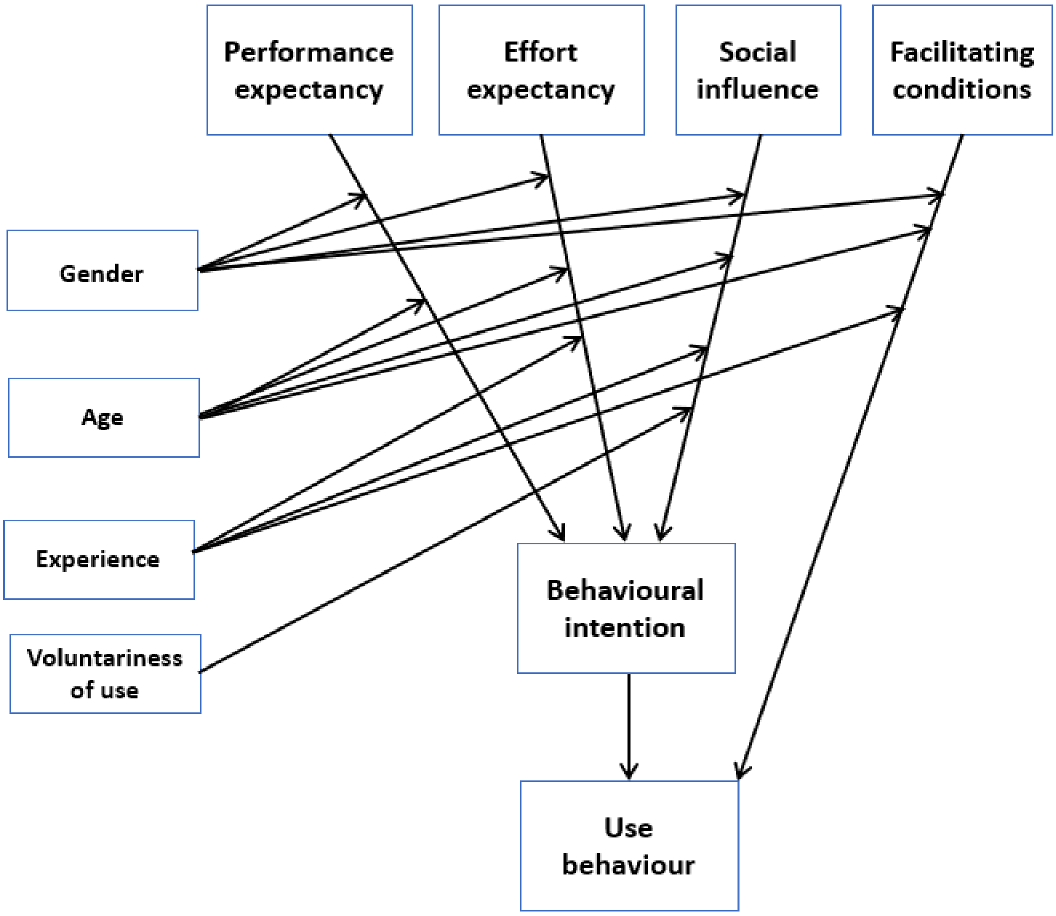

Figure 4.3: The unified theory of acceptance and use of technology model (Adapted from Venkatesh et al. 2003).

Other motivating psychological factors may also influence an individual's decision about how and when he/she can implement and use the technology or practice. These factors are situated within the technology acceptance model which was proposed by Davis (1989) and is deeply rooted in the theory of reasoned action proposed by Fishbein and Ajzen (1980). The technology acceptance model highlights the psychological factors and they are namely, perceived usefulness and perceived ease of use (see Figure 4.4).

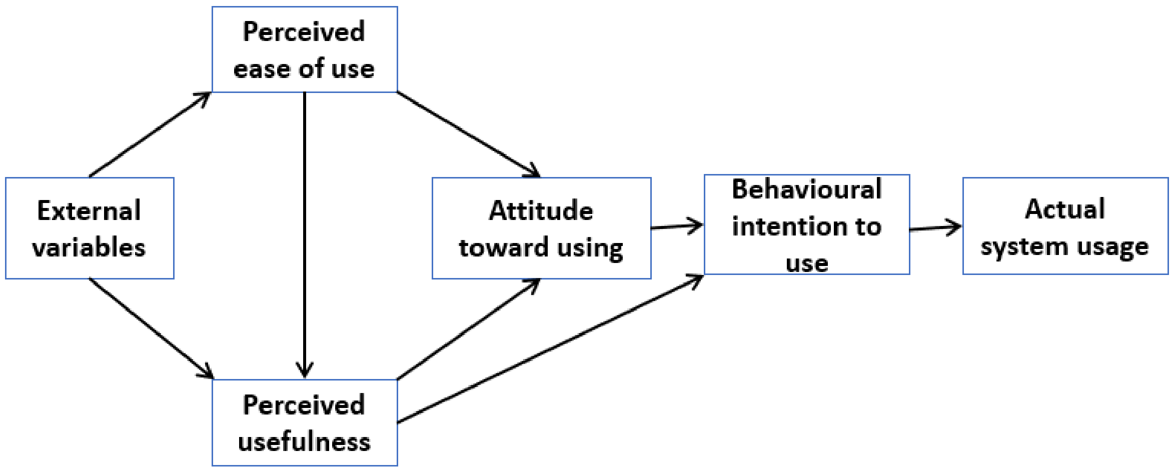

Figure 4.4: Technology acceptance model (Adapted from Davis 1989). This idea of their influence on the intention to adopt or acceptance to use is conceptualised towards both agroecological practices and the m-app for the interactive knowledge exchange (i.e., the actual system usage).

4.4.4 Perceived usefulness and perceived ease of use

The importance of perceived usefulness and perceived ease of use has been explored both in agriculture (Adrian et al. 2005) and in information and communication technology system context (Cheung et al. 2020). Perceived usefulness is defined as the degree to which an individual believes that using a particular approach or initiative would result in enhanced output, whereas perceived ease of use is the degree to which an individual feels that the approach will need little or no effort to implement or use (Dillon 2001; Samaradiwakara and Gunawardena 2014). Figure 4.4 illustrates how perceived ease of use and perceived usefulness can determine a person's intention to use a system, with intention to use serving as a moderator for the actual system use. Perceived usefulness is directly influenced by perceived ease of use. Moreover, the underlying links between the two major constructs and users' attitudes, intentions, and actual usage behaviour of the technology or practice are determined by external and/or internal variables. The person's attitude and perceived usefulness determine the behavioural intention, and the attitude is determined by perceived ease of use and perceived usefulness. In context, perceived usefulness is characterised by trust, that is, how much does a person believe that using a particular approach will improve his/her output, while perceived ease of use is characterised by skill and confidence. The extent to which a farmer believes that a specific practice can improve yield outcome, as well as the usefulness of the information relating to the implementation determines whether he/she adopts the practice (Adnan et al. 2017; Zeweld et al. 2017).

In summary, these various factors can influence farmers' behaviour towards the adoption of an agricultural practices such as agroecology, as well as the use of the m-app. According to Darnton (2008), the external (e.g., characteristics of the farmer, environment, and benefits of the proposed practice etc.) and internal (e.g., knowledge, perceptions, and attitudes of the farmer) influence farmers' behaviour. This means that intentions leading to change in behaviour, a person's belief that he/she can do something successfully, and ensuring completion, can enhance the overall outcome. These attributes clarify why farmers may or not change their behaviour, as farmers' behavioural change towards agroecology may be difficult if there is a lack of self-confidence or efficacy. The use of the m-app can also be constrained if there is perceived lack of usefulness or ease of use. Darnhofer et al. (2010), noted that farmers' choices are constrained by their individual personality, skills and preferences, as well as external structures such as social norms, technologies and natural agroecosystem. Moreover, willingness to perform a behaviour is also important. Dwyer et al. (2007) observed the importance of farmers' willingness to change in order to ensure behavioural change. In another perspective, Burton (2004) postulates that the perceived behavioural control can play a significant role within an agricultural context, where farmers are subject to variations in the physical, economic, and political environment. This refers to the perceived level of autonomy regarding decision-making that farmers feel they have and also, the self-efficacy. In context, if a farmer feels that he/she is being told what to do, instead of being in control, or feels that he/she do not have the required skills, knowledge, or a practical environment to apply a management practice, it will be unlikely that the action will be executed (Elliot et al. 2011; Hayes 2012). Moreover, change takes time and can be uncertain, especially to adapt to farming cultures, and instead of changing attitudes, new beliefs about sustainable agricultural practices, as well as social structures could require time to develop (Dwyer et al. 2007). Therefore, it is important to involve the farmers through the change process and their skills and confidence can also be built through collaboration and learning (e.g., Burbi 2014). Unfortunately, there could be a situation where some farmers may not be part of any initiative and therefore miss the opportunity to learn, whilst others may simply do not want to take part in the change, or the risks might be much for them to bear (Dwyer et al. 2007). To secure a lasting change effectively requires shifts in attitudes, habits and norms as well as fixing external factors through policy interventions (Dwyer et al. 2007; Pike 2008). Although attitude change may not necessarily change behaviour, the willingness to change which could be motivated through participation[24] and peer-to-peer knowledge sharing can influence behaviour (e.g., Burbi 2014; Mills et al. 2016). Potential therefore exists in understanding the factors that can influence behaviour and utilise a multidisciplinary approach for internal, external, and social change (e.g., using participatory action research approach, design science research etc. to engage potential users). However, where policies promote conventional methods, it is, therefore, necessary to explore the social contexts such as farmer-to-farmer or farmer-to-other actors' engagement that can promote knowledge sharing and influence decision-making. As the lack of information within knowledge groups (i.e., lack of agroecological research or access to agroecological knowledge) can have a negative effect on farmers' intention to transition towards agroecology. The source of information can significantly influence the acceptance (Burbi 2014), hence, a collaborative approach in knowledge development is important. Thus, collaborating with farmers to experiment with agroecological systems based on experience and within their own context, is vital to gaining credibility and their trust, as well as help researchers, focus on practical problems, instead of distantly prescribing or proposing solutions based on theories. To gain farmers' willingness to participate and/or collaborate with other agents requires facilitating the generation, sharing and exchange of knowledge between farmers and their social groups (Hoffmann et al. 2007; Islam et al. 2013; Modirwa and Oladele 2017; Raymond et al. 2010).

4.4.5 The concept of communication in agricultural extension

Early communication scholars described the communication process within the agricultural extension discipline as the transfer of agricultural information from the sender (encoder) to the receiver (decoder) (Laswell 1948; Schramm 1954; Rogers 1962). Early communication theories such as two-step[25] flow and diffusion of innovation[26] supported this orientation (Lazarsfeld et al. 1944; Rogers 1962). Consequently, various philosophies and methods of communication used in extension services were based on this model and have been used widely in Africa, Nigeria included (FAO and World Bank

[24] Self-identification of one's problem and the ability to find a solution to the identified problem.
[25] The two-step flow of communication is characterised by the flow of information from mass media to opinion leaders or gatekeepers and then from them to the public as it is believed that the opinion leaders will influence adoption or acceptance (Lazarsfeld et al. 1944).
[26] The process of transferring information from the initiators to the recipients (Rogers 1962).

2000; World Bank 2011). The popular, as well as dominant model that existed since the 1970s and 1980s is the transfer of technology [TOT] (i.e., top-down technology transfer method where technologies or innovations are generated at the research institutions and diffused to farmers using the extension services (Gemo et al. 2005)). The TOT methods are strongly associated with the philosophy of diffusion of innovation which states that technologies are communicated over time among the social system members and adopted based on the various characteristics of the users and technology (Rogers 2003). The model is focused on linear technology development and has been criticised due to its pro-innovation bias, non-recognition of farmers' innovative skills and knowledge and lack of the technique's attention to the social, cultural, and dynamic context of communities (Davis and Sulaiman 2016).

Other participatory methods that were intended to allow the farmers to articulate demand and contribute to research and extension activities have been developed. Examples are the farmer field school [FFS], farmer-to-farmer extension [F2FE], and farmer study circles [FSCs] etc. FFS is a group-based adult learning method where farmers are thought how to experiment and solve their farming issues independently. Farmers interactively share knowledge as well as observe and engage with facilitators regularly. This method has been successfully used in organic agriculture and mostly used by FAO in more than 90 countries of the world (Dhamankar and Wongtschowski 2014). FFS has been attributed to strengthening farmers' skills and willingness to collaborate (David and Cofini 2018). On the other hand, the F2FE or lead farmer is the provision of training by farmers to their peers through a structured farmer-trainers approach. The programme has become common in Africa, although there have been recent reports on the scarcity of training materials on the use of the techniques and analyses (Franzel et al. 2015). Whereas, FSCs is a concept of a study circle i.e., a small group of individuals with common interests who come together to learn topics of their own choice that is based on adult learning principles. The aim is to create learning, capacity, and empowerment amongst smallholder farmers through a self-directed approach, learning from peers' experience and collaborative exchange of knowledge (Chipeta et al. 2016). These various reforms have been applied in numerous African countries to enhance the efficacy of extension and advisory services (see Klerkx and Gildemacher 2012; Roling 2007). However, in Nigeria, the research, extension, and farmer linkage systems are characterised as weak, while participatory extension approaches are almost non-existent (e.g., Fawole and Olajide 2012; Ogbe 2016; Okojie 2020). While some researchers have begun to call for improved extension delivery systems in Nigeria, ones that promote interactive exchange of knowledge (Emeana et al. 2019; Okojie 2020), others have argued that ICTs such as mobile phone and its applications can promote the process (Haruna et al. 2013; Nnadozie et al. 2015). Accordingly, Fabregas et al. (2019) noted that mobile phones especially smartphones can facilitate farmers' contribution to knowledge. ICTs have also minimised costs, time and risks associated with farmers' buying and selling related journeys, as well as enhanced farmers' access to agricultural facilities (Heeks 2018; Martin and Abbott 2011; Munyegera and Matsumoto 2016).

4.5 Exploring ICT for development [ICT4D] theories

ICTs have continued to transform society by connecting remote areas and availing access to information and learning (Evans 2018b; Webster 2014). This development led to the alliance of the ICT4D initiators and the global development programme in the early 2000s which still existed to date (Heeks 2008; Techpoint 2021; United Nations 2016). Although ICT-based development initiatives have continued to expand, they are still uneven and there is a 'digital divide' in which individuals in developing countries have relatively less access to and use of technology-enabled facilities than their counterparts in developed countries (ITU 2018). Although this has been the case, countries like Nigeria are experiencing an increasing mobile penetration rate as well as adoption (see GSMA 2018c). On a larger scale, ICTs are developing faster in Africa than any other continent and have continued to play a major role in agriculture and rural development (Chavula 2014). Thus, as confirmation and practical studies within the ICT4D communities on the increasing potential of ICTs continue to emerge (Graham and Dutton 2019; Unwin 2017), it is essential to understand the theories that underpin ICT research and how the facilities such as mobile phone-enabled applications can enhance the interaction and exchange of agroecological knowledge.

The calls for an underlying unifying construct and explicit approach when considering and defining ICT research philosophies and paradigms have continued (Gomez and Day 2013; Heffernan 2018). Reacting to this, Heeks and Walls (2018) outline studies within the ICT4D research domain that utilise two paradigms namely; interpretivism and positivism (e.g., Alao et al. 2017; Erumi-Esin and Heeks 2015), while proposing critical realism as the third paradigm for an improved approach to address the connection between the use of ICTs and development. However, there are other existing communication theories such as actor-network theory [ANT], sustainable livelihoods approach [SLA] and Sen's capability approach [CA] that also support ICTs for development. These theories often shape the methodological concepts and tools for the interpretation of study phenomena and are often used in ICT4D research (Awa et al. 2016; Birke and Knierim 2020; Heeks 2010; Kivunike et al. 2015; Walsham 2017). As such, when researchers are concerned with the potential impact of ICTs on people and society, questions about what type of developmental outcome is desirable becomes crucial. In the context of this study, Sen's capability approach becomes relevant (see Kivunike et al. 2014, 2015)

The capability approach was postulated by Sen (1999). In his book 'Development as Freedom, Sen conceptualised 'freedom' in detail to refer to as effective opportunities we have to lead the type of lives we have reasons to value. CA claims that freedom to achieve well-being is a matter of what people can do and to be (Robeyns 2017). The term capability can be easily confused with a person's skills, aptitudes and abilities, or organisational capabilities. However, Zheng (2015) notes that to clarify the concept of capabilities is to differentiate it from functioning, where functioning is accomplishment and capability is the ability to achieve. The application of CA in the field of ICT4D is faced with various challenges, however, the approach leads to vital questions such as ICT4What? (Kleine 2010). Here Kleine argues that instead of trying to make ICTs fit with a linear conceptualisation of impacts and frequent economistic view of development, ICT4D should be used as a key example of a development process that has to be analysed holistically and systematically (Kleine 2010). Additionally, the CA approach leads to the question of what space of development does ICT4D contribute to and inequality of what? (Zheng and Walsham 2008). The approach ensures that the researchers answer the question of ethics and technology design to encourage a capability sensitive design or human-centred design instead of design for market or profit (Oosterlaken 2009).

The need to understand the actual benefits of ICTs in terms of what they are used for within various context requires other strategies. Consequently, the ICT4D value chain model serves as a guide in understanding the ICT4D implementation lifecycle or evaluation. Accordingly, Heeks and Molla (2009) adapted the input and output model and divided the associated resources and processes needed for ICT4D initiatives into four categories namely, readiness, availability, uptake, and impact (see Figure 4.5). Readiness is the systematic fundamental requirement for any ICT4D initiative placed at the national level, this includes, ICT infrastructure, implementation skills and policy as well as the specific inputs (soft and hard) that contribute to such initiatives. Here, the assessment may be focused on the presence or absence of the resources and capabilities (Heeks 2010). Availability describes how the implementation of an ICT4D initiative converts the inputs into a set of tangible ICT deliverables such as that may be a telecentre or mobile phones. Here, the assessment can be focussed on either the delivered resources including the delivery process (Heeks 2010). Uptake is defined as the process where access to the technology is turned into actual usage. In addition, it is worth noting that major concerns around this process and the ability to contribute to development, relates to the sustainability of the use over a period, also, for various interventions that are prototyped, the potential or actual result of scaling –up. In practice, the usage indicators may be assessed often than the uptake processes. Impact can be sub-divided into three elements as per the value chain. These are the outputs (i.e., the micro-level behavioural changes associated with the use of technology), outcomes (i.e., the general costs and benefits associated with ICT) and development impact (i.e., the contribution of the ICT to wider development objectives) (Heeks 2010; Kivunike et al. 2014).

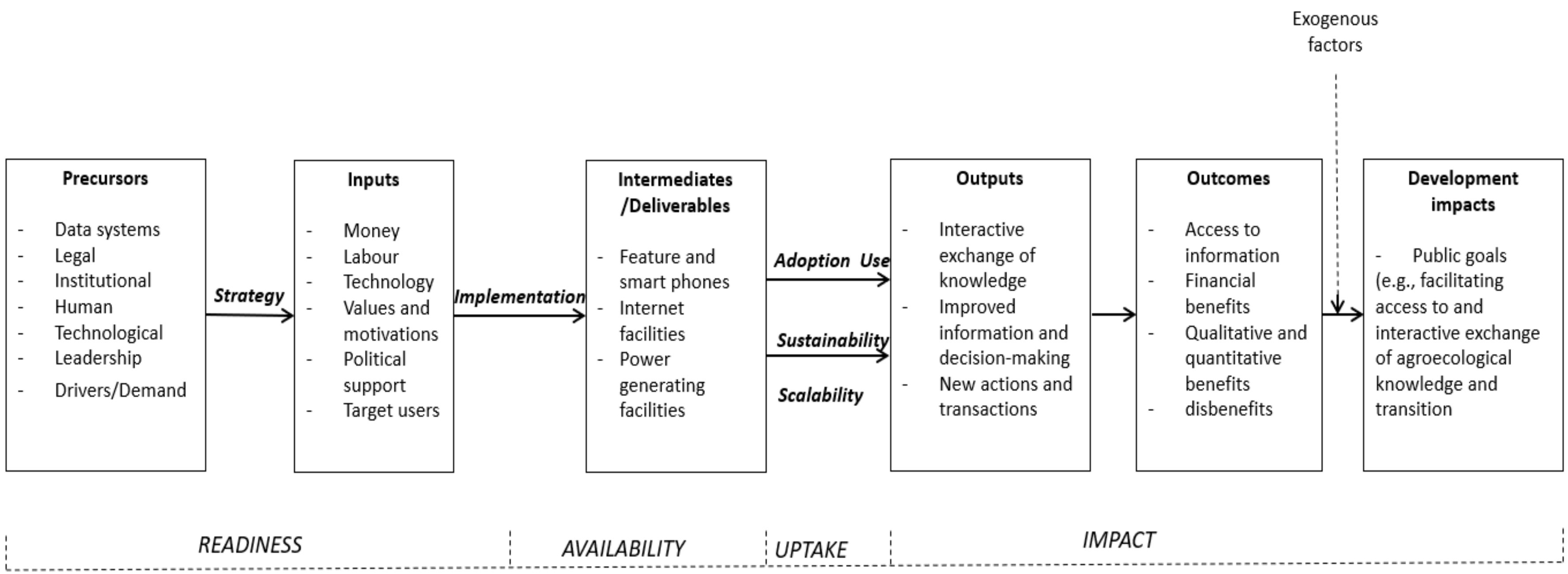

Figure 4.5: The ICT4D Value Chain (Adapted from Heeks and Molla 2009). The figure illustrates the required precursors, inputs and deliverables that are important in actualising ICT4D initiatives. In this study, the m-app is expected to facilitate interactive exchange of knowledge, help target users make informed decisions, and lead to transition towards agroecology if the precursors and inputs are in place.

4.5.1 ICT for Agricultural innovation

At present, agricultural innovation is recognised as a process by which new concepts within a certain location or context are put into practice, as such, changing the situation of those living in that location for good. According to Sulaiman (2015), ideas could be a new way of irrigating a field, a new way of bringing female farmers together to bulk their produce or a new policy that supports farmers' access to bank loans. However, some agroecology activists have called for a collective definition of the types of innovation they want (i.e., agroecological innovation) and those they do not want (co-opted practices that are toxic to what agroecology stands for), as well as to remain focused in the ways innovation is being framed specially in agroecology based studies/activities as the vagueness may prove difficult to push back against a technology-focussed approach to innovation (IFOAM EU Group et al. 2012; Maughan 2018; Moschitz et al. 2015; Silici 2014). Hence, this study conceptualises agroecological innovation as farming practices established on smallholder farmers' traditional and local knowledge (know-how) as well as new management approaches embedded in the ecological processes of their farms (agroecological experimentation). Such initiatives strengthen cooperation within farmers' networks, shortens food chain, empowers smallholders, conserves natural resources, and promotes diverse systems of local crops and livestock production (see El Bilali 2019; Hubert et al. 2017). While ICT innovations for agroecological development are ICT-based initiatives that can facilitate interaction, exchange and knowledge flow among various actors such as farmers, service providers, policymakers, researchers, traders, NGOs which will result in agroecological innovation (see Hall et al. 2001; Hall 2009). This type of innovation can be achieved through the use of modern ICT enabled platforms such as mobile phone-enabled applications, web applications etc. Such initiatives can enhance network building, support training, learning and knowledge exchange, as well as creating spaces for dialogue between stakeholders on agroecology. The initiative can also facilitate decision-making amongst smallholder farmers as well as promote demand-led services (e.g., Bell 2015; Blum and Mbaye 2009; FAO 2014).

An example of an ICTs' innovation or intervention is the Plataforma de Tecnología, Información y Comunicación Agropecuaria y Rural [PLATICAR] in Costa Rica which was aimed at improving access to agricultural information with knowledge sharing as well as supporting linkages among all stakeholders and creating opportunities for collaboration.

[31] The environment may include food production and consumption pattern, markets, climate, and resources etc.

The platform aimed to encourage interaction between farmers, researchers and specialists to identify knowledge needs as well as develop collaborative efforts to exchange knowledge (Ramirez et al. 2011). Although ICT4Ag has great potential to enhance interactive knowledge sharing (Blum et al. 2020; Senyo and Addom 2017) as well as facilitate agroecological knowledge exchange (see Chapter 9), there are questions about sustainability. These sustainability challenges are linked to access to use, ability to use, actual use and impact of use which covers the economic, social, and environmental challenges of such initiatives (Arun et al. 2004; Baumuller 2018; Emeana et al. 2020; Prasad 2008; Remy et al. 2018). Some researchers have proposed frameworks for evaluating the sustainability of ICT-enabled interventions (Remy et al. 2018; Toyama 2015), while others have called for a fundamental re-thinking of the approach in ICT4Ag initiatives by providing more information-sharing opportunities, enhancing easy access to, transparency, accountability and ownership over knowledge and information, to empower smallholder farmers (Aker et al. 2016; Blum et al. 2020; Roedl et al. 2017; Van Schalkwyk et al. 2018).

4.6 Exploring sustainability and design concepts in ICT4Ag

ICT4Ag initiatives are facilitating improvement in various sectors of agriculture (e.g., Ajwang 2014; Arinloye et al. 2015; Baardewijk 2017; Baumuller 2015; Cole and Fernando 2012; Hanson and Heeks 2020). These improvements are thought to have emerged from the increasing affordability of ICTs, faster processing and communication of data as well as increasing social interaction (Heeks 2018). However, there have been issues raised on whether such initiatives are sustainable in and through their design, encourage sustainable behaviours or have an impact on the sustainability of real-world practices in the targeted agricultural system (Blevis 2007; Brynjarsdottir et al. 2012; Remy et al. 2018). According to Beale et al. (2009), improving the impact of ICT4Ag initiatives requires the understanding of human-computer interactions [HCI][32] for development, i.e., HCI4D[33]. The goals of HCI are to ensure that usable and safe systems, as well as functional systems, are produced. This is to be achieved by

[32] HCI is the study of how humans interact with ICTs and to what extents ICTs are or are not developed for successful interaction with humans. HCI consists of the user, the device itself and the ways they work together (Ho et al. 2009).

[33] HCI4D is a sub-discipline of human-computer interaction that specifically focus on the relationship between human and ICT devices such as computers, mobile phones etc. in the context of development. The concept helps to understand the interaction between humans and ICTs as well as how to improve the relationship (Anokwa et al. 2009).

understanding the factors that determine how humans use ICTs, and then developing tools and techniques to build suitable systems, as well as putting people first to achieve efficient and safe interaction (Ho et al. 2009). Sustainable ICT4Ag initiatives then refer to the services that are developed to place the needs, capabilities (social and physical constraints) and preferences of the smallholder farmers at the centre (Bødker 2006; Brynjarsdottir et al. 2012; Chetty and Grinter 2007; Steyn and Van Greunen 2014; Winters et al. 2009), however, this is not often the case (Remy et al. 2018). Addressing the sustainability[34] challenges in ICT4Ag initiatives demands a holistic understanding of the political situations, social, economic and environmental impacts as well as the wider problems of designing, developing and deployment of services to underserved areas (Baskerville et al. 2009; Heeks 2009; Thapa and Sæbø 2014; van Reijswoud 2009; Winters et al. 2009; Zewge and Dittrich 2017). In addition to how these marginalised groups adapt to initiatives (Walsham 2010). Understanding the exact needs of the smallholder farmers can be complex as well as the design and management of m-apps (e.g., see Kim and Malhotra 2005; Sayago and Blat 2010). This, therefore, can in the short term, lead to initiatives that fail to tackle farmers' major needs and/or deliver overperforming initiatives that may be unnecessarily costly which may end up being abandoned (Aker et al. 2016; Lawrence et al. 2010). It then requires a closer relationship and continued communication between target user(s) and other major stakeholders[35] to ensure a sustained initiative.

ICT4Ag initiatives have a great potential to improve agriculture-based livelihoods as well as influence the way farmers and other key stakeholders interact. In particular, m-apps help to bridge the gap created by issues related to poor infrastructures such as weak research-extension-farmer linkages, bad roads, increased cost of buying and selling, poor access to agricultural information etc. (Baumüller et al. 2015; Emeana et al. 2020). Moreover, m-apps can enhance the interactive exchange of knowledge between farmers, extension, researchers etc. as well as encourage participation and decision-making (Yonazi et al. 2012). This could possibly result in the transition and/or adoption of agroecology and farmer engagement with the practice. But what is the actual concept behind the design of an m-app that could solve this identified real-world problem? Hence, the need for a pragmatic approach in achieving the overall aim of the study.

[34] Sustainability here means a continued long-term contribution of ICT4Ag initiatives towards improving the livelihoods of smallholder farmers without extorting them or causing more harm than good in the area of economic, social and environmental aspect (Brynjarsdottir et al. 2012).
[35] These include funders, developers, implementers etc.

Simon (1996) conceptualised that design science (see further details in the next section) supports a pragmatic research paradigm that seeks the creation of innovative artefacts to solve identified problems in the real world. Pragmatism is concerned with action and change and the interaction between knowledge and action (Goldkuhl 2012). It is characterised by a flexible approach to research design, one which takes into account the aims and context of a study (Seale et al. 2007). This assertion significantly positions it as a basis for research methods intervening into the world and not just observing the world.

4.7 Methodological approaches used in this study

Given the hegemonic nature of agriculture in Nigeria, the researcher approached the development and recognition of agroecological systems and strategies for the transitioning through a transformative framework, following Mertens' conceptualisation of a transformative framework that knowledge is not neutral, and that it reflects the power and social relationships within society (Mertens 2003). Action Research [AR] and Design Science Research [DSR] are two methodological frameworks that address design-oriented research problems from a technical and socio-cultural view (Baskerville et al., 2007; Iivari and Venable 2009). AR provides a methodological approach and pragmatic guidance for constructing credible knowledge while addressing social challenges (Huang and Wang 2005). It investigates a phenomenon through intervention in a problematic situation by making an improvement in such a situation while interrogating the phenomena of interest. As such, the collaborative activities benefit both the community of research focus and the researcher (Iivari and Venable 2009). However, DSR creates and evaluates information technology artefacts intended to solve identified community and/or organisational problems or improve the current state of practice and/or existing research knowledge (Baskerville et al. 2018; Hevner et al. 2004; Hevner and Chatterjee 2010). The concept involves a rigorous process to design artefacts, contribute to research, evaluate the designs, as well as communicate the result to the appropriate audiences (Hevner et al. 2004). Examples of such artefacts[36] include constructs, information technology interfaces, mobile and/or phone applications, models, social innovations, instantiations, or any design object with an embedded solution to any understood research problem (Peffers et al. 2007). Although situated in the information

[36] In the case of this study artefact is the mobile phone-enabled application used for agricultural development (m-apps). An example is the SmartAgroecology developed by this study (see Chapter 9).

system research field, DSR can be applied in social science. Whereas social science attempts to understand reality, DSR tries to create things that serve human purposes (Iivari 2015; Simon 1969; Winter 2008). Various studies have introduced the principles that define the meaning of DSR, goals as well as guidelines for conducting and justifying the outcome (Adams and Courtney 2004; Archer 1984; Fulcher and Hills 1996; Hevner et al. 2004; Peffers and Tuunanen 2005; Reich 1994; Venable et al. 2016; Walls et al. 2004). Hevner et al. (2004) argued that DSR must produce an artefact created to address a perceived issue. They further noted that the artefact should be relevant to the solution of the problem as well as its utility, quality, and efficacy. As such, Hevner et al. (2004) and Peffers et al. (2007) outlined a six-step framework for applying a DSR methodology which includes:

1. Problem identification and motivation – This stage requires the researcher to define the specific problem and justify the value of the solution. The resources needed are the knowledge of what the problem is and the importance of the solution (Peffers et al. 2007).
2. Defining the objectives for the solution – The purpose of the intended solution from the identified problem and understanding of the possible and feasible solution. The objectives can be quantitative (i.e., where a desirable solution is expected to be better than a current one), or qualitative (i.e., a description of how a proposed artefact is expected to support solutions to identified problems not previously addressed). This requires knowledge of what the problem is and current solution if any as well as efficacy (Peffers et al. 2007).
3. Design and development of the intended artefact – The activity involves determining the functionality and architecture of the desired artefact and then creating the actual one. This stage requires knowledge of theory and expertise that can be utilised in a solution (Hevner et al. 2004; Peffers et al. 2007).
4. Demonstration – Demonstrate or experiment with the use of the artefact in solving the identified problem. The resources required in this stage include how to use the artefact to solve the identified problem (Peffers et al. 2007) as well as observing users' capability and updating the artefact if need be.
5. Evaluation – This is an iterative process to observe and measure how effective the artefact supports a solution to the identified problem using relevant analytical techniques such as surveys, feedback from target users etc (e.g., qualitative, or quantitative results) (Peffers et al. 2007).

6. Communication – This stage is important to diffuse the knowledge gained from the results to the relevant audience through the form of conferences, journal etc. (Hevner et al. 2004).

However, Lawrence et al. (2010) noted that the design context could vary depending on the potential user(s) background and could result in an inappropriate artefact. Lawrence et al. (2010) modified the framework and suggested that the evaluation stage should be the entry point instead, referring to the revised process as ‘an evaluation-based initiation’ where target users’ capabilities are critically understood, thus, allowing a critical understanding of the problem and actual process of the possible solution.

Although both approaches (i.e., AR and DSR) appear to be different, they can be integrated (Iivari and Venable 2009). Combining them in research ensures a relevant grounding of design science research effort in the real understanding of relevant situational problems and promote evaluation of the newly designed technology (Baskerville et al. 2007; Baskerville et al. 2009; Bilandzic and Venable 2011; Cole et al. 2005; Sein et al. 2011; Venable 2006).

4.7.1 Participatory action and design science research [PADR]

PADR includes Participatory Action Research [PAR] that was developed in the field of organisational behaviour (Argyris and Schön 1989; Wadsworth 1998) and Participatory Design [PD] which is most visible in social sciences and information system design research field (Bilandzic and Venable 2011; Kensing 2003). PAR involves participants as both subjects and co-researchers and their involvement requires active participation throughout the research process. PAR approaches have proven effective in bringing different actors together at various levels, enhancing social capital and encouraging user-centred design to collectively solve problems identified (Baskerville et al. 2009; German et al. 2012; Joseph and Andrew 2008; Pretty and Buck 2002; Spinuzzi 2005). PAR approaches facilitate ‘space’ for empowering communities, target beneficiaries to contribute to decision-making for planning, execution, and evaluation of impacts of initiatives. These attributes make PAR approaches different from conventional empirical research (Dearden and Rizvi 2015; German and Stroud 2007). Various PAR methodologies have been successfully applied in ethnographic research[37] (Mapfumo et al. 2013; Oliver et al. 2012). An example is the Participatory Rural Appraisal [PRA][38] which is often used to obtain preliminary information from the target research community (i.e., study participants) (McCracken et al. 1988). Although PRA has limited advantages in addressing the problems from researchers' technical viewpoint, it is responsive and flexible to new learning and conditions on the ground (German et al. 2012; Kruger and Sturtevant 2003). Similar to PRA, are other participatory approaches used to promote farmer-to-farmer knowledge sharing, bring together the knowledge and research capabilities of the smallholder farmers with the research institutions in an interactive way as well as ensure transparency and respect for all parties involved (Barakabitze et al. 2017; Selener 2007). A few examples of such approaches include participatory learning and action research, participatory communication, farmer participatory research, participatory information and communication technology development, participatory video, informal mobile learning research etc. (Barakabitze et al. 2017; David and Asamoah 2011; Gadhi et al. 2007; Selener 2007; Toyama et al. 2009). PAR approaches regarding data collection include interviews, focus group discussions etc. (Mapfumo et al. 2013). Most importantly, PAR has been successfully used in addressing local challenges faced by rural communities and in strengthening agroecological practices in other African countries (Fitzpatrick 2015; Nyantakyi-Frimpong et al. 2016).

Participatory design [PD] on the other hand addresses similar issues and is concerned with information system development in practice instead of research per se (Kensing 2003; Schuler and Namioka 1993). According to Kyng (2010), PD allows the participation and contribution of the potential user representatives, who work with the researcher to produce a system that can be understood and managed in practice by the users. The approach is also used to diagnose the ICT needs of rural dwellers (e.g., smallholder farmers) (Barakabitze et al. 2017; Joseph and Andrew 2008). As such, the approaches can facilitate farmers' or target users' participation in developing ICT4Ag initiatives (Barakabitze et al. 2017). According to Walsham (2012), the quest for the future in ICT4D is towards the use of participatory user-centred approaches in developing ICT4Ag

[37] Ethnographic research requires that the researcher(s) observe and/or interact with the study's participants in their real-world environment helping the researcher to gain deeper understanding of the problem. This could be achieved through participants' observation, focus group discussions, interviews, consultations etc (Mapfumo et al. 2013).

[38] PRA is a suitable approach that can be applied as a pilot when embarking on research that involves farmers. This involves an informal, rapid, exploratory survey to understand the local agricultural conditions, problems and characteristics (German et al. 2012).

initiatives. The use of the PD approach is suggested to enhance a sustainable information system where knowledge about cultural, environmental, economic, organisation and political conditions from the multiple stakeholders are integrated throughout the entire process of the initiative (Parmar 2009; van Reijswoud 2009). Although PD has its challenges as in who participates, with whom, at where, in what, how they are invited and why? (Bratteteig and Wagner 2014; DePaula 2004; Kendall and Dearden 2018), the approach provides users with the opportunity to actively participate in the technical design, enhance collaborative learning and create mutual understanding between various participants (Dearden et al. 2010; Doerflinger and Dearden 2013; Winschiers-Theophilus 2009). Adapting participatory design processes (i.e., in design, development and usage pattern), proved effective in the study carried out by Agarwal et al. (2010). Such participatory design approaches as in data collection include focus group discussions, design, and development workshops etc. (Rossi and Sein 2003). The concept of applying these approaches in this study meant that the researcher drew insight from various fields of study including non-scientific communities (e.g., social and information science, farmers etc.) which is termed as transdisciplinarity or transdisciplinary approach.

4.8 Transdisciplinary approach

Five decades ago, saw the gathering of Jean Piaget and other scholars in human development and knowledge, as well as higher education leaders gathered in France to speak about the importance of moving beyond the disciplines' research and innovation. At the seminar organised by the Organization for Economic Cooperation and Development, the term transdisciplinary was formed and differentiated from interdisciplinary and multidisciplinary contribution (Apostel 1972).

Transdisciplinary approaches are considered a new form of learning and problem-solving that involve actors and/or concepts from both the scientific community and other relevant sectors to tackle real-world problems. The approach helps researchers to deal with tangible and complex research questions that societies need to tackle (Lawrence 2010). Gibbons et al. (1994) argue that the conventional styles of carrying out research are insufficient and that joint problem solving amongst communities. Various studies have indicated the importance of addressing the current challenges facing the agricultural sector using a transdisciplinary approach (Hicks et al. 2010; Sunderland et al. 2012). The approach allows the establishment of collaborative action between farmers, researchers, extension agents, public and private organisations in order to solve practical issues. It enables researchers to combine theories and applicable strategies in discussing and critically analysing farmers' farming practices, knowledge and experience and the opportunities for improvement (e.g., agroecology as an alternative). Most importantly, the strategy is aimed at enhancing the exchange of knowledge between farmers, extension agents, researchers and other relevant stakeholders as well as promoting farmers-driven research. In this case, various qualitative methodologies, as well as design science approaches, are blended in order to engage with the stakeholders by establishing a two-way dialogue between the investigator and participants.

Chapter summary

This chapter has enumerated the theories that underpinned the processes and assumptions made in this study. Moreover, the chapter established that various schools of thought have used different models in postulating sustainability transitions in agri-food systems. Prominent amongst these is the Gliessman (2016) five-level transition framework which emphasised the importance of smallholders' change of practices at the farm level through to the transformation of the entire food systems. Contextualising this framework, the chapter illustrated the levels of agroecological transition that best suites Nigeria and especially the smallholders' that will be surveyed in this study. This approach was informed by the present agricultural systems in Nigeria that appear to be dominated by conventional systems. It also explored the theories that were applied in various related studies that supported the intrinsic and extrinsic factors that shape how individuals behave towards accepting and/or rejecting a particular practice or system over others in an ideal world.

The scope of this thesis also cuts across information and communication technology for development studies. This implied that this chapter also evaluated some other related theories that have been applied in various capacity in ICT studies and most importantly, ICT for agricultural development. This chapter elucidated the various approaches used for communication in agricultural extension and outlined the importance of mobile phone-enabled applications. Moreover, it highlighted the concept of sustainability in ICT4Ag initiatives and explained the methodologies adopted by this study to ensure that the outcome of the thesis is grounded within the context of sustainability to some extent. The researcher adopted a transdisciplinary approach to accomplish the aims and objectives of this study.

Given the understanding of the theoretical background that informed this study, it is imperative for the researcher to clarify the relationship of these theories with the study's concept and how the entire study aims, and objectives is achieved, hence, Figure 4.6 sheds more light. Consequently, the following chapter details the methods, participants involved, description of the study location and research design adopted in this study.

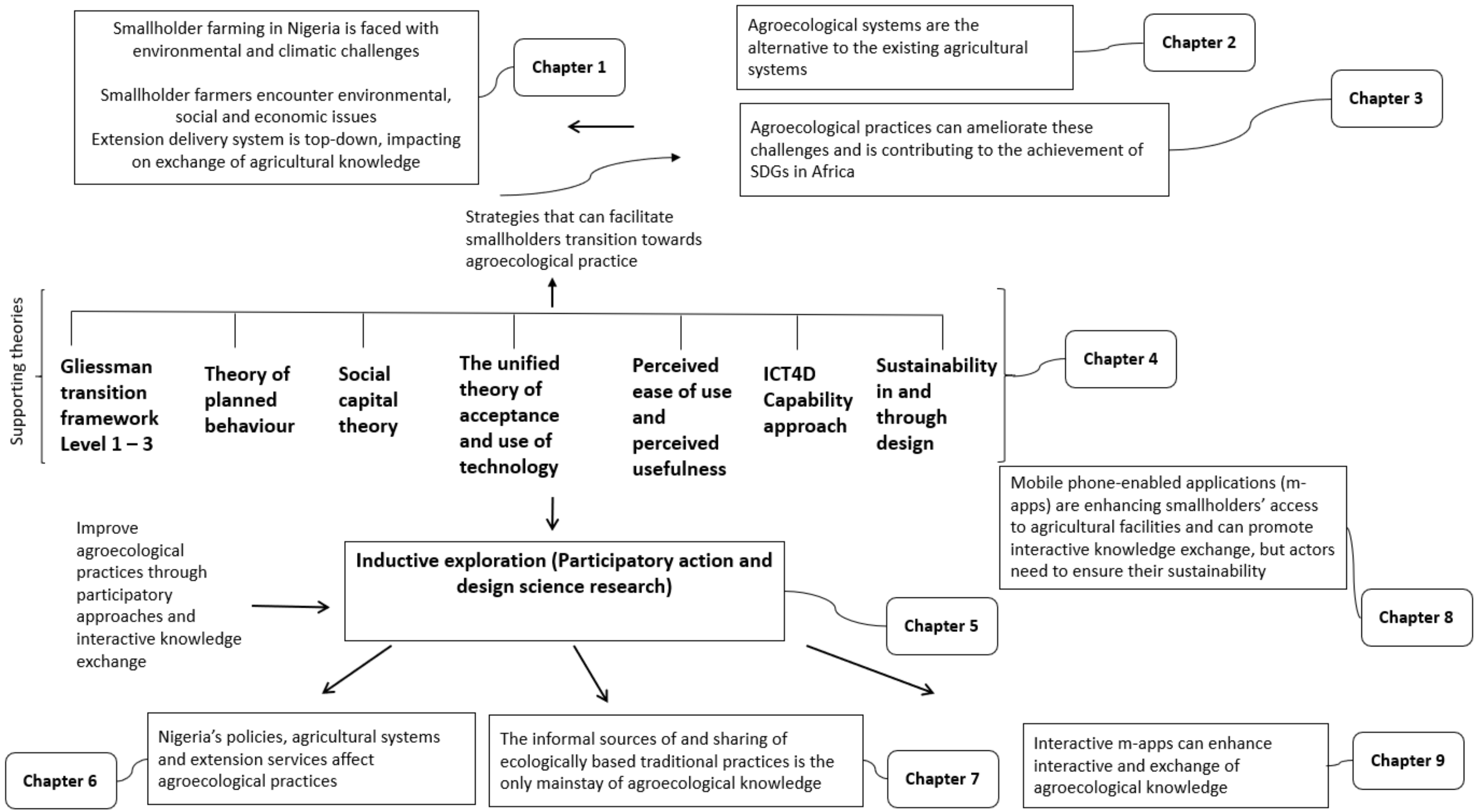

Figure 4.6: Diagrammatic presentation of the theoretical framework

Chapter 5: The research process and design

All research is characterised by some underlying beliefs and traditions about what constitutes valid research and which research method(s) is or are suitable for the development of knowledge in a given research project or study, as well as reasons for choosing a particular location(s). This chapter, therefore, addresses the methodological protocol, research tools and steps involved in actualising the overall thesis aims and objectives. Additionally, this chapter provides the justification for the researcher's choice of methods, participants and study location, as well as the philosophical perspective underpinning this study. Although some of the information pointed out in this chapter may somehow be replicated in the subsequent chapters where the details of the specific methods used are also outlined. This chapter provides additional information on the activities and encounters during the course of this study. The ethical considerations are also presented followed by a chapter summary.

5.1 Introduction

The importance of outlining and understanding the methodological process, principles and philosophical assumptions underpinning this thesis cannot be overemphasised. This is so because, for a qualitative study of this kind to be accomplished, the researcher has agreed to the underlying philosophical assumptions and applied his/her own world views that shaped the direction of the research. Such views influence the type of problems that needed to be researched, what questions were asked or how data was gathered and analysed (Creswell and Poth 2017; Yeung 1997). The nature of the overall study (i.e., aiming to solve real life-world problems) and engagement of key stakeholders or actors in the agricultural sector (e.g., farmers, extension agents, lecturers), warrants the integration of collaborative action between the researched and researcher. See Burbi 2014; Feola and Binder 2010; Hicks et al. 2010; Jolibert and Wasselink 2012; Pohl and Hadorn 2007; Sutherland et al. 2012; van Rijnsoever and Hessels 2011; Weichselgartner and Kasperson 2010, for examples of studies that incorporated such approaches. Hence, the following sections provide a detailed description of the study location, assumptions and processes involved in actualising the aims and objectives of this study.

5.2 Characteristics of the ecological zones in Nigeria and their agriculture and extension services

The climate of a place determines the natural vegetation, the crops that can be grown and the livestock management. Nigeria has two broad distinct ecological zones which are the forest and savannah (Kayode 2010). The forest is the ecological zone that consists of dominant tree species, while the savanna is the grassland area with scarcer tree cover. Each of these ecological zones has different weather conditions and the intensity of the weather elements varies from one zone to the other, determining the length of the farming season and crop yields (Kayode 2010). The forest zone is characterised by a prolonged rainy season with an annual rainfall above 2000mm which is very important for biodiversity and food production, making it favourable for agricultural activities (Sowunmi and Akintola 2010). See Figure 5.1 for the different ecological zones with the fieldwork location highlighted.

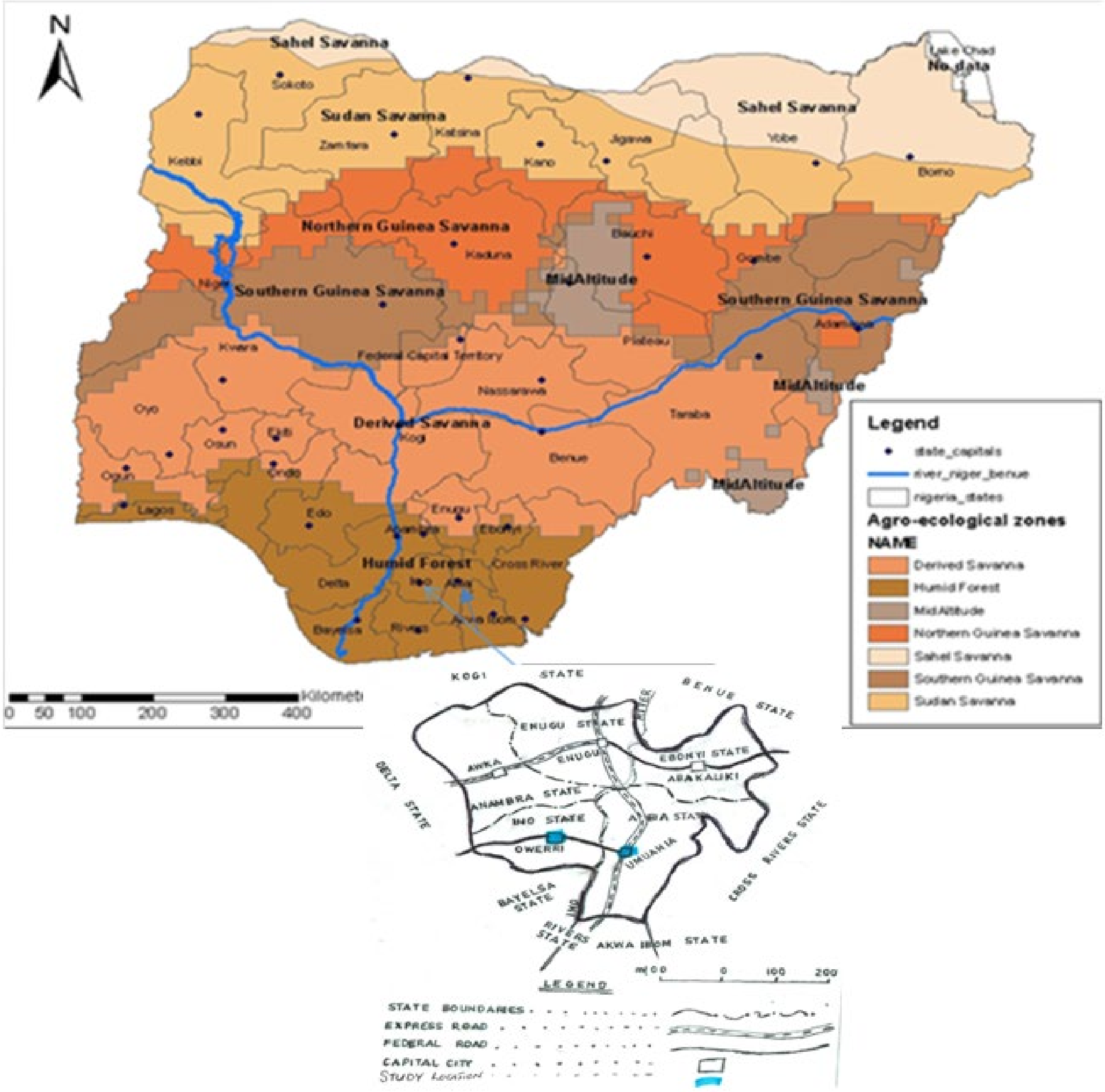

Figure 5.1: The ecological zones in Nigeria, the blue arrow and highlight indicate the states selected for this study (Adapted from Aregheore 2005 and World Bank 2014)

Smallholders generally constitute most of the farm holdings, with medium and large-scale producers relatively scattered in all the zones. The savannah zone was recorded as having a larger number of households participating in agriculture (World Bank 2014). Staple crop farming (e.g. cultivation of cassava, yam, maize, sorghum, cowpeas, melon, groundnuts etc.) is the most common farming activity in both zones, with livestock activities much more common in the savannah zone compared to the forest zone. Although cowpeas and sorghum are very popular in the southern guinea savannah, a few farmers have begun to grow such crops in the forest zone (World Bank 2014).

Each of the regions in Nigeria namely; north-east, north-central, north-west, south-east, south-south and south-west, have one National Agricultural Extension and Research Liaison Service [NAERLS] zonal office each that supervises the agricultural activities and transfer of technology in each of the 36 states of Nigeria including the FCT that are within their host region. Each of the NAERLS' zonal offices performs their supervision and extension-farmer linkage through the various State's Agricultural Ministry and Agricultural Development Programme Unit [ADP] (each state's ministry and ADP are located in the state's capital city). The research-extension linkage is carried out by the NAERLS' zonal office partner agricultural universities and research institutes in the states. Both activities are part of the REFILS (i.e. research-extension-farmer-input-linkage system) initiative (Sani et al. 2015). All the NAERLS zonal offices report to the NAERLS headquarters, which is located in Zaria, Kaduna state. Table 5.1 shows the different regions of the country, their respective states and NAERLS zonal office location.

Table 5.1: Regions and NAERLS zonal office locations

Regions and respective states (each state has its own State Agricultural Ministry and ADP)		**NAERLS zonal office location (the zonal office overseas the activities of the states under its jurisdiction)**
South-east	Abia* Anambra Ebonyi Enugu Imo*	Umudike – Abia state
North-east	Borno Yobe Bauchi Gombe Adamawa Taraba	Maiduguri – Borno state
North-central	Benue Kogi Nasarawa FCT Plateu Niger Kwara	Bedeggi – Kogi
North-west	Jigawa Zamfara Kaduna Kastina Kebbi Sokoto Kano	Kano – Kano state
South-south	Akwa Ibom Bayelsa Cross River Delta Edo Rivers	Port Harcourt – Rivers state
South-west	Osun Oyo Ekiti Ondo Ogun Lagos	Ibadan – Oyo state

*Study location (see detailed sample selection strategy in Section 5.7.2 in this chapter)

5.3 Study location

The study is focused in south-eastern Nigeria and two states namely, Imo and Abia were chosen as the study sites (see Figure 6.1 in Chapter 6 for map of Nigeria which shows the various regions). Southeast Nigeria is in the rainforest ecological zone. The zone lies within the latitudes of 5^0 to 6^0N of the equator and longitudes of 6^0E and 8^0E of the Greenwich Meridian. The zone occupies a total landmass of 10,952,400 hectares with an estimated population of over 25 million (National Bureau of Statistics 2016). The zone is characterised by wet (between April and October) and dry (between November and March) seasons. Precipitation is heavier in the southeast which receives more than 120 inches (i.e., 3,000 mm) of rain yearly, compared with about 70 inches (i.e., 1,800 mm) in the southwest. Rainfall decreases progressively away from the coast and the temperature and humidity remain relatively constant throughout the year in the south generally. In terms of settlement patterns, the rural areas are densely populated with settlements consisting of dispersed homesteads known as compounds. Each compound is made up a household which comprises a man, his immediate family, and some relatives (National Bureau of Statistics 2016).

5.3.1 Criteria for site selection

Imo and Abia have close border boundaries with a travelling distance of 42 miles and similar agronomic and climatic characteristics as well as ethnic and cultural settings. The characteristics of their farm activities, access to land, market, livestock management and extension service delivery are very similar and so comparable with other states in the southeast region (NAERLS 2012). The similarity in climatic and agricultural activities of these two selected states with other three states in the southeast, implies that the prospect of promoting agroecology in the entire region could be considered. Generally, the digital rural-urban divide especially the aspect of internet penetration is also reported to be improving in the region (Gillwald et al. 2018), which is also important for this study.

These study sites were primarily selected because of the active engagement of the smallholder farmers in agricultural production and extension activities. In particular, Abia state was chosen because it is the home of NAERLS' southeast zonal office which is located at Umudike in Ikwuano Local Government Area of the state and this is where the extension subject specialists in charge of the southeast zone are situated. In addition, the proximity between the NAERLS southeast zonal office and the University of Agriculture Umudike facilitated the researcher's access to the agricultural lecturers that participated in the study. On the other hand, Imo state was selected because the closest Adopted Village Scheme (AVS) of the NAERLS southeast zonal office is located in the state (see description of AV scheme in section 5.4). Moreover, the field extension agents and coordinators of extension services for Imo state jurisdictions are situated in the Extension Department of the ADP, Imo state.

Umuakaobia was selected based on the presence of the AVS, an extension-supported initiative designed to support farmers in crop and livestock management and access to agricultural information. This provided an opportunity to explore the effect of the extension advisory service provided to these adopted farmers by the extension agents and their role in promoting agroecological knowledge since it is a government agricultural support programme (NAERLS 2015). Additionally, the accessibility of other neighbouring communities availed the researcher an opportunity for a further selection of other smallholder farmers from Ezinnachi and Enyiogugu who were not part of the adopted village concept. This helped to understand more broadly the agricultural knowledge and innovation system and/or agricultural innovation system (see more details in Chapter 7), as well as the state of agroecological approaches beyond those who receive advice through AVS. Figure 5.2 shows the various study sites. The lists of the smallholder farmers in the study area and extension agents were collected from the ADP and NEARLS' zonal office, respectively, while the lecturers were accessed through their university department.

Studying these various stakeholders (i.e., AVS/adopted farmers, non-AVS farmers, extension agents and agricultural lecturers) enabled an important evaluation of smallholder farmers' information needs and sources as well as the constraints to access agricultural information and opportunities to enhance such constraints using an interactive mobile phone application. From the context of the fieldwork, the three selected farm communities in Imo state are very similar in their farming activities and living conditions (i.e., smallholder farming and live in small decentralised settlements), however, the difference is that one was under the extension adopted village scheme which could mean that the smallholder farmers' extension experience and decision-making towards the adoption of agricultural practices might be different.

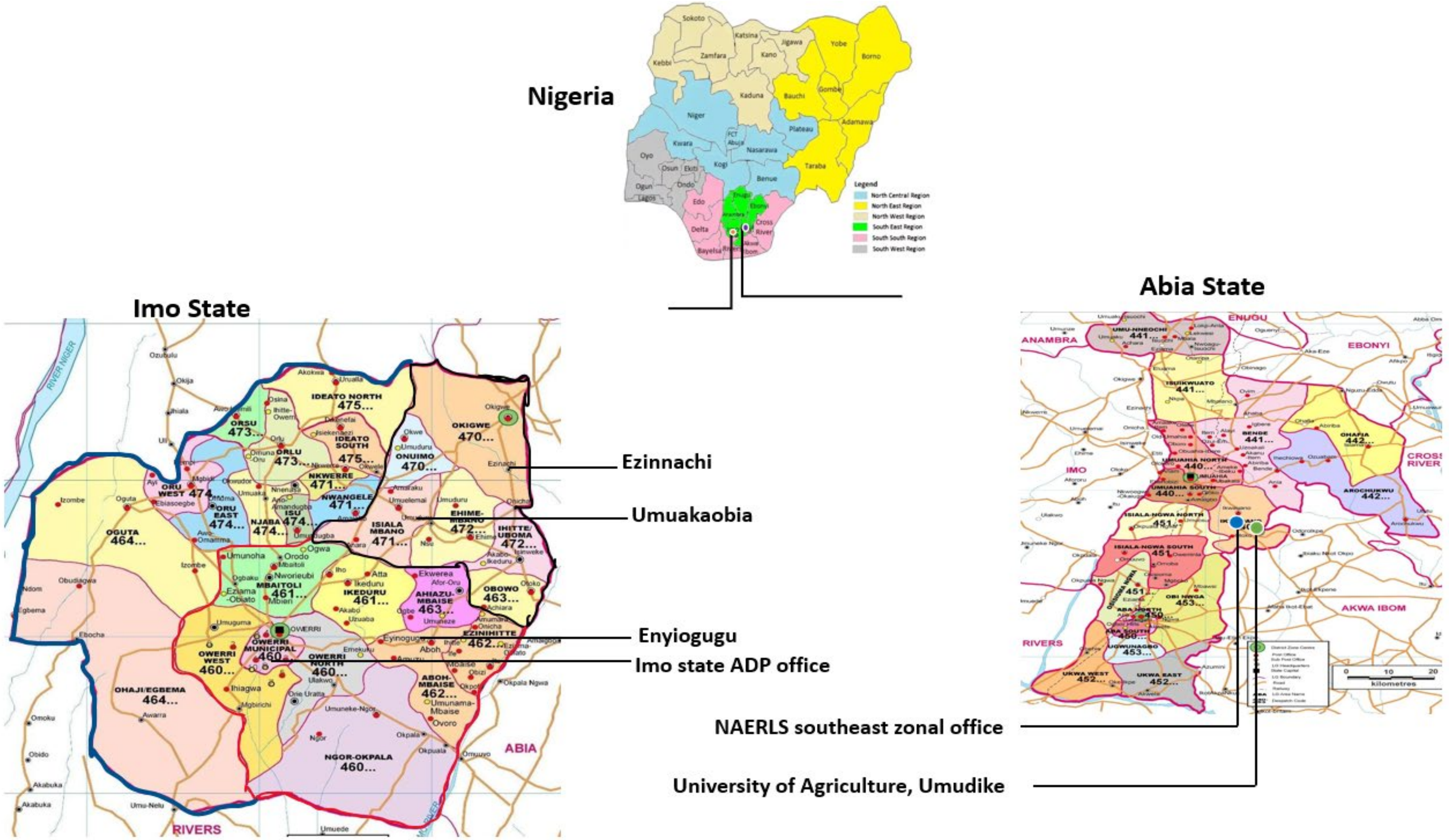

Figure 5.2: The study sites in Imo state (i.e., Ezinnachi, Umuakaobia, Enyiogugu and Imo state ADP office) and Abia state (i.e., NAERLS zonal office and University of Agriculture, Umudike). The blue, red and black highlighted areas in Imo state shows the Orlu, Owerri and Okigwe agricultural zones, respectively (adapted from Google Maps).

5.4 The concept of AVS

The concept of the AVS was born out of the government's initiative through the Agricultural Research Council of Nigeria [ARCN] to improve access to farmers as well as linking farmers to the research institutes via the extension agents (Mustapha et al. 2013). As such, the ARCN issued a directive that each research institute including agricultural universities and colleges identify two communities within 20-kilometre distance from each of the NAERLS zonal offices in the country with the mandate of enhancing farming practices and agricultural policies (NAERLS 2014). Accordingly, the selected community farmers are being engaged with using their farmlands to demonstrate farming activities or a particular agricultural innovation and thus, their farms serve as demonstration sites for other neighbouring farmers. Umuakaobia community is one such communities that fall within the 20-kilometre distance of NAERLS southeast zonal office, Abia State.

The principal aim of AVS is to address the challenges of reaching remote farmers as well as accelerate the adoption rate of new agricultural practices and/or innovations. According to NAERLS (2014), this flagship concept also aimed to:

- Empower the communities through the provision of infrastructural development.
- Enhance the economic status of the farming communities using capacity building initiatives.
- Provide information resource centres where farmers can easily access research-based agricultural information.
- Build a productive and self-sustaining community, as well as creating new markets.

The approach aimed to create opportunities for researchers and extension agents to work together with farmers who are willing to experiment with farming ideas in their farms (Sanni et al. 2012). The programme is targeted to strengthen the knowledge and skills of farmers on agricultural production through ad hoc training and empower them in identifying their farming problems and search for sustainable solutions (Adeogun et al. 2017). Evaluating the effectiveness of AVS, NAERLS (2014) and Sani et al. (2015) reported that the concept has improved farmers' access to agricultural information, as well as extension agents' direct access to farmers generally. Given the objectives of this scheme, it is expected that the programme could facilitate the promotion of sustainable agricultural farming systems such as agroecology, hence, the motive for the case selection.

5.5 Researcher's inspiration for this study

This study is born out of the researcher's engagement in smallholder farmers' livelihood development projects and interest in environment-friendly agricultural practices, as well as her years of experience as an agricultural research and extension officer. She is naturally drawn to the experiences of smallholder farmers who were either struggling with pests, insect and disease infestations in their various farms or were grappling with continuous application of agrochemicals on the improved seeds they purchase every planting season. These experiences, combined with anecdotes from other agricultural researchers, created the awareness of the issues facing Nigeria's smallholder agriculture. Enete (2014) and Osuafor and Nnorom (2014) in their respective studies, highlighted that Nigeria's agricultural sector is facing multiple challenges ranging from environmental problems associated with modern agricultural activities (conventional systems of agriculture) to climate change exacerbating food crises.

On the other hand, there is increasing and documented evidence of the positive impacts of agroecological approaches on human and environmental health across regions like Latin America, Europe and some other parts of Africa (Nyantakyi-Frimpong et al. 2016; IPES-Food 2018; Snapp et al. 2010). In order to inspire the smallholder farmers to adopt agroecological approaches or revitalise their own traditional knowledge, they must have awareness and knowledge of agroecology as well as access to agroecological information (Altieri and Nicholls 2017). In Nigeria, the lack of adequate information about environment-friendly agricultural practices is considered to be one of the major constraints to farmers' adoption of agroecological practices (Enete 2014; Mgbenka et al. 2015). However, with the present AVS initiative, the researcher is curious to unveil the impact of extension and advisory services in agroecological development. Given the established role of the ICTs such as mobile phones in enhancing smallholder farmers' access to agricultural services in Africa Nigeria included (Aker et al. 2016; ITU 2016), the researcher explores an innovative way that might improve information access and encourage interactive agroecological knowledge sharing amongst agricultural stakeholders in Nigeria.

5.6 The philosophical assumptions and positionality

Over a decade, the philosophical assumptions made by qualitative researchers have been articulated in various SAGE Handbooks of Qualitative Research by Denzin and Lincoln (1994; 2005; 2011). Guba and Lincoln (1988) defined these assumptions as guiding philosophy behind qualitative research. Such beliefs have been referred to as paradigms (Lincoln and Guba 2011; Mertens 2010); ontologies and epistemologies (Crotty 1998); alternative knowledge claims (Creswell 2009); and as broadly conceived research methodologies (Neuman 2000). Philosophy deals with the ontology (i.e. what is the nature of reality), where the researcher embraces the idea of multiple realities and provides reports on the realities by exploring various forms of evidence in themes, using the verbatim quotation of different individuals' experiences and perspectives (Moustakas 1994). Epistemology (i.e. what counts as knowledge, how are knowledge claims justified and what is the relationship between the researcher and the researched), here the researcher tries to get closer to the participants (the researched) to gain first-hand information and assemble subjective evidence based on participants' views (Guba and Lincoln 1988; Wolcott 2008). This also involves axiology (i.e. what is the role of values in research), the researcher makes his/her values open in the study and actively reports the values and biases, as well as the value-laden nature of the information gathered. Finally, the methodology (i.e. what is the process and language of research) is characterised as inductive and shaped by the researcher's experience in data collection and analysis. Sometimes, the research questions and data collection strategies may change as the study progresses. Hence, Denzin and Lincoln (2011) consider these four assumptions which are: 1) embracing the reality; 2) a closer relationship with researcher; 3) being open with the research values and information retrieved; and 4) inductive approach to research as to the major foundations that are embedded in social science research. As such, this thesis is situated in these viewpoints following a constructivist approach by Shoqirat (2009) which emphasises the importance of how people feel and construct their own understanding of the world they live in as well as their individual experiences and reflection on such experience.

This study involved the development and demonstration of an interactive mobile phone-enabled application that is embedded in the research to solve the perceived problem. The iterative process is an important part of the design science research methodology which reveals the reality and knowledge that originates from the research efforts. The action of dialogue to understand the existing situation (i.e., smallholder farmers' agricultural activities, access to relevant, timely information and associated issues) and identify and design a possible solution (i.e., aiming to provide accessible interactive coproduction of agroecological knowledge) also situated this study in the context of Participatory Action Design Research [PADR] (Haj-Bolouri et al. 2016; Bilandzic and Venable 2011). Accordingly, Bilandzic and Venable (2011) and Iivari (2003) in their respective studies, argued that PADR enables closer collaboration between participants and the academic researchers as well as bridge the gap of the implications for the design of technology. In this context, this study involved the collaborative efforts of the study participants in the knowledge inquiry, identification of the problem, action for change and solution to the identified problem. This strategy is important to support learning and empowerment as well as ensure that a solution does not induce more problems than it solves (Dearden and Rizvi 2008; Kolko and Rose 2007). Moreover, such participation is what Oakely (1991) referred to as the third level participation, which seeks to build the community's capacity to manage their own problem.

The researcher's positionality can be relationally unstable, not fixed and contextually situated. This means that his/her position can shift throughout the research process depending on where the researcher stands in relation to power (Greene 2014; Grimaldi et al. 2015; Merriam et al. 2001). The positioning could be attributed to the cultural values of both the researcher and participants. Accordingly, Sikes (2004) noted that some of the features of positionality are culturally fixed, for example, nationality, language, gender, race etc., while other characteristics such as experience and personal life history are subjective and contextual. Here the researcher is part of the social world he/she is researching. The researcher's position as an insider or outsider to the context being studied could possibly put the researcher in an advantage or disadvantage position and might influence the research process (Hammersley 1993). As such, this study considers the researcher's position as an outsider with an insider background as a former extension officer and critically examines how the challenges were overcome (see section 10.5). The researcher's background in agricultural extension also influenced the positioning of this study as multi-paradigmatic research with an interpretive perspective that aligns with the established philosophical assumptions. Moreover, the researcher's position in this study classifies her as a pragmatist (e.g. Bunge 1984; Checkland and Scholes 1999; Henry 2004; Pierce 1931). Epistemologically, the researcher understands that a piece of information is factual and what the information means through the process of iteration.

Goldkuhl (2012) suggests that qualitative research can adopt a pragmatist stance which aims for constructive knowledge that is appreciated for being useful for the research community or an interpretive position which aims towards an understanding that is appreciated for being interesting in the field of study.

Pragmatists contend that the most important determinant of any adopted research philosophy is the research question, claiming that one method may be better than the other for tackling a particular research question. These advocates agree that it is perfectly possible to work with both philosophies (pragmatism and interpretivism) (Braa and Vidgen 1999; Baskerville and Pries-Heje 1999; Bilandzic and Venable 2011; Martensson and Lee 2004; Cole et al. 2005). Patton (2002) also argued in favour of pragmatism, and Barbour (2008) claimed that there is no shame in using different approaches that suite the research questions.

5.7 Research approaches and strategies

Given the fact that agroecology is a practice that supports smallholder farmers' traditional knowledge (Altieri et al. 2017; Wezel et al. 2009), taking a pragmatic approach towards research will help to overcome difficulties in communication between the researcher and the farming community as well as improve practice-based activities. The approach allows the description and understanding of the situation rather than predicting and controlling the situation, as the participants' views and activities are revealed without manipulation (Gilbert 2001; Leininger, 1985; Streubert and Carpenter 1995). Hence, this thesis adopted PADR approaches which are situated in the pragmatism and interpretivism paradigm (Baskerville and Myers, 2004; Goldkuhl 2007; Goldkuhl 2012; Goles and Hirschheim 2000). Figure 5.3 below represents this study's research design process. The techniques used for data collection include focus group discussions, design and development workshops, field observations, and interviews as described by Kemmis et al. (2014) and Rossi and Sein (2003). On this note, the researcher believes that it is important to combine different research methods that best answer a study's research questions (Maarouf 2019; Ritchie et al. 2013), hence approaches used in data collection and analysis and their rationale are detailed in subsequent sections.

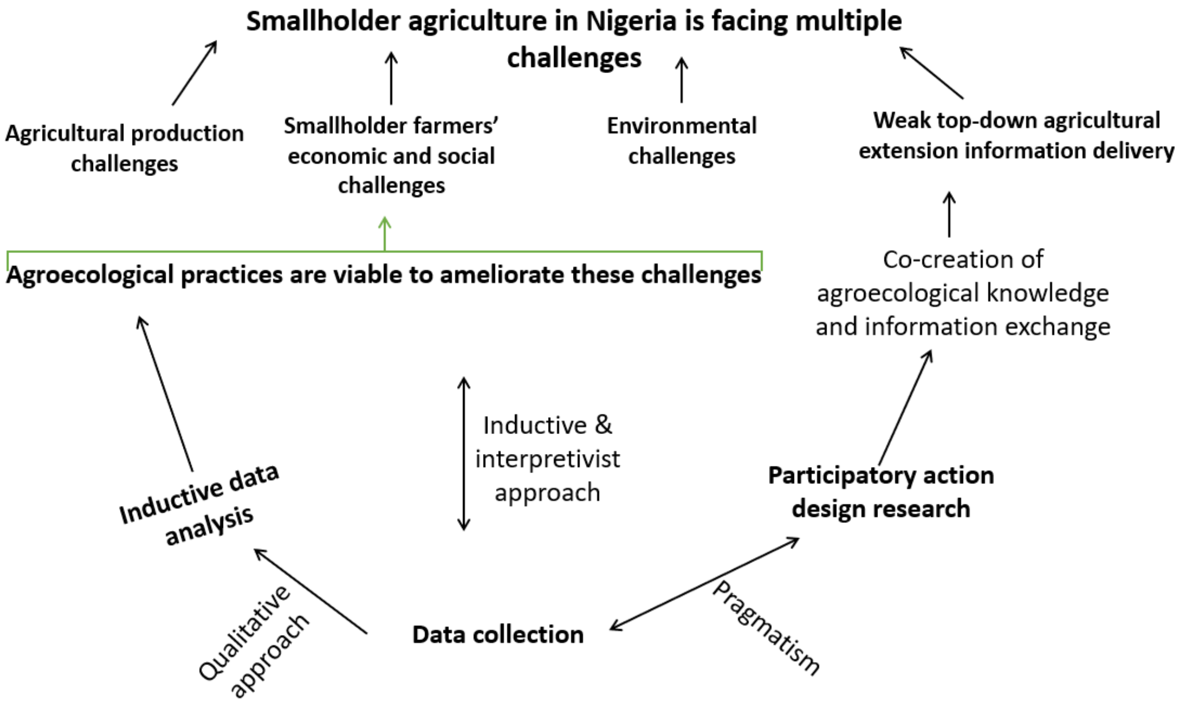

Figure 5.3: The research design process

5.7.1 Case study approach

As mentioned earlier, the study sites were purposively selected based on the criteria detailed in section 5.3.1 above. In line with the researcher's epistemological stance, the participants' insights were used as the source of knowledge to help understand how agroecological knowledge and access to information can be enhanced in the area. The researcher emphasised the participants' perspectives by immersing herself into their stories and events (i.e., to view the meaning they have created and understand the reality). A qualitative case study [CS] approach was employed to facilitate a holistic view and flexibility in the collection of data. Accordingly, Yin (1994) states that case studies help researchers to understand complex social phenomena. This study looks in-depth at the real-life experiences of smallholder farmers that engage in the AVS and cross-examine other smallholder farmers' who are not under the scheme. Moreover, the CS approach allowed the researcher to engage iteratively between the diverse stages of the study and seemed appropriate to answer the 'how' 'what' and 'why' questions that formed this study research questions (Yin 2014). The process warranted the researcher to collaboratively analyse and define the problem with the participants, as well as plan for the action in line with the identified problems through their experience, opinion, and motivation. The approach also allowed the researcher to evaluate the preliminary need and forms of the mobile phone-enabled application (i.e., m-app for short) and in its validation (Costa et al. 2016). The use of the CS approach in the context of multidisciplinary research (i.e., the intersection of this study within the field of information system and social science) of this kind has been contested (Costa et al. 2016). As some authors argue that CS should be used only for any technological initiative's ex-post[39] evaluation (Peffers et al. 2012; Prat et al. 2014; Venable and Baskerville 2012), while others insist that CS can be applied as a method for data collection through interviews, focus groups etc. that will function as an input for the design of such initiative and its subsequent ex-ante[40] validation (Costa et al. 2016; Vahidov 2012). In the case of this study, the initiative represents the m-app. However, methodologically, there have been some critiques about CS. Kerlinger (1986) highlights that CS lacks flexibility in handling independent variables, has a risk of erroneous interpretation as well as difficulty to randomise. A similar observation has been made about qualitative research as Lee (1989) claimed a lack of controllability, deductibility, generalisation, and repeatability as the weaknesses. Furthermore, CS is frequently criticised on lack of rigour and issues of external validity (Yin 2013). It has also been argued that the researchers' personal views could influence their findings, however, it is important to be precautious in designing the research protocols to minimise research biases (Yin 2009). Merriam (1998) and Dul and Hak (2008) suggest conducting effective qualitative interviews, being a careful observer and encouraging the interviewees to narrate their experiences.

5.7.2 Sampling frame

According to Sharma (2017), sampling is a procedure adopted by a researcher to systematically select a relatively smaller number of representative individuals (i.e., a subset) from a pre-defined population to serve as subjects (data source) for observation to achieve the objectives of the study. A sample is the actual number of individuals selected from particular populations. As such, the first 30 smallholder farmers included in this study were randomly sampled from a broader group of 71 farmers who were part of the AVS situated in Umuakaobia, Imo state. The random purposeful sampling was employed because the researcher had no obvious reasons of selecting any particular AVS participant over another but only that they are information-rich case (Sandelowski

[39] This is the evaluation done after the completion of the artifact or initiative (e.g., mobile phone application [m-app] as in the case of this study) (Hevner et al. 2004; Peffers et al. 2007).
[40] The process that enhance the design and development of the artifact (Costa et al.).

2000). The AVS farmer group were selected on the fact that they actively receive information directly from the extension agents and their farms are frequently visited by these agents. Additionally, five smallholder farmers each from Ezinnachi and Enyiogugu were purposively selected as they are not in direct contact with the extension agents as in the case of the AVS farmers. The individual farmers' farm sites were visited by the researcher and observations recorded. Twenty extension agents were purposively selected from NAERLS and Imo State ADP primarily on the basis that they are actively engaging with the farmers, especially the AVS farmers. Engaging with the extension agents clarified the type of agricultural practices and information available to individual smallholder farmers. The need to understand the AKIS, type of agricultural information available in the agricultural institutions, and to sample the opinion about collaborative development of agroecology from the educational institution perspective meant that this study also included 10 purposively selected agricultural lecturers from the University of Agriculture, Umudike. Concerns have been raised about the use of purposive sampling in research. Some studies have argued that the strategy is highly prone to researcher bias as well as raising concerns over the representativeness of participants (Sharma 2017). The technique was efficiently used to identify and select participants that are most knowledgeable or experienced with the research interest. Bernard (2017) noted the importance of willingness and availability of the intended participant to participate, and the ability to communicate experiences and opinions articulately, expressively, and reflectively. Moreover, the method provides researchers with the justification to make generalisations from the sample being studied based on a logical, theoretical, and analytical framework (Sharma 2017). Critical to this study, the use of the purposeful random sampling technique added to the credibility and reduced judgemental bias and not representativeness of the entire population. Detailed information about the participants is outlined in Table 5.2 below.

Table 5.2: List of study participants, their designation and the sampling technique used for selection (n = 70)

Designation	Participants	Sites recruited from	Sampling technique
Smallholder farmers	AVS farmers (30)	Umuakaobia, Imo State	Purposive random sampling
	Non-AVS farmers (5)	Ezinnachi, Imo State	Purposive sampling
	Non-AVS farmers (5)	Enyiogugu, Imo State	✓
Extension agents	Field extension agents (8)	ADP, Imo State	✓
	Extension coordinators (6)	ADP, Imo State	✓
	Extension subject specialists (6)	NAERLS' zonal office, Abia State	✓
University lecturers	Agricultural lecturers (10)	The Federal University of Agriculture, Umudike, Abia State	✓

Source: Field survey (2017/18)

5.7.3 Methods of data collection

The transdisciplinary nature of this study meant that it adopted a pragmatist approach to data collection involving a multi-methods strategy which is common with a PADR study (Resnick et al. 2005; Rossi and Sein 2003; Venable 2006). The multi-methods approach is characterised by combining complementary methods that are aimed at addressing the research aims and objectives from multiple perspectives resulting in an in-depth understanding (Philip 1998). According to Greener (2008) and Hall (2013), the multiple methods' approach requires that researchers adopt different techniques of data collection that belong to the same category either qualitative or quantitative. Similarly, Fetters and Molina-Azorin (2017) contend that the approach involves using more than one method of data collection that can be all qualitative or all quantitative. One of the most important characteristics differentiating what is generally referred to as qualitative inquiry from quantitative one is the type of sampling used. While quantitative study typically involves probability sampling to permit statistical inferences to be made, qualitative research ideally involves purposeful sampling to improve understanding of cases that are information-rich (Patton 2005). For this study, qualitative data collection involving in-depth interviews, focus group discussions, participants' observation and workshops were appropriate to gain an in-depth understanding of the smallholder farmers' agricultural practices and their concerns about the state of their farms. Additionally, the strategy provided the researcher with great opportunities to immerse in the processes of agricultural extension and advisory service and familiarise herself with the context and content. This strategy was also invaluable for the researcher to gain insight into the general concept of agricultural courses in Nigeria's agricultural universities. The workshops were appropriate for capturing participants' mobile phone use capabilities as well as access and ownership. Moreover, the methods helped in integrating participants' views in the establishment of the m-app (Peffers et al. 2007). On the other hand, secondary data were retrieved through desk reviews from various scholarly sources and in some cases as in chapters 3 and 8, a scoping review method is strictly applied. The details of the fieldwork activities are outlined in Table 5.3, the fieldwork activities' section below and Table 9.1 in Chapter 9 (i.e., the third stage of data collection).

Table 5.3: The fieldwork activities in 2016 and 2017

Date	Stages of data collection	Methods used	Duration		Participant involved	Activities involved	The theme of the discussion	Chapters where data is presented
March 2016	Preliminary stage	Community meetings Seminal participation Ad hoc interviews Dialogue	Day 1 – 5 (24th, 25th, 28th, 29th, and 31st of March)	5 meetings, 4 to 5 hours per session 5 to 10 minutes unplanned interviews with attendees	Farmers, extension agents, government representatives, researchers, agricultural students, and lecturers.	Presentational events, seminars, and university students' demonstration site visits	State of agriculture in southeast, Challenges facing agriculture in the region. Policies in place for agricultural development in the region and across Nigeria Agricultural information delivery challenges and the orientation of extension and advisory services generally. Any idea about agroecological approaches, benefits, challenges, and supports.	The encounter informed the overall concept and research questions, aims and objectives of the entire study
January – March 2017	Second stage	Individual semi-structured interviews Farm visits Participants' observation	Day 6 – 19 (10th, 11th, and 13th, 16th, 17th, 18th, 19th, 20th, 23rd, 24th, 25th, 26th, 27th, 30th of Jan)	30 sessions, 1 to 2 hours per session	30 farmers were visited in their own farms	Farm touring, interviewing and observation	Type of agricultural activities and practices. Crop and livestock management practices, challenges, and any advantage. Information needs, sources, and availability. Who is responsible for agricultural information sharing?	Chapter 6

							Extension activities and the presence of extension agents. Knowledge of agroecological approaches and any available support. Benefits and challenges of agroecological. Source of agroecological information or knowledge.	
		Individual in-depth semi-structured interviews Office visits Participants' observation	Day 20 – 28 (31st of Jan; 3rd, 6th, 7th, 9th, 11th, 13th, 14th and 15th of February)	20 sessions, 1 to 2 hours per session	20 extension agents were visited in their various offices	Office visits, interviewing and observation	Roles of extension and advisory services. Information delivery systems. Types of agricultural information available and policies available. The role of government in the extension, advisory and delivery systems Challenges facing extension activities.	Chapter 6
		Individual in-depth semi-structured interviews Farm visits Participants' observation	Day 29 – 33 (16th, 17th, 20th, 21st, and 22nd of February)	12 sessions, 1 to 2 hours per session	12 farmers were visited in their various farms	Farm touring, interviewing and observation	How, what, and why agricultural information is shared. Approaches used for agricultural information sharing, access, and sourcing. Information needs, sources, and availability. Crop and livestock management practices, benefits, issues, and importance.	Chapter 7

							Knowledge of agroecological practices, benefits, challenges, and support. Are there mechanisms of agroecological knowledge exchange and/or sharing? Opportunities to promote agroecological knowledge.	
		Individual in-depth semi-structured interviews Office visits Participants' observation	Day 34 – 37 (23rd, 24th, 27th, and 28th of February)	8 sessions, 1 to 2 hours per session	8 extension agents were visited in their various offices	Office visits, interviewing and observation	Approaches used for information delivery. What type of agricultural information is available and who is responsible. Knowledge of agroecological approaches, any mechanism for agroecological information delivery or knowledge exchange and/or sharing and any support available.	Chapter 7
		Individual in-depth semi-structured interviews Office visits Participants' observation	Day 38 – 41 (1st, 2nd, 3rd, and 4th of March)	10 sessions, 1 to 2 hours per session	10 lecturers were visited in their various offices	Office visits, interviewing and observation	Available agricultural research and who is responsible. Agricultural curriculum, structure and policies. Are there agroecological innovations and any support for agroecological innovation or research?	Chapter 7

Source: (Field survey 2016/17)

5.8 Fieldwork activities

The study is equipped with primary material collected through fieldwork in Nigeria and supported by the analysis of relevant policy reports and documents, as well as secondary materials such as scholarly literature etc. The fieldwork activities within the two-year period as presented in Tables 5.3 and 9.1 provided the researcher with the opportunity to spend approximately one year within the research time-frame with the participants in an iterative process, with the outcome of each activity and analysis informing the next activity, methods used, and questions asked. The fieldwork-generated material is applied extensively in chapters 6, 7, and 9. As stated above, the PADR framework calls for a practical and collaborative inquiry with participants and not 'on' or 'to' participants (Daiute and Lightfoot 2004). Therefore, the following sections detail the strategies used for data generation and scenarios captured during the process. It is also worth mentioning that these processes overlapped at some points (i.e., strategies for knowledge inquiry, design, development, and demonstration of the m-app with the participants).

5.8.1 Preliminary phase, problem identification and motivation

This phase allowed a broad understanding of the conditions of agricultural practices (e.g. conventional and traditional systems) and what understanding of agroecological knowledge and information is available in Nigeria. During this period, the researcher participated in community meetings with various agricultural stakeholders. The stakeholders include farmers from different localities; local, state, and federal government representatives; extension agents, agricultural researchers/lecturers; and students in agricultural-related courses via seminal workshop aided by NAERLS. The activities provided the researcher with the opportunity to hear individual stories and experiences from different areas. This phase gave an intensive view of the community concerns and provided a useful prospect in identifying agricultural information sources and needs. Accordingly, Ohmer et al. (2009) suggested that initial community meetings can be useful in identifying community problems, assess their needs and even suggesting questions that may require further study. After the workshop, the researcher carried out informal interviews with some government representatives, extension agents, agricultural lecturers and students to generally understand the nature of agricultural policy, hierarchy of and measures for information flow and its availability to the smallholder farmers at the local level. Some of the interviewees travelled from other neighbouring states (evidence from interviewee responses). Although other agricultural representatives and the students were not listed as the target participants, the researcher felt the need to engage these groups due to their relevance in leading answers to study questions that can unravel the reality. And so, some of their responses informed the main study questions, aims and objectives.

Additionally, there were visits to the University of Agriculture, Umudike, where the researcher engaged with some of the agricultural course directors, lecturers, and students, as well as visits to the students' demonstration farms. The researcher's encounter revealed how conventional agricultural systems and practices are being placed at top priority for agricultural extension and agricultural education curriculum in Nigeria. However, the time spent provided a great opportunity to engage in dialogue with high-level agricultural professionals who could drive an agenda for agroecology on the political shores of Nigeria. Thus, requires further attention on how the agroecological system can be incorporated into the existing system to facilitate the transition. During this period also, the thoughts for an interactive initiative that can facilitate the exchange of agroecological knowledge was established as the researcher sampled the opinion of the potential participants and the expected functionality was critically discussed.

5.8.2 Individual in-depth interviews

An extensive part of the fieldwork activity was carried out when the researcher was awarded a six months internship funded by Coventry University under the Supporting Postgraduate Students in Industry for Employability Research [SPIDER] Scheme. This was hosted by NAERLS. The internship provided opportunities to shadow the field extension agents and visits to smallholder farms as well as interact with the farmers locally to understand their needs and practices. Furthermore, the researcher deliberated on the research objectives with the prospective participants and networked with the key practitioners in extension. Moreover, there were opportunities to advocate for including agroecology in the extension system during NAERLS' annual impact assessment review conference (see evidence in Appendix 5). The researcher also participated in various seminars and collaboratively identified potential solutions to some of the perceived problems.

A total of 80 interview sessions were carried out with 70 participants individually interviewed for the actual study. Some participants were interviewed twice to realise the objectives set out in chapters 6 and 7 respectively, while some participated in the third stage (i.e., the focus group discussions) to realise the objectives set out in chapter 9 (see

Tables 5.3 and 9.1 for details). An interview schedule was developed before the interviews took place with questions that could answer the various objectives (see Appendix 6 and 7). The questions were pilot tested before the commencement of the study to ensure clarity in meaning (Majid et al. 2017). The in-depth interviews (i.e., semi-structured) allow a better understanding of the current agricultural practices, dynamics of the practices, farmers' information needs, the knowledge and information sources and opportunities for improvement. This study specifically chose this method because it produces rich data and offers valuable insights into the subjects (MacDonald 2012). Although there may be disadvantages peculiar to the use of interviewing as a data collection tool such as being time-consuming, costly etc., the approach is flexible. This approach enabled the participants to describe their situations and for the researcher to inquire more in-depth understanding about their experiences and ideas. MacDonald (2012) stated that interviewing gives the researcher access to participants' ideas in their own words, rather than the researcher's words. This is an effective way of extracting information from some participants who may find it difficult to explain their views in writing (Schmuck 2009). Interviewing facilitates reciprocal learning between the interviewer and interviewees throughout the process. During the interview, fixed lists of questions may not necessarily be important as the interviewer is required to conduct the process naturally by adding questions following the interviewees' responses, whilst guiding them to focus on the objectives of the study (Schmuck 2009). Each one-to-one meeting between the researcher and an interviewee was recorded and lasted about one and a half to two hours. At the end of each interview process, the researcher compiled the recorded data and transcribed it accordingly.

5.8.3 Focus group discussions [FGDs] and design and development workshops

A total of 10 FGD sessions and six design and development workshops (i.e., 16 sessions in total) involving 50 participants who also participated in the previous interview sessions were carried out (see details in Chapter 9, Table 9.1). The focus group sessions overlapped with the design and development workshops then followed by the demonstration workshop (see description of demonstration workshop in the next section). The FGDs were used to probe the participants' opinions on the possible ways of ameliorating the issues identified, their knowledge of the benefits of agroecological practices and the potential for an interactive app to enhance knowledge exchange and information sharing (see discussion guide in Appendix 8). This approach allowed the emergence of rich data through interaction and further helped to explore the general nature of the comments from different individuals within the group (Mishra 2016; Shneiderman and Plaisant 2006). Accordingly, Morgan (1996) opines that FGD is used to understand the underlying meanings of the participant's views. The method discovered how the various groups of participants feel about the study focus and offered them an opportunity to seek clarification. The maximum number of persons in each group aligns with Marshall and Rossman (2014) suggestion that a focus group discussion should consist of seven to twelve individuals who share common characteristics that are relevant to the study's focus. A small number of participants in a group facilitates an environment for ideal communication amongst the individuals hence increased potential for the generation of useful data (Marshall and Rossman 2014).

On the other hand, the workshop as a methodological frame is dated back to Osborn (1948) who first described it as a method for creative group problem-solving (Osborn 1948). In the 1990s, the term was used in conjunction with participation (Cornwall and Jewkes 1995). And since then, workshop as a research approach has continued (Jaipal and Figg 2010; Yurdakul et al. 2012; Baran et al. 2014) and has been applied as a participatory design approach (Buur and Bødker 2000; Cobb et al. 2003; Kensing et al. 1996; Kensing and Blomberg 1998; Rossi and Sein 2003). In this study, therefore, the design and development workshops were collaboratively carried out by the researcher and participants allowing mutual interactions (Darsø 2001). Although there may be challenges inherent in the use of workshops such as power imbalance (Chambers 2002; Durance and Godet 2010), the researcher adopted Darsø (2001) and Öberg and Hernwal (2016) strategies of being accountable and constantly aware of her positionality during the research practice, as well as adopting an inductive approach. During the process, the prospective content of the m-app was generated based on the participants' agricultural information needs (the study referred to this process as co-creation of knowledge with service beneficiaries). This process also allowed participants' contribution to the context, design, and useability of the app (Peffers et al. 2007; 2012; Rossi and Sein 2003). During the workshops, other agricultural information delivery sources such as printed media, radio, face-to-face etc. were compared with m-app. The USAID mobile phone application capability checklist, ICT option assessment tool and infrastructure questionnaire, and a decision-making and planning framework were used to ascertain individual participants' capacity in the use of feature and smartphones, ownership, as well as the potential relevance of the m-app (see Appendixes 9 – 12 for details (Bell and Payne 2011)). The researcher hired two application developers to create the essential requirements (i.e., architecture, functionality, and useability) for the m-app.

5.8.4 Demonstration workshops

Another five months was spent in the field to demonstrate the SmartAgroecology m-app with the study participants (see further details in Table 9.1). A total of six workshops involving eight to nine participants in each session were carried out. The group was kept small to allow everyone personal attention and the opportunity to be heard (Ørngreen and Levinsen 2017). During the demonstration workshops, the common rules relevant to group deliberation were explained to the groups and these were observed (Dilshad and Latif 2013; Resnick et al. 2005). This stage was important to understand the useability and usefulness of the m-app and observe participants' reactions towards the m-app (Peffers et al. 2018). Aier and Fischer (2011), suggest criteria that are independent of the type of any technology initiative (i.e., the SmartAgroecology m-app in the case of this study), while Rosemann and Vessey (2008) argue the importance of ensuring the relevance of such initiative. Choosing the criteria for demonstration requires that the researcher pays attention to balance the interest of everyone involved in the research which is a central aim of DSR. Hence, the researcher adopted the criteria outlined in Table 5.4 below to ascertain the progress of the m-app. The checklist was adapted from (Aier and Fischer 2011; March and Smith 1995; Neely et al. 2000; Sonnenberg and Vom Brocke 2011). As at the time of data collection completion due to the researcher's university requirement for overall study duration, the m-app was not fully functional hindering the evaluation of its completeness, effectiveness, and generalisation.

Table 5.4: Criteria used in demonstrating the m-app (SmartAgroecology) with the participants

Criteria	**Ascertained**	**Not ascertained**
Completeness		X
Ease of use	✓	
Effectiveness		X
Suitable in a real-world phenomenon	✓	
Generality		X
Acceptance from users	✓	
Operationality and simplicity	✓	
Understandability	✓	

Source: Field survey 2017/18

Generally, during the FGDs and workshops, the participants used post-it notes to elucidate their views, whilst verbal contributions were recorded and transcribed after each session. For the data collection processes and visual engagement with some of the activities, see Tables 5.3 and 9.1 and Figures 5.4 to 5.8 respectively.

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Figure 5.4: The researcher giving a presentation about agroecology at the NAERLS' zonal office annual review conference (Survey 2017/18)

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Figure 5.5: From top left: 1) one of the visits to the farm for a clear understanding of their farm practices; 2) a workshop with some agricultural professionals; 3) one of the fewer farms where some of the agroecological approaches are practised (a garden beside a farmer's compound); 4) farmer-led discussion/reflection about their existing agricultural practices and the significance of transitioning to agroecology; and 5) improved variety of maize farm intercropped with pumpkin and being managed with fertiliser (Survey 2017/18).

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Figure 5.6: The researcher observes some of the farms with the farmers (Survey 2017/18)

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Figure 5.7: A closer look at the farming patterns as the farmers explained that they incorporate tree planting to control soil erosion, use for live fencing and to enhance diversity (Survey 2017/18).

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Figure 5.8: From top left: 1) participants show excitement about the developed m-app (SmartAgroecology); 2) one of the participants interacting with the proposed app during the demonstration stage; 3) a student preparing his demonstration plot; 4) after a discussion on the outcome of the research with the group (Survey 2017/18).

5.8.5 Observation of participants

During the entire data collection process, the researcher recorded some of the observations and referred to her notes during data analysis. DeWalt and DeWalt (2002) state that fieldwork involves the process of active looking, informal interviewing, note taking and patience. This allowed the researcher to align with the critical reality and match some of the participants' responses with the nature of their environment (Marshall and Rossman 2014). The process also enabled the researcher to immerse herself and learn about the activities of the participants and also informed some of the questions that contributed to answering the research objectives. Although there are critiques about participant observation, e.g. Bernard (1994) argued that the process requires a certain amount of deception and impression management. He further expresses that researchers need to maintain a sense of neutrality through distance (Bernard 1994). Participant observation is characterised by such actions as having an open, non-judgmental attitude, being interested in learning more about others, being aware of the tendency for feeling culture shock and for making mistakes. However, these can be overcome through being an active listener, a careful observer and open to embracing any eventuality (DeWalt and DeWalt 2002).

5.9 Data analysis

This study is characterised by qualitative data collection and hence the qualitative data analysis. According to Graue (2015) and Elliott (2018), qualitative data takes the form of a large amount of unstructured textual material and there is no structured way for analysis. Basit (2003) concludes that the choice of technique is dependent on the size of the project, funds and time available, as well as the inclination and researcher's expertise. This study adopted Miles et al. (2018) strategy by manually conducting the data analysis instead of relying on a computer assisted qualitative data analysis software [CAQDAS]. Although CAQDAS has been ascribed to creating efficient modes of qualitative data analysis (Davis and Meyer 2009), social scientists have continued to advocate the relevance of manual data analysis strategies (Richards 2020; Saldaña 2021; Weitzman 2000). For this study therefore, the researcher ensured ownership of the data by manually transcribing the 70 interviews and recordings from the FGDs and workshops. Each individual transcription process lasted for about two to three and four to five hours, respectively. Field notes were also triangulated with the transcripts to enhance confidence in the findings (Bryman 2004). Additionally, the data were organised according to dates, times, pseudonyms, and place, and the transcripts were iteratively read to achieve familiarity. In offering interpretations, the researcher adopted a thematic analytical strategy and inductively assigned codes to the data sets (Braun and Clarke 2013; Braun and Clarke 2013; Ngulube 2015). This process was achieved by highlighting various relevant and interesting phrases in the individual texts and labelling them to correspond to different codes. This was done iteratively until no new codes emerged. Additionally, the data were collated into groups identified by code and this allowed a condensed overview of the key points (Kiger and Varpio 2020). This approach offered a technique for identifying themes in the dataset and helped in describing and interpreting the meaning and importance of data (Braun et al. 2016). After iteratively reading and assessing the initial categories assigned to the data, related and contradictory views were consolidated into four broad themes (Elliott 2018; Thomas 2003). These emergent concepts from the responses include practice, institution, opportunities, and challenges. Before assigning these concepts, the researcher ensured that all the data were accounted for, with every code sufficiently explained and supported by the data. Moreover, emergent themes are further grouped into five namely; 1) state of agroecological practices; 2) impact of extension and advisory service on agroecology development in Nigeria; 3) sources of agroecological information and knowledge; 4) challenges for agroecology transition; and 5) potential for m-app to enhance interactive agroecological knowledge exchange and information sharing. These five specific themes are used to detail the study findings. The researcher also presented some of the participants’ responses verbatim to contextualise and support the findings and themes (Elliott 2018; Ngulube 2015).

5.10 Strategies adopted to ensure trustworthiness in the study

The trustworthiness of qualitative research is constantly questioned by positivists (Dixon-Woods et al. 2004; Rolfe 2004). This could possibly be because the positivist concepts of validity and reliability cannot be handled in the same way as in naturalistic research. However, several authors such as Silverman (2013) have demonstrated how qualitative researchers can integrate strategies that can ameliorate these issues. To ensure that trustworthiness is maintained, this study adopted the four strategies suggested by Guba and Lincoln (1981) which are credibility-internal validity; transferability-external validity and/or generalisability; dependability-reliability; and confirmability-objectivity. Accordingly, Shenton (2004) state that trustworthiness is established by ensuring the credibility of the research. Therefore, to ensure credibility, this study adopted well-established research methods in social science. The strategies include a purposive selection of information-rich participants, in-depth interview and consultation of appropriate documents, triangulation, iterative questioning, participants selected voluntarily, and inductive analysis. Yin (1994 and 2003) acknowledges the importance of integrating actual operational measures for the concepts under study.

Considering the nature of the activities in the field, the interaction between the researcher and participants can be ethically challenging, as the researcher is personally involved in all the phases of the study (e.g. from designing the study to reporting the findings) (Sanjari et al. 2014; Truscott 2004; Van den Hoonaard 2002). This, therefore, required that the researcher had to ensure that the necessary guidelines were followed and adhered to. For example, risk assessment in the area of study and ensuring anonymity and confidentiality. By so doing, the researcher complied with all the Coventry University research ethics policy applicable to the frame of this thesis (see evidence of the supporting documents in the Appendixes 13 – 18). During the fieldwork activities, the researcher took cognisance of some of the limitations inherent with the data collection techniques. Some of these limitations or challenges include time management in organising the activities, participants' commitment towards the research, divergence in individual opinion as well as issues of power imbalance amongst the participants. The researcher's personality could also influence or hinder some of the participants' response in expressing their opinions truthfully. These challenges are well documented in the literature (Freitas 1998; Gillis and Jackson 2002; McNiff and Whitehead 2006; Schmuck 2006). However, to minimise the effect of these factors, the researcher ensured flexibility, respect and patience as well as making sure that each participant was given equal opportunity (Grønkjær et al. 2011). The research objectives were also clearly explained, and an oral description of the characteristics highlighted. For example, the participants were informed about the approximate duration of interview or focus group sessions.

To ensure transferability, the researcher provided a detailed description of the research problem and approaches used. Although transferability is considered a challenge in qualitative research due to the researcher's subjective stance, transferability can be enhanced through detailed research methods, contexts and assumptions underlying the research (Shenton 2004; Strang 2015). This strategy was also adopted for maintaining the dependability of the study. Lincoln and Guba (1998 cited in Shenton, 2003) noted the relationship between credibility and dependability, stressing that, in practice, well-demonstrated credibility ensures dependability. This could be achieved through the use of overlapping methods (Shenton, 2003).

Furthermore, the confirmability of the research findings was ensured by adopting triangulation (i.e., transcript and observation notes) in data analysis to reduce the effect of the researcher's bias (Miles and Huberman 1994). Additionally, the rationale for choosing a particular approach over others was outlined and a detailed description of such an approach maintained (Shenton 2004).

Chapter summary

This chapter presented the methodological framework of this study and philosophical perspective, as well as motivation for the study and choice of location. The chapter detailed the strategies used for data collection and showcased some of the fieldwork activities. It then outlined some of the implications inherent in qualitative research and discussed the various techniques the researcher employed and adapted to ameliorate such challenges to complete this thesis. The understanding of these methodological process, therefore, provided a clear focus of the study. Hence, chapters (Chapter 6, 7 and 9) present the outcomes.

Chapter 6: Understanding the impact of public extension and advisory activities on smallholder farming practices in Nigeria

Following the review of the current state of agroecology across Africa, this chapter builds upon the major themes reflecting the importance of smallholder farmers' access to information for their livelihood improvement and agricultural development. The chapter, therefore, investigates the activities of the public extension agents and their potential role in facilitating farmers' access to information on agroecology. Involving both the smallholder farmers and the extension agents, the study uses qualitative methodologies to identify their knowledge and perception about agroecology and agroecological approaches and determine whether the activities of the extension personnel influence farmers' farming decisions. The chapter further identifies the factors that influence the extension activities, as well as the constraints to the transition to agroecology and opportunities for improvement.

This chapter is a peer-reviewed journal article published by Agroecology and Sustainable Food Systems as:

Emeana, E. M., Trenchard, L., Dehnen-Schmutz, K., and Shaikh, S. (2019). Evaluating the role of public agricultural extension and advisory services in promoting agroecology transition in Southeast Nigeria. *Agroecology and Sustainable Food Systems*, *43*(2), 123-144.

See the published paper title and abstract in Appendix 19 of this thesis.

6.1 Introduction

Agroecological practices are gaining support for their viability in improving agroecosystems. The practices are helping smallholder farmers, especially in Africa to achieve food security without a negative impact on the environment (De Schutter 2010; AFSA 2017; Oakland Institute 2017). This they are achieving through the use of ecological concepts that limit the use of external inputs and allow ecosystem interaction (Altieri and Nicholls, 2012; Altieri et al. 2017; Wezel et al. 2014). Agroecological practices are also being promoted because they contribute to ameliorating to environmental impacts caused by the continued use of conventional agricultural practices. The impact of conventional agriculture and climate change is in no doubt affecting Africa's agriculture and more especially smallholder farmers (Aziz et al. 2015; Bhandari 2014; Kalia and Gosal 2011).

This study focuses on Nigeria as an example of an African country facing several of the challenges from conventional agriculture, climate change and increasing human population. Agricultural activities in Nigeria have changed and continue to evolve as the country has embarked on various agricultural development projects that are focused on conventional practices in the quest to increase food production. Such projects include the agricultural transformation agenda and the growth enhancement scheme (Federal Ministry of Agriculture and Rural Development (FMARD) Agricultural Policy and Strategy Document 2013; 2016). These projects have been reported to be very successful in restructuring the fertiliser procurement system and deregulation of seeds (Akinwumi 2013; Igudia 2017). This shift has enhanced farmers' access to genetically modified seeds and encouraged excessive use of agrochemicals, most importantly the use of nitrogen fertilizers (Akinwumi 2013; FAO 2017b; FMARD 2016). Furthermore, the projects support the use of intensive irrigation, mono-cropping and use of growth hormones and antibiotics for livestock production and have led to a reduction in fallow systems (Oguamanam 2015). The impacts of these policies include climate change exacerbation, ecosystem distortion, surface and underground water pollution, increasing soil infertility, as well as human health-related problems (Alufohai and Oyoboh 2013; Oguamanam 2015). The agricultural practices and issues therein, are in contrasts with the Nigerian Environmental Protection Policy, 1999, which aims to preserve the country's biodiversity and improve the livelihood of the population (Kankara et al. 2013).

Nevertheless, in some areas of the country existing traditional methods of farming which have elements of agroecological practices are still practised, while in others, they have been abandoned (Adebayo and Oladele 2014; Nwachukwu 2010; Oguamanam 2015). Smallholder farmers' lack of interest in or abandonment of their traditional practices has been linked to lack of government support for traditional methods (AdeOluwa 2010; FMARD 2016).

An effective agricultural extension delivery system is invaluable in motivating farmers to adopt new or existing innovation (Aphunu and Otoikhian 2008; Rivera and Qamar 2003; Zwane 2012). The National Agricultural Extension and Research Liaison Services [NAERLS] is a public institute under the Federal Ministry of Agriculture and Rural Development responsible for agricultural information dissemination in Nigeria. NAERLS coordinates national agricultural training activities; planning and development of extension liaison services throughout Nigeria; researches agricultural technique transfer and adoption and collaborates with research institutes and Agricultural Development Programme [ADP] units in transferring existing knowledge and innovations (NAERLS 2017a). NAERLS established the Research Extension Farmer Input Linkage System [REFILS] and Adopted Village Scheme programme [AVS] to improve the agricultural information dissemination and utilisation (NARLS 2017b). In ensuring access to information and effective delivery system, NAERLS selected 120 communities on the mandate of an "adopted village scheme" each within a 20-kilometre distance from the headquarters and respective zonal offices (NAERLS 2017b). The institute further adopted a targeted information delivery method by setting up Information Resource Centres [IRCs] in each of the selected communities to care for their agricultural information needs (NAERLS 2017b; Sani et al. 2015). Evidence suggests that these three schemes have facilitated better access for extension agents' to smallholders and successfully improved agricultural information delivery (NAERLS 2017b; FAMRD 2016; Sani et al. 2015). According to Sani et al. (2015), farmers' access to agricultural information improved through IRCs in the various adopted villages.

Given these structures, NAERLS seems ideally placed to facilitate the adoption of agricultural practices in these selected communities. This study, therefore, evaluates the potential role of the public agricultural extension and advisory services in enhancing the transition to agroecological practices in southeast Nigeria. The study uses a qualitative approach to explore this potential role by addressing the following research questions;

- What are the agricultural activities in the study area?
- What are the activities of the extension agents?

- What are the factors that influence the extension activities?
- How do extension activities influence farming activities?
- What are the key constraints to the wider adoption of agroecological and/or organic farming methods?

6.2 Methodology

This study uses a qualitative research methodology in keeping with the methodological tradition of political ecology that requires sensitivity to context, multiple views and social relations, and in identifying the major stakeholders involved in the implementation and receipt of the programme under study (Palys 2008; Patton 2014; Watts 2000).

The study location is the south-eastern zone of Nigeria, where the NAERLS' southeast zonal office is located. The zonal office has the mandate of supervising the agricultural extension activities in the five south-eastern states namely; Abia, Anambra, Ebonyi, Enugu and Imo through their respective state ADP units. (Figure 6.1 shows the map of Nigeria highlighting the six regions).

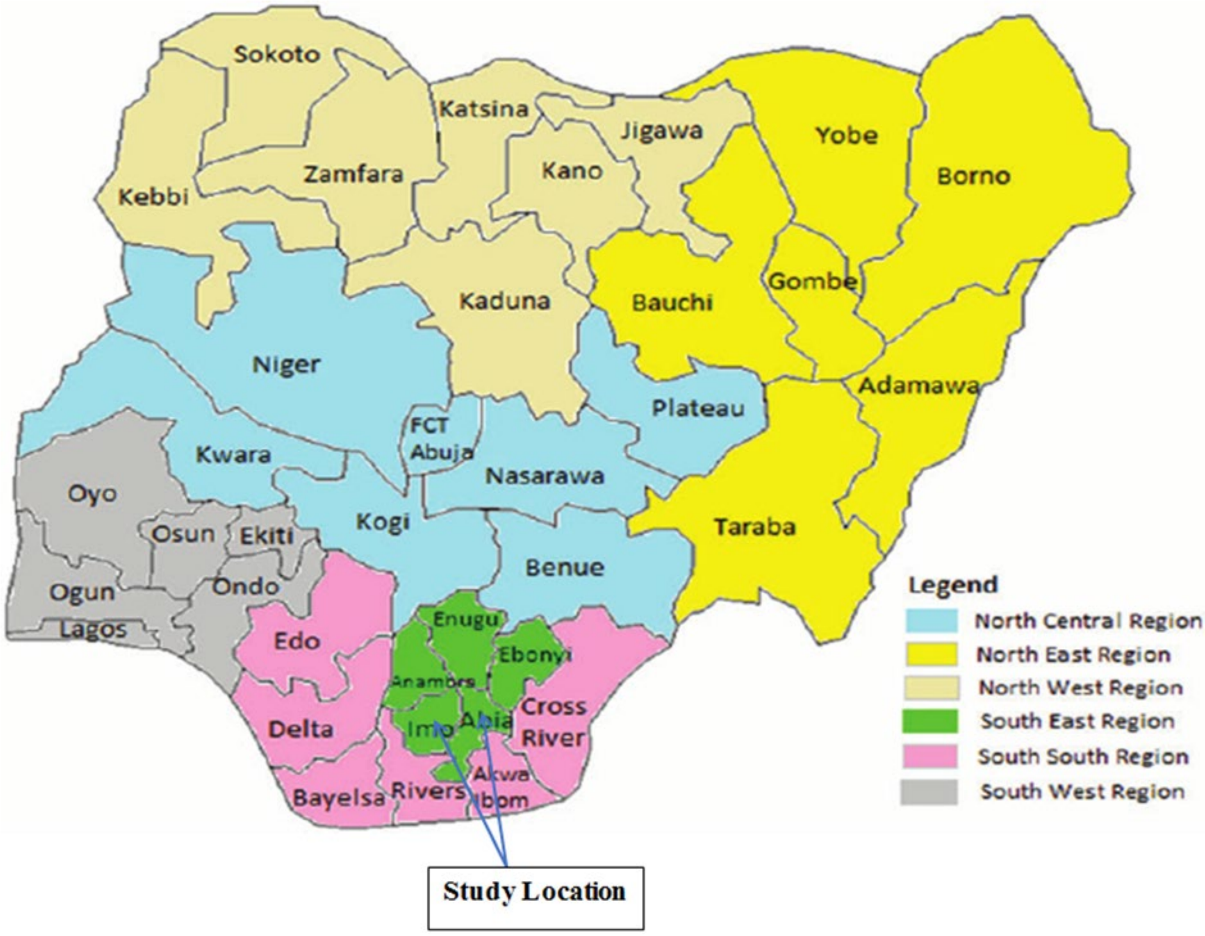

Figure 6.1: Map of Nigeria, indicating the study area where the Imo state ADP and NAERLS zonal office are located, respectively (modified from National Agricultural Extension and Research Liaison Services South-east Zonal Office n.d).

6.2.1 Data collection strategy

Data was collected through in-depth interviews with 50 respondents comprising extension agents at the Imo state ADP office and NAERLS' southeast zonal office, and farmers from Umuakaobia an adopted village in Imo State under the NAERLS southeast zonal office. The 50 respondents included 30 smallholder farmers from Umuakaobia, eight field extension personnel and six extension coordinators from the state ADP and six extension subject specialists from NAERLS. The farmer respondents were selected using a purposeful random sampling technique, while the extension agents were purposively selected (see Section 5.7.2). The randomised sampling strategy was adopted to increase credibility not to foster representativeness.

The study was approved through Coventry University's ethical approval procedure and written informed consent was obtained from each participant prior to the data collection. Ensuring a suitable environment for the interviewees, the interviewing researcher visited the participants in their public offices and farms. Telephone calls were made to inform the respondents of the study aim and expected questions before visiting. The researcher adopted a systematic questioning technique to gain in-depth responses. During the interviews, semi-structured questions were used to gain a rich description of their farming practices and extension activities. Questions were worded to suit the individual participant's English proficiency. The questions included the demographic characteristics of the respondents, type of crops and farming practices, style of extension delivery systems and type of information available, level of experience, and their knowledge about agroecology and agroecological practices. Questions to assess whether the information needs of the farmers are met by the extension agents and whether the extension service influenced their (farmers) farming practices were included. Included were questions to assess the factors that influenced the extension activities which may have impacted on the development and extension of agroecological practices, as well as any innovation or research for agroecological practices. All data were collected between March 2016 and August 2017.

6.2.2 Data analysis

Interviews were audio-recorded and transcribed verbatim to prevent bias. Additionally, the researcher's participants' observation notes were analysed side-by-side with the transcripts to ensure triangulation of data and enhance the credibility of findings. The study adopted Miles et al. (2014) strategy by manually conducting the analysis using hand-coding, instead of relying on computer analytical software. This was achieved by iteratively reviewing the raw data, codes were inductively derived, organised, and emergent codes summarised in themes. The results were organised and presented in three sections based on the interview questions. The first section is an account of the farming activities, participants' knowledge of agroecological systems and the extension and advisory activities in the area. The second section outlines evidence of how the extension activities have influenced smallholder farmers' farming decisions and their information needs with a focus on the type of information they receive from the extension agents. The last section describes the factors that affect the transition to agroecological approaches. All responses were grouped into two categories namely; farmers' perspective and extension agents' perspective. Accordingly, the study adopted Miles et al. (2014) result presentation strategy by presenting the results in two formats, namely; verbatim quotations from the respondents which serve as low-inference descriptors; and summary of recurrent themes clarifying the most articulated themes. The verbatim quotations which are the core study results indicate how participants attached meaning to each theme. The emerging themes are summarised, and a number of participants who articulated each theme recorded and presented in tables. Although the use of numerical data in qualitative research has been contested (Maxwell 2010), this study uses the summary tables to show the number of participants that articulated each emergent theme. Furthermore, the factors identified that hinder transitioning to agroecological practices were summarised in sub-themes and tabulated.

6.3 Results

The results are presented in sections according to the interview checklists. Table 6.1 summarises the demographic characteristics of the respondents, highlighting the participants' age, gender, level of experience in agriculture and knowledge about agroecological systems.

Table 6.1: Respondent's descriptive characteristics (n = 50)

Demographic characteristics	Farmers (n=30)	Extension (n=20)
Age (years)		
30 – 39	6	7
40 – 49	8	5
50 – 59	11	8
60 – 69	5	0
Gender		
Male	19	15
Female	11	5
Years of experience in agriculture		
1 – 4	3	2
5 – 9	7	5
10 – 14	12	4
15 – 19	5	2
20 – 24	3	7
Knowledge about agroecological farming systems:		
Know about agroecological related practices but do not understand practices	17	
Know about agroecological related practices, understand practices and use them	8	
Know and understand agroecological practices but rarely use them	5	
Know about agroecological related practices and have the extension skills		2
Know about agroecological related practices but lack the extension skills		18

Data presented based on the participants' profile (field survey March 2016 to August 2017).

The farmers' and extension agents' were aged between 30 and 69 and 30 and 59 years, respectively. While most of the respondents were male, levels of farming experience were very different. For all participants, agroecology appeared to be a new word, however, they are aware of organic agriculture[41] and referred to it as a sustainable practice. Hence, the majority of the farmers indicated that they know about this particular approach – that is organic agriculture, but do not understand the methods. Farmers with more years of experience tend to know more about the practice, but rarely use most of the techniques. Farmers that understand and use some of the techniques also explained that they lack proper skill in the procedures and management. In the same vein, all the extension agents know about organic farming, but the majority lack adequate skills for

[41] Organic agriculture is the term the study participants referred to at the outset of the study, but as the study progressed, they realised the principles and elements that underpinned agroecology. This also increased the awareness of agroecology and agroecological practices amongst the participants in the survey.

informed agroecology and/or organic farming extension services. Thus, some of the extension personnel explained:

> "*I have read about organic agriculture but have not received training on that*" (A field extension agent).

> "*I was fortunate to attend training outside Nigeria that was specifically for sustainable agricultural practices which organic agriculture was incorporated in the workshop*" (A coordinator).

Table 6.2 highlights the diversity of the farming activities engaged in by the farmer and shows that majority of the farmers engage in only crop production, a few combined with livestock. Most farmers in the study area grow staple food crops such as maize, cassava, yam, okra, and vegetables, very few farmers in the study complemented their food crops with nitrogen-fixing crops such as groundnuts. The ones that keep livestock had mainly goats, sheep and chickens.

Table 6.2: Farmers' diversity in farming practices and their engagement in selected agroecological and conventional farming practices (Number of farmers =30)

Farming practices	**Number of farmers**
Crop production	20
Livestock production	4
Crop and livestock production	6
Use of local seed varieties	2
Use of hybrid seed varieties	25
Use of both local and hybrid varieties	3
Use of agrochemicals (fertiliser, pesticides and herbicides)	30
Use of agroecology farming methods such as:	
Mixed cropping with leguminous crop	7
Crop rotation	5
Fallow systems/shifting cultivation	8
Farmyard/animal manure and composting	6

Data extracted from field survey (March 2016 to August 2017) (Some farmers combined two agroecological methods, but all used agrochemicals with the intent to improve yield).

Improved or hybrid varieties are the most commonly used crop varieties in the area and none of the farmers who use such crops, practice seed recycling (i.e. seed saved from harvest). There are still some traditional family farmers who grow a variety of plants grown from seeds passed down from generation to generation (i.e. their local seeds). These farmers expressed concerns that their local crop varieties are being practically lost to transgenic crops. A farmer explained:

> "*We used to have our own native seeds, like the maize and okra varieties, but now it's difficult to see one farmer who has such*".

A few farmers practice some of the widely accepted agroecological practices such as shifting cultivation, crop rotation, manuring, and mixed cropping. However, they depend on synthetic fertiliser and other agrochemicals for enhancing yield (see Table 6.2).

The agricultural information delivery or advisory activities provided by the extension personnel in the area include assisting the farmers with information about agrochemicals and their use, access to available markets for improved seed varieties and access to information about crop and livestock management. The extension agents noted that the AVS programme enhanced their direct access to the farmers as they can visit them on their farms. As this agent stated:

> "*Farmers are guided on how to manage their farm crops and animals to maximise yield, we advise them to put the right fertiliser to the right crop and where to buy them*".

> "*Initially, it was a challenge in meeting farmers' needs as there was no means [structure] for that, but now we can visit them directly in their farms, as you see we monitor them during the land preparation, planting and harvesting and this has been made possible due to the government programme [AVS programme]. Though our visit is not regular sometimes because of maybe the money for fuel, logistics...*"

6.3.1 The impact of extension activities on farming practices and the potential for agroecology transitioning

The farmers were interviewed based on their activities, information needs and their experience with the extension agents. Whilst the extension personnel were questioned regarding the policies to encourage research and extension support for agroecological farming systems, and a general evaluation of the institutes' activity in improving the extension of agroecological practices.

Farmers' perspectives

The farmers explained some of the extension agents' activities that influence their soil fertility management, choice of crops and methods of farming. Disregard of farmers' own traditional knowledge by the extension personnel emerged as a significant impact on their farming decisions. Such a situation arises where the farmers are advised and/or encouraged to abandon their traditional methods in order to adopt the intensive use of agrochemicals, including inorganic fertiliser and improved seeds, as well as a lack of opportunities to share information on the benefits of their own traditional methods with the extension personnel. Hence, a farmer narrated:

> "*Here in my farm I plant various crops in the same piece of land, but I buy and apply fertilisers and pesticides because the extension agents will always advise we use chemicals, even when you tell them our own method is good, they do not listen, they want us to do away with our ancestral ways of farming and adopt their style*".

The situation is a challenge because these groups of farmers rely solely on the extension field personnel for information regarding their day-to-day farming activities and tend to be influenced by the information they receive. The farmers tend to react positively to agricultural information that comes from the extension services, even when it is contrary to their practice and/or local knowledge. Most of the farmers expressed concern that the extension agents go as far as convincing them to buy external inputs even when is not cost-effective. Another farmer explained:

> "*This time one spends a lot in buying seeds which you cannot even replant, they tell you not to because it will not germinate, or it will multiply diseases,*

> *and the fertiliser application needs continuous efforts, sometimes these seeds do not even germinate that means you keep replacing them*".

The reasons why these smallholder farmers continued to use the improved seeds even when they experience such issues are not simple, perhaps there may be other reasons. It could be that these farmers' decision-making may have been influenced by their perception that the seeds are high-yielding i.e. perceived usefulness or due to their mutual relationship with the extension agents to be in their good book i.e. social influence (see Samaradiwakara and Gunawardena 2014; Venkatesh et al. 2003).

The interviews further revealed that farmers who practice some agroecological related techniques do so on their own initiative. Extension agents do not provide advice or information on agroecological techniques, farmers do share information informally on such techniques, but without the support of extension agents farmers were concerned that these practices could not continue in the long term. Moreover, the application and use of agrochemicals are perceived by the farmers as requiring less labour. A quote from one of the farmers read:

> "*I use farmyard manure on my farm because I keep lots of goats, I even go as far as other neighbouring communities to source for other animal dung. But you see my problem is, is difficult to prepare especially when combining with other raw materials for composting. The agriculture people do not say how to do it or apply it, so I gave up with the large farm and do it only at my backyard farm which is small. The fertiliser application is easier, even if no one tells you; you can manage to do it yourself*".

However, some farmers in the study were convinced of the efficiency and viability of agroecological practices in the improvement of yield and soil health in a small-scale farm setting as this farmer explained:

> "*it [organic] is the best practice, the yield is more and better soil quality with high organic matter content*".

Other farmers pointed out the benefits of integrating livestock with crop production, suggesting that keeping livestock improves the opportunities for the improvement of soil health by facilitating the fallow system and sharing of nutrients. Furthermore, it emerged that farmers who engage in both crop and livestock farming tend to apply some of the agroecological approaches such as manuring and fallow systems.

Among the farmers who keep ruminant animals, one explained:

> "*I prefer to leave some of my farmland fallow for three to four years that helps me in feeding my sheep and goats, and putting them out for grazing, which at the same time restores the soil fertility*".

When asked to elucidate on their perspective on the current extension activities in enhancing agroecological farming systems, most farmers explained that the extension and research institutes' activities revolve around promoting the use of external inputs which include synthetic pesticides and fertilisers, hybrid and genetically modified seeds. In which the extension services term as '*progressive ways of farming*' (multiple narratives from farmers).

Extension personnel perspectives

During their interviews, most of the extension personnel explained that the agricultural extension policy does not cover agroecology nor agroecological practices. They revealed that the government programme known as the 'agricultural transformation agenda with the focus on increased productivity' has the mandate of ensuring provision and availability of improved seeds and agrochemicals which heavily influences the available agricultural information that reaches the farmers. One of the extension agents commented:

> "*Organic farming [agroecology] is not part of the farming system yet, no structure put in place for an organic farming extension, however, some farmers actually practice it unknowingly. The government implements policies on how extension services are run, so research is geared towards achieving the nation's mandate for food security*".

The interview responses also suggest that the Nigerian government through the research institutes and extension services is keen on improving food production in the region.

However, this is based on practices which are detrimental to both the environment and human health. Most significantly, all the extension personnel in this study articulated that research and extension interventions widely promote conventional farming. Another corroborated this opinion by saying:

> "*The government is interested in providing and increasing food production for the populace so what matters is sufficient food, not how is produced or what is used. Although farmers find it hard to cope with the high-priced external farm inputs, we rely on policy, irrespective of any interest in organic farming [agroecological approaches] as there is no structure in place for such information*".

6.3.2 Factors influencing both the extension services and agricultural practices

Obviously, the public extension services are being driven by the government focus on increasing the quantity of food production. Their research is focused on hybrid seeds and animals, and managing disease/pest infestations to increase production. The farmers in the study explained that recent agricultural research institutes' exhibitions mostly showcase breakthroughs made with genetically modified organisms. Rights to land ownership emerged as constraints to maintaining or adopting agroecological approaches. Farmers reported that increases in household size reduces the size of land inherited by each farmer. For example, family farms are shared by adult male(s) in the family and if land available is limited and there are too many beneficiaries, it means that they get very little land each to farm, too little to make a living. Increasing household size also requires an increase in food production for the household and many farmers interviewed considered that these smaller parcels of land available for farming and the need to increase production meant that they needed to rely on conventional techniques and this limited their ability to continue using traditional practices in these circumstances. Most farmers noted being sceptical with the initial yield as they need immediate food available to take care of their increasing households. The majority of the farmers articulated that younger adults show reduced interest in farming generally. When probed on what could have triggered the reduced interest, it emerged that the youth migration to the urban areas in search for paid employment played a significant role in the older farmers abandoning the traditional methods due to required labour. Thus, their narrative read:

"*We are eleven in my household and our land is very small, because that is the portion I inherited from my father and no money to acquire more, so if we rely entirely on traditional systems, although it's sustainable, the high yield is not immediate. Even the soil has poor quality, so I am forced to spend more on external inputs to ensure a decent yield*".

"*I hire labour for digging the soils and making ridges even during weeding, gathering animal dung from my livestock and preparing the manure requires a lot of work and the required labour is expensive and the youths are no longer interested in farming. But fertilizer is easier to use, and I can do it on my own*".

The farmers noted that some of their local crop varieties of maize and cassava are easily affected by heavy rains and storms, although improved varieties perform better in these conditions, such varieties do not last until the next planting season as the seeds perish quickly. Additionally, access to some organic farm resources such as the neem leaves for biological control of pests is limited in this area due to deforestation. This, therefore, made it less accessible for some farmers who wish to use such methods. Hence, they explained:

"S*ome of our own crop varieties grow taller and rarely withstand storms, so the agriculture people insist we use improved varieties that mature quickly and dwarf in nature, but their own spoils quickly after harvest and tasteless*".

"*I do use neem plant leaves mixed with pepper which I learned from my father for controlling pests in my farm, before it was easier to see the trees, but now it's difficult to get the trees around here*".

Significantly, there was interest in agroecological practices among the farmers, although limited access to useful information on the availability, preparation and application of the farm input and practices emerged as one of the constraints. A quote from a farmer read:

> “*We know that our own local practices [traditional practices] help us to manage the farm and will want to continue with them and then combine other agroecological practices that are adaptable, but understanding how to make it work for us, I mean improve them, is a problem and that’s not the kind of information we get from extension people. So, you will want to get on with the ones you have information on*”.

These smallholder farmers’ perceptions of agroecological approaches appeared positive after understanding the positive impacts of the agroecological practices, however, their external environment such as lack of access to valuable resources and knowledge, contribute to the non-adoption.

On the other hand, the extension personnel highlighted some of the key constraints to enhancing agroecological systems that are in some way in line with the farmers’ observation. The majority explained that the extension agents are yet to be convinced about the effectiveness of applying agroecological principles and have inadequate skills in the practice. This a quote from one of them (extension agents):

> “*I think what we need is better knowledge and skills of organic practice to be able to work with the farmers*”.

Extreme weather conditions such as heavy rains also affect pre- and post-harvest management resulting in farmers’ inability to recycle and sustain their indigenous local crops varieties and a reduced interest in seed preservation. Others explained:

> “*these farmers cannot feed themselves if left alone with their indigenous farming practices, so the government is playing a significant role in the distribution of fertilisers at subsidised rates, and we encourage them to buy improved seeds because their own seeds get infested easily and cannot withstand drastic weather*”.

> “*Preserving the local seeds requires more care and knowledge, and sometimes the weather condition is not favourable for prolonged drying due to rains. So, the farmers find it hard to manage pre- and post-harvest seasons*”.

The responses from the farmers and the extension personnel are summarised in Table 6.3 (see Appendix 20). Their responses illustrate the importance of agroecology as mentioned by a few farmers and how research and extension activities, social and environmental issues in the area have influenced farming decisions and practices. Furthermore, the participants were asked to indicate the most fundamental factors that affect agroecological development generally in the area. The factors identified by both farmers and extension personnel were summarised in Table 6.3 below illustrating the number of participants who mentioned each factor. Critically, these intrinsic and extrinsic factors hinder the adoption and/or transition towards agroecological practices.

Table 6.4: List of factors that hinder the adoption of and/or transition towards agroecological practices as identified by both smallholder farmers and extension agents

List of factors mentioned by participants	**Number of smallholders who mentioned this factor (n=30)**	**Number of extension agents who mentioned this factor (n=20)**
Existing agricultural policies	26	20
Agricultural transformation agenda and related schemes	28	19
Extension and advisory services influenced by agricultural policy initiatives	26	19
Government influenced research activities in favour of conventional systems	15	18
Limited access to available farm resources	27	15
Limited access to agroecological information	24	11
Limited skills in agroecological farming systems, resource preparation and management	18	17
Environmental issues	21	13
Social and economic issues	14	9

Source: Field survey 2016/17

The factors mentioned by participants in Table 6.3 illustrate the strong focus of Nigeria's agricultural sector on conventional farming systems. A majority of participants highlighted government policy as a key factor which prevents the wider adoption of agroecological practices. Participants also indicated that limited information, knowledge and resources, as well as environmental and social problems played a crucial role in determining farmers' decision-making towards agroecological practice.

6.4 Discussion

The main findings of this research show that the public agricultural extension and advisory services currently focus almost exclusively on intensive agricultural practices, with little concern for the incorporation of agroecological farming practices. The focus on conventional farming in Nigeria is based on the current Nigerian agricultural policy, whose aims are based on '*agricultural transformation agenda*', and the existing policies that have the notion of '*food quantity for overpopulated nations*' and '*improving supply of specialised fertilisers and protection chemicals, as well as wider scale use of high improved yielding seeds'* (Federal Ministry of Agriculture and Rural Development 2016, The agricultural policy promotion 2016 – 2020, p. 4-6). Even though the conversion of land into agricultural purposes contributes to ecosystem depletion and soil contamination, this study found that there were few practical activities by the national extension services to encourage farmers to sustain the environment. Thus, undermining the government policy which seeks to promote "*farmer's quality of life and use of environment-friendly practices*" (FMARD 2000). Furthermore, the findings revealed that there is no agroecological farming systems' policy and no structure yet for an agroecological farming extension to enhance organic farming awareness. The findings support the evidence that there is a lack of appropriate agricultural policy for agroecology and related practices such as organic agriculture and other ecologically-based practices in Nigeria (Atoma and Atoma 2015).

There is an overwhelming disconnection between policy and practice with the government's policies for preserving the ecosystems as outlined in the Environmental Protection Decree 1999 (Kankara et al. 2013), improving farmers' livelihoods as stated in the agricultural policy objectives (FMARD 2000, 2011) and the research and extension activities in Nigeria. The institute has made little or no effort to discourage the increasing use of agrochemical inputs amongst smallholder farming communities. Their activities clearly promote commercial transgenic seeds, and the use of chemical fertilisers, insecticides and pesticides to increase yield. Seemingly ignoring their potential detrimental impact on natural farming resources required for production. This finding corroborates DeSchutter (2014) by drawing attention to the need to protect smallholder farmers' welfare and the ecosystem in Nigeria using agroecological practices.

Furthermore, the findings revealed that the extension personnel actively discourage farmers' reliance on indigenous knowledge systems both in farming practices, particularly local seed preservation and use. This poses a threat to the traditional locally relevant methods that have been developed and replicated over decades and further jeopardising the call for an urgent shift to agroecological practices globally.

The local knowledge of the farmers should not be underestimated because it constitutes the capacity needed for conserving the local ecosystems. According to Tella (2007), local or indigenous knowledge is the systematic body of knowledge or skills acquired by people through accumulated experiences and informal trails that helped them to understand their environment. Indeed, agroecological approaches combines traditional farmers' knowledge with modern ecology, soil management and crop production in designing and managing the ecosystem. It improves and sustains on-farm production fertility which in turn reduces farmers' reliance on external inputs and government subsidies helping vulnerable smallholder farmers less dependent on loans (Altieri 2015). The findings also confirm that agroecological practices such as animal manuring improves soil fertility and thus, can promote crop yield within the smallholders' farming context. Similar studies in Nigeria by Akanni et al. (2005) and Okon et al. (2016) confirmed that soil treatment using animal manure improved soil health and subsequently enhanced yields. Furthermore, the findings corroborate evidence from other parts of the world that the combination of livestock and crop production enhances agroecological farming practices. This is because the animals provide manure and other types of animal waste which can improve the nutrient cycle and organic matter important for the maintenance of soil structure and fertility (Reents et al. 2008). However, the situation still requires that the extension practices and policies should be redirected to focus on supporting and empowering farmers in their decision-making process that is within the context of their environment, health and socioeconomic conditions.

The findings corroborate Sani et al. (2015) that extension agents' direct access to smallholder farmers improved because of the AVS supported Information Resource Centres (IRCs) implemented by NAERLS. This is because these smallholder farmers under this scheme often relied on the extension personnel for agricultural information. Farmers' reliance on external inputs significantly increased and where some farmers rely on the private input supply sources for agrochemicals, they are often supplied to them at exorbitant costs. Most significantly, the farmers rely on purchasing new seeds every planting season and are discouraged from seed saving and using traditional varieties. It was observed that farmers in the study area rarely practised solely agroecological systems. Gliessman (2014) opined that hybrid seeds are undesirable for planting as they are susceptible to disease and pest infestations, encourages mono-cropping and transgenic manipulation, thus requiring farmers to purchase seeds every planting season. This study corroborates Gliessman (2014) notion in the case of the farmers in the study area.

The findings revealed that the current extension services in most cases disregard farmers' traditional knowledge and do not support the sharing of their own traditional knowledge with the extension personnel such that traditional practices can be replicated. This approach does not support the spread of existing traditional knowledge. Better interaction with the farmers and promoting farmer experimentation are approaches that can improve the development and spread of innovation, hence the efficacy of extension (Hagmann et al. 2007). The research and extension management need to give farmers important, consistent, and impartial advice and services on how to make significant use of their indigenous/local knowledge for sustainable farming and food security to align with the government agenda to improve productivity. However, there must be a policy reform to include agroecology in both the research and educational systems to enhance the potential extension agents' skills to promote this in the long term. There should also be the incorporation of platforms for improving farmers' knowledge sharing on ecosystem conservation to instigate collaborative action amongst farmers and extension agents to engage in agroecological farming practices.

The findings revealed that farmers who have more years of experience in agriculture have a deeper understanding of agroecological farming practices, but rarely applied most of the practices. This study contradicts Odoemenam and Ajuka (2015) that older farmers with a higher level of experience are less likely to adopt new technologies, rather in the case of the farmers in the study area, the extension personnel had more influence on their decision-making in adopting the intensive use of agrochemical inputs.

The farmers stated that the indigenous farming practice is almost disappearing due to some social issues such as the high cost of labour, lack of awareness and access to basic information. From the farmers' perspective, increasing household numbers which reduces the available size of land inherited by each family head reduced the sole practising of agroecological related farming practices. Additionally, pressure from the government through the extension personnel to adopt conventional methods has reduced their interest in such practices. However, most farmers in the area are willing to rejuvenate their existing traditional systems and are open to adopting other widely accepted agroecological practices. The findings corroborate Iyagba and Ovai (2015) that most of the farmers are desiring to practice sustainable practices.

Environmental factors such as poor soil quality, disease and pest infestation, unfavourable weather conditions and scarcity of local and biological farm resources impact on farmers' engagement in agroecological related practices which influences their wider adoption. Farmers' inability to tackle these issues in a more sustainable way, could be attributed to their limited skills and lack of information on agroecological practices and sources of resources that can ameliorate such farming issues. Other socio-economic factors which influence their interest in agroecological farming are farmer's concerns about the initial yield of agroecological production, as well as the required labour in maintaining the practice (see Darnhofer et al. 2010; Fishbein and Ajzen 2010). Extension agents commented that these factors were the reason why the farmers should embrace the conventional agricultural systems and abandon the traditional systems or agroecological practices.

Smallholder farmers' seed recycling or seed saving[42] practice (i.e., their traditional plant varieties) is attributed to helping them to maintain their seed varieties, improve diversity and increase food security (LaDuke 2012; Winter 2010). The cultural importance of seed saving is also connected to the food sovereignty concepts which is one of the principles of agroecology. Therefore, minimising seed losses by equipping farmers with the right management skills could be a resource-efficient way of improving seed viability and strengthening food security. Accordingly, Atoma and Atoma (2015) noted that inadequate information, lack of expertise about agroecological practices and unavailability of organic resource inputs are some of the constraints to using such practices. The only available management methods offered by the extension personnel is the use of synthetic agrochemical inputs. For the farmers and extension personnel in the area, all farming issues are solved with chemicals. This study corroborates Mustapha et al. (2012) that the extension agents still believe in the positive impact of conventional systems; thereby ignoring sustainable farming practices that are deeply rooted in agroecological principles with the notion of the latter cannot solve food insecurity. This study findings show that public extension and advisory services in Nigeria still ignore the

[42] While saving seed and even exchanging seed with other farmers for biodiversity purposes has been a traditional practice, these practices have become illegal for the plant varieties that are patented or otherwise owned by some entity (often a corporation) (Mechlem and Raney 2007).

increasing research that shows that the productivity of smallholder, ecologically-based, agroecological and traditional knowledge systems can equal conventional systems' productivity when measured by the number of people fed per unit of land (Ponisio et al. 2015).

There is an indication that most of the extension personnel lack the required skills to support agroecological techniques that can replace or substitute the use of agrochemical and genetically modified crops that are compatible with the environmental conditions and livelihood of the smallholder farmers. The findings revealed a clear bias from the training and research institutes in Nigeria towards high input agriculture that has inspired the use of transgenic crops and agrochemicals. This study draws the attention of the agricultural universities in training the extension professional to acquire the relevant skills, knowledge and attitudes towards the promotion of sustainable and environmental-friendly farming systems. Accordingly, Iyagba and Ekpete (2017) reported the need for elaborate knowledge and in-service training about organic farming amongst agricultural teachers. Their study indicates the developing interest amongst agricultural scholars in agroecological approaches in Nigeria. It is imperative that national extension services should acknowledge these factors to inform their decision-making and policy implementation in the services delivered to the farmers. This is significant because farmers rely on the results of demonstrations.

6.5 Conclusion and recommendations

The Nigeria public extension and advisory service are regulated by national government agricultural policies. These policies have focused solely on the maximisation of food production using intensive methods with the aim of improving food security for the population. They have failed though to acknowledge the impact of intensive agricultural practices on human health and the environment. Although these policies state that improvements in food production should be achieved in a sustainable manner, policy guidelines mean that extension personnel provide advice and information only on conventional methods. The farmers in the study area rely on the extension personnel for agricultural information and this, in turn, influences their farming decisions. Currently, most farmers in the area depend on agrochemicals for yield improvement, although a few still combine the practice with indigenous practices such as integration of crop and livestock production, mixed cropping, manuring and crop rotation. These indigenous practices are often compatible with agroecological approaches. Many farmers are concerned by the impact of intensive farming methods and there is a general willingness amongst these farmers to engage in more sustainable practices. Although farmers in this study were interested in agroecological practices due to the perceived benefits, they may not engage in new practices if they perceive other intrinsic and extrinsic factors such as their environment, social status, inaccessibility of required resources, labour scarcity, access to market etc. that may impact their decision-making. Moreover, lack of access to necessary information and opportunity to learn new skills that are context-specific could deter them from adopting and/or transitioning to desired practices. Farmers tend to be conservative and unwilling to risk money and time on new techniques without proof of their effectiveness. Their primary source of information is the extension service, but extension personnel also lack adequate expertise in agroecology. This correlates with the theory of reasoned action approach which indicates that other factors can influence farmers' intentions to or not use a practice (Ajzen 2011; Fishbein and Ajzen 2010).

There are several reasons for this, including a lack of locally relevant research, lack of opportunities in education and training in agroecology for extension personnel and academics and lack of support for agroecology in government. These various social, environmental, research and extension management factors hinder the transition.

This study recommends that research in agroecology approaches should be intensified and extension personnel must be encouraged by providing adequate funding for working resources and updated training on ecologically compatible practices. In this regard, agricultural extension services should be reinvigorated through policies and projects that are geared towards promoting sustainable agricultural practices such as agroecological approaches. Drawing evidence from other countries where agroecology farming systems are practised, this study also recommends a participatory approach that incorporates farmers' own traditional knowledge and methods.

Chapter summary

This chapter has formed opinion about the existing agriculture regime in Nigeria. The chapter showed that the regime does little to support agroecological systems and skill acquisition on agroecological practices and further unveiled other challenges confronting the progress of transitioning towards agroecological approaches. This chapter identified the importance of access to information and opportunities to learn the skills. Therefore, it is imperative to understand the existing agricultural knowledge and information system

[AKIS] and/or agricultural innovation system [AIS] i.e. how the agricultural knowledge flows, the sources, and who is responsible, so as to understand the mainstay of the existing agroecological knowledge in the area. As well as how improvement can be made to enhance the exchange of such knowledge. Hence, the proposed framework for an interactive agroecological knowledge platform for the collaborative agroecology-based exchange of knowledge and learning is explored in the following chapter.

Chapter 7: Exploring the present AKIS and/or AIS and how alternative methods (e.g. use of a mobile interactive platform) can facilitate agroecological knowledge exchange and transition

The outcome of the empirical findings in the preceding chapter (Chapter 6) suggested the need to understand the AKIS and AIS in the area. Given the significance ascribed to access to knowledge for the improvement of adoption of an innovation by the participants in Chapter 6, this chapter seeks to understand what, how and why agricultural information is shared to establish any available, accessible and flow of agroecological knowledge. It uses qualitative methods involving farmers, extension agents and agricultural university lecturers to explore the information needs of the smallholder farmers and identifies factors that facilitate their access to and sourcing of knowledge. By so doing, the chapter identifies the explicit and implicit agricultural knowledge systems and the sources, as well as how knowledge flows within the setting. Most significantly, the chapter ascertains the motivating factors for smallholders' share of their own traditional knowledge, and further proposed an interactive framework that could aid exchange of knowledge among agricultural actors with an intent to promote its usefulness to achieve a transformed agroecological society.

This chapter is a manuscript in preparation for peer-review as:

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See the proposed title and abstract in Appendix 21.

7.1 Introduction

The current global agri-food system which is mainly dominated by conventional or agribusiness farming has continued to be criticised in the debates on global agriculture (Bauer and Mesquita 2008; La Via Campesina 2012). Whilst there are claims that corporate involvement in agriculture and food systems is vital to meeting the current and future challenges, others are dismayed by the role played by large, multinational agri-food corporations in rural displacement and in harming and disorganising smallholder, non-industrialised agriculture (FAO 2012; McMichael 2009). Thus, resulting to hegemonic struggles[43] between scientists, corporate and state actors as well as the civil society actors (AFSA 2017; IFOAM EU 2018; La Via Campesina 2014; Levy 2008). In responding to the negative aspects, some civil societies have backed reduced corporate hegemonic control over food and agricultural systems, claiming that it will lead to more democratic and equitable outcomes (Altieri et al. 2015; Bauer and Mesquita 2008; La Via Campesina 2014).

Agroecological practice has formed part of the important discourse around the these debates as organisations (AFSA 2017; Groundswell International 2019; La Via Campesina 2014), including non-governmental organisations (FAO 2015) and scientists (Altieri et al. 2015) are proposing the practice as the best alternative to conventional agriculture. Grounded in the sustainable agriculture concept (Pimbert and Moeller 2018; Schaller 2013), this study adopted the definition of agroecological practice as opined by De Schutter (2010) which highlighted that:

> '*agroecological practice seeks ways to enhance agricultural systems by mimicking natural processes, thus creating beneficial biological interactions and synergies among the components of the agroecosystem. It provides the most favourable soil conditions for plant growth, particularly by managing organic matter and by raising soil biotic activity*' (De Schutter 2010).

Agroecology as a set of practices is argued as adaptive agricultural strategies that can reduce the impact of agriculture on climate change in a sustainable way, whilst still producing enough food to feed the growing population which is estimated to reach nine

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[43] Reflecting a conflicting situation where powerful actors in the agri-food system promote commercial interests over societal and environmental concerns and demands, and the demand for more desirable farming systems that work for farmers, the society and environment as well as how they can be shaped and established (Bellamy 2018).

billion by the year 2050 (Poux and Aubert 2018; Tomich et al. 2011; Wezel et al. 2014). Examples of farming techniques that use agroecology include organic farming, diversified crop rotations, biological pest control, agroforestry and some other widely accepted techniques (Arc2020 2018; Loconto and Fouilleux 2019). Additionally, concerns about the negative consequences of current agricultural production practices help support calls for the transitioning towards more agroecological approaches (Lacey 2007; Liu et al. 2015; van der Meer et al. 2020; Wezel et al. 2014). Increasing evidence of the viability of agroecological approaches, particularly from farms in Latin America and to a lesser extent from Asia, Europe and some parts of Africa show that agroecological practice is gaining the recommendation to be mainstreamed to other parts of the world (AFSA 2016; Altieri and Toledo 2011; De Schutter 2014; FAO 2015; La Via Campesina 2014; Pimbert 2015). However, to actualise this goal requires an improved knowledge innovation system i.e., an enhanced information and knowledge flow to and from within the specific location, as there is a positive relationship between enhanced flow and access to knowledge and agricultural development (Fawole 2008; World Bank 2004).

A Knowledge Innovation System (KIS) in agriculture is a framework used to investigate and understand the relationships that underpin how agricultural knowledge is generated, transformed, transmitted, consolidated, received and fed back. When used in a collaborative manner this enhances its use by the stakeholders (Roling 1988). The knowledge innovation system is based on the process in which knowledge production is primarily built around collaborative relationships between relevant actors who are the knowledge producers or users (van Mierlo et al. 2017). According to Padel et al. (2018), agroecological transition is an active process which requires a shift from the process of knowledge transfer to knowledge exchange. Consequently, the knowledge exchange process could be achieved through interactive social, peer-to-peer learning and networks related to agroecological approaches (Padel et al. 2018). Although there may be an unequal power relationship inherent between science, corporations and indigenous communities during the interactive process, various authors advocate for respectful collaboration that recognises the farmers' vulnerability to their environment as well as their indigenous knowledge (Altieri et al. 2015; Snapp 2017).

Nigeria is among the African countries that depend on the dominant conventional agricultural systems for the improvement of her economy. Conventional agriculture as practised in Nigeria relies on the use of agrochemicals, monocultures and modified seeds (Mgbenka et al. 2015; Olaito 2014). Whilst oil production is the most economically important sector in Nigeria, agriculture still employs over 36% of the active labour force at an estimated value of ₦803 Billion ($2 Billion) in 2019, thus a meaningful source of livelihoods for the populace (National Bureau of Statistics 2021; Oyaniran 2020). Nigeria's agricultural sector is comprised of sub-activities such as crop production, livestock, fishery and forestry. The country's varied climatic conditions allow it to produce a wide variety of food and cash crops (FAO 2018; International Fund for Agricultural Development [IFAD] 2016). However, with the increasing demand for food, the impact of climate change and agricultural challenges in Nigeria (Erhunmwunse et al 2012; FAO 2015; Nnamonu and Onekutu 2015; Olulakin et al. 2015), the need to enhance the practice of agroecological approaches becomes critical. As there is currently little support for agroecology among policymakers.

Agricultural research, extension and knowledge transfer in Nigeria currently follows a very traditional hierarchical pattern. Nigeria has 21 National Agricultural Research Institutes [NARIs] and numerous agricultural universities and colleges that are tasked with generating agricultural knowledge (Agbamu 2000). The country also has a nationwide agricultural extension and advisory system manned by the National Agricultural Extension and Research Liaison Service [NAERLS]. The remit of this organisation is to enhance stakeholders' access to agricultural knowledge. However, despite the large body of knowledge that exists in these institutions, access to adequate agricultural information remains poor (Arokoyo 2003). The situation was attributed to the weak linkages between research institutions, extension agents, farmers and policymakers as well as implementation of policies that do little to promote the collaborative knowledge transfer/exchange approaches (Agwu et al. 2008; Asiabaka 2007; Munyua 2011; Nnadozie et al. 2015; Sani et al. 2015). In attempts to promote the transfer of knowledge/innovation from the NARIs to the farmers and address the weak linkages in the system, two initiatives were created by NAERLS. These were: 1) the Research Extension Farmer Input Linkage System [REFILS]; and 2) the Adopted Village Scheme [AVS] (Agricultural Research Council of Nigeria 2011). REFILS coordinates the research and extension activities whilst promoting research trials. The AVS concept is an extension model to facilitate the trial and adoption of new scientific research findings. Trials are carried out in the farmers' own fields, where the farmers take the role of observers if the trial is managed by the researchers, or executors if managed by the farmers themselves. Although the REFILS and AVS initiatives have enhanced farmers' access to formal, conventional agricultural knowledge, they could not completely address the weak linkages, lack of two-way interaction, nor influence the integration of smallholder farmers' own innovations or indigenous/local/informal agricultural knowledge in the development/production of the knowledge (Asiabaka 2007; Emeana et al. 2019; Nnadozie et al. 2015; Sani et al. 2015). The importance of understanding the farmers' existing knowledge and learning from their problem-solving and adaptive experimentation, to enhance knowledge generation has been noted by a number of authors (Ngulube 2002; Warren 1991). Ngulube (2002) pointed out that the research and innovation approaches in Nigeria leave little or no opportunity to integrate indigenous knowledge into the exogenous knowledge system.

Globally, research shows that subsistence farmers depend on their local, indigenous knowledge which is specific to their local environment in managing their agricultural activities (Eyong 2007; Grenier 1998; Mosissa et al. 2017). Altieri (2017) suggests that agroecological approaches are deeply rooted in the ecological rationale of indigenous knowledge systems worldwide and that, family farmers should be at the centre of such knowledge systems to drive agroecological practices. Specifically, in Nigeria, a number of studies made similar observations that some farmers still follow traditional practices and that these can be considered to be agroecological (Ajibade and Shokemi 2003; Emeana et al. 2019; Olatokun and Ayanbode 2009). However, in Nigeria, as in other sub-Saharan African countries such as Botswana, Ethiopia, Ghana, Senegal etc., governments, through their various agricultural research institutions, education and advisory systems, influence communities to follow government-led programmes that are based on intensive agricultural systems (AGRA 2018; Shiferaw 2017). These reject smallholder farmers' traditional knowledge, try to change their indigenous practices and encourage dependence on agrochemical inputs. These government-led programmes are sometimes felt by farmers to be inferior (Abay et al. 2017; Emeana et al. 2019). By so doing, the government persuades communities to stop using their local seeds, use agrochemical inputs, practice one-cropping systems and supersede their traditional shifting cultivation calendar to year-round cultivation period. The government is doing so to homogenise its own agricultural systems and/or formal knowledge (Roy 2017; Timmermann and Felix 2015). The pressure is so strong and effective because it is further motivated by the formal education system that places little or no value on local knowledge and classifies indigenous agricultural practices as primitive (Olatokun and Ayanbode 2009; Roy 2017). This outlook persists and jeopardises the wider application of agroecological practices and development of indigenous agricultural knowledge in Nigeria. Hence the need to adopt an interactive agricultural innovation system thinking that will enhance the exchange of indigenous/agroecological knowledge.

Access to accurate and appropriate information, as well as a collaborative link between the relevant actors, are important for agricultural development (Roling 1990). Moreover, the ability to collaborate and share knowledge is important for improving agroecological approaches (AFSA 2017). This study, therefore, explores how smallholders' traditional knowledge or agroecological knowledge is currently incorporated in this system, with the view to enhance access to and exchange of agroecological knowledge. This concept may help to understand the Agricultural Knowledge and Innovation System in the areas and how the actors such as agricultural extension and advisory services, research and education, farmers, policy and regulatory bodies and other agricultural stakeholders (World Bank 2004) can interact to foster agroecological knowledge development. Thus, to achieve the overall aim, the study intends to:

- Evaluate the agricultural information needs of the farmers;
- Consider how agricultural knowledge is exchanged among the stakeholders;
- Evaluate the relevant structures in place for knowledge exchange;
- Determine the factors that contribute to effective knowledge flow;
- Propose a knowledge exchange/transfer framework that integrates mobile technology to enhance agroecological practices.

Given the understanding of the actual aim and objectives of this study, the subsequent sections present the review of relevant agricultural innovation systems, detailing their role in agricultural development. Furthermore, the conceptual framework of this study is highlighted, and the methods used in collecting and analysing data explained. Following the presentation of the study results and discussion of key findings, is the conclusion and recommendations.

7.2 Review of relevant agricultural innovation systems

This section covers the general review of relevant literature that is associated with the innovation, flow and exchange of agricultural knowledge. In this section, the concept of innovation system, knowledge sharing, exchange and transfer of technology, agricultural knowledge and information system, and agricultural innovation system are presented to conceptualise the aim of this study.

7.2.1 Innovation system

An innovation or information system can be defined as a network of institutions or individuals founded with the aim of generating new ideas or information, processes and products into economic usefulness, together with policies that affect the behaviour and performance of the individuals and institutions (Klerkx et al. 2012). Policy decision bodies, universities, private sectors and research institutions form the important part of the larger innovation system and interactions that allow various agricultural stakeholders with different strength to come together to set a common goal for innovation. In Nigeria, the government still plays a major role in overseeing the affairs of the agricultural sector and directing agricultural production activities (Agwu et al. 2008). Hence, the innovation system appears to provide opportunity for the understanding of how the country's agricultural sector generates and makes use of information and innovation.

7.2.2 Knowledge sharing, transfer and exchange

The three terminologies 'Knowledge Sharing', 'Knowledge Transfer' and 'Knowledge Exchange' share similar explanations and are occasionally used interchangeably (Badaracco 1991; Hansen 1999). However, recently, various authors have demonstrated the variances (Easterby-Smith et al. 2008; Fernie et al. 2003; Paulin and Suneson 2012). Wang (2010) explained that *knowledge sharing* is the process of sharing of knowledge by the source and acquisition and application of this knowledge by the recipient (see further illustration in Figure 7.1 below). It also involves the multi-directional movement of knowledge between the institutions or individuals involved. The sharing of knowledge can be formal or informal which may involve the use of formal or informal communication media (Zahra et al. 2006). The informal type of knowledge sharing practices can enhance the sharing of implicit knowledge which are hard to define, codify and express (Azudin et al. 2009; Jewels et al. 2013). The difference between tacit and explicit knowledge is first identified by Polanyi (1958). Tacit or uncodified knowledge or 'know-how' can be acquired through individual practice, experience, inner knowing or intuition and may not relate to cognitive learning (Botha et al. 2008; Curry and Kirwan 2014). In order words, explicit or codified knowledge can be easily reported and documented, even as it may require to be translated into a more adaptable knowledge that is suited for practical application (European Union Standing Committee on Agricultural Research [SCAR] 2012). However, implicit knowledge can be made explicit (Nonaka and Toyama 2003), through an appropriate channel or source. Thus, enhancing access to agricultural knowledge requires a great deal of determining how tacit and the explicit knowledge-sharing process is used to guarantee the success of agricultural knowledge sharing.

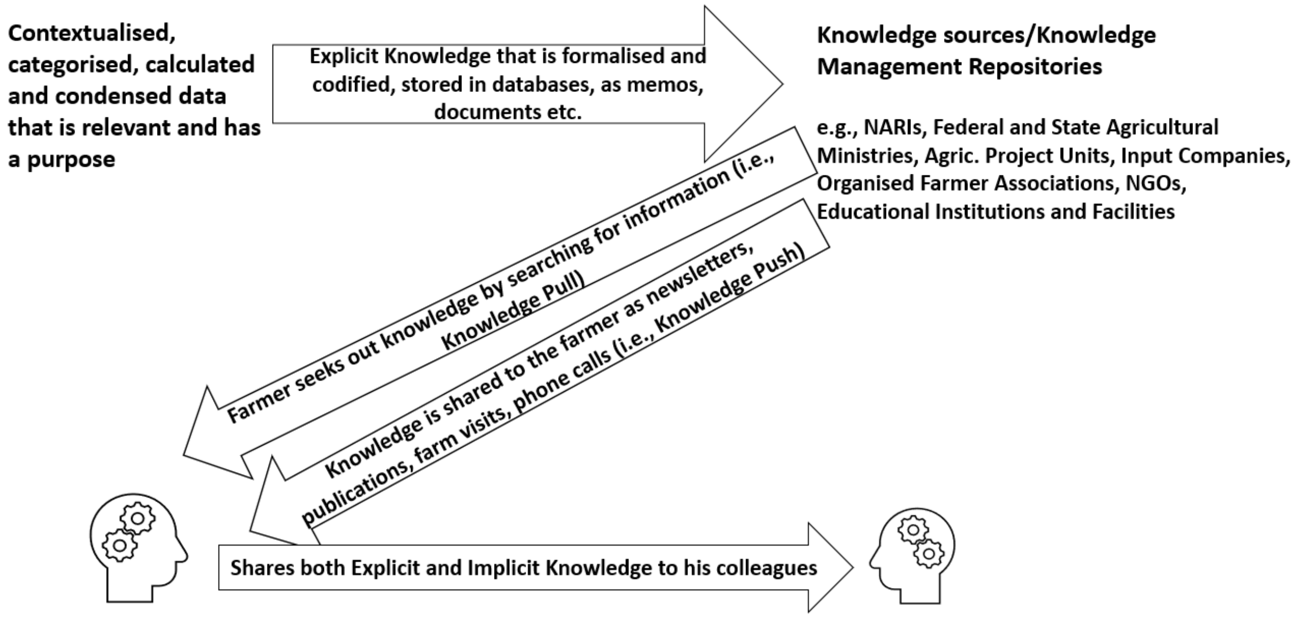

Figure 7.1: Knowledge sharing process (The knowledge sharing could depend on the habit and willingness of the farmer to seek out and/or be receptive to the agricultural knowledge sources) (Author's compilation).

Conversely, *knowledge transfer* is the process by which research-generated information is promoted or sent by the researchers to the users (i.e. farmers) (Mitton et al. 2007). Knowledge transfer involves the dissemination of knowledge from one individual/group or location to another and recognises that one unit could be affected by the experience of other units (Argote and Ingram 2000; Inkpen and Tsang 2005). The process entails a one-directional movement of knowledge, from those who generate and/or own the knowledge to those who need it or are thought to lack the knowledge (see Figure 7.2). Hence, for improved access to knowledge and/or effective knowledge transfer process, it is important to clearly and comprehensively understand how implicit and explicit knowledge transfer settings can be embedded to facilitate knowledge accessibility, as well as the sources and destination of the generated knowledge.

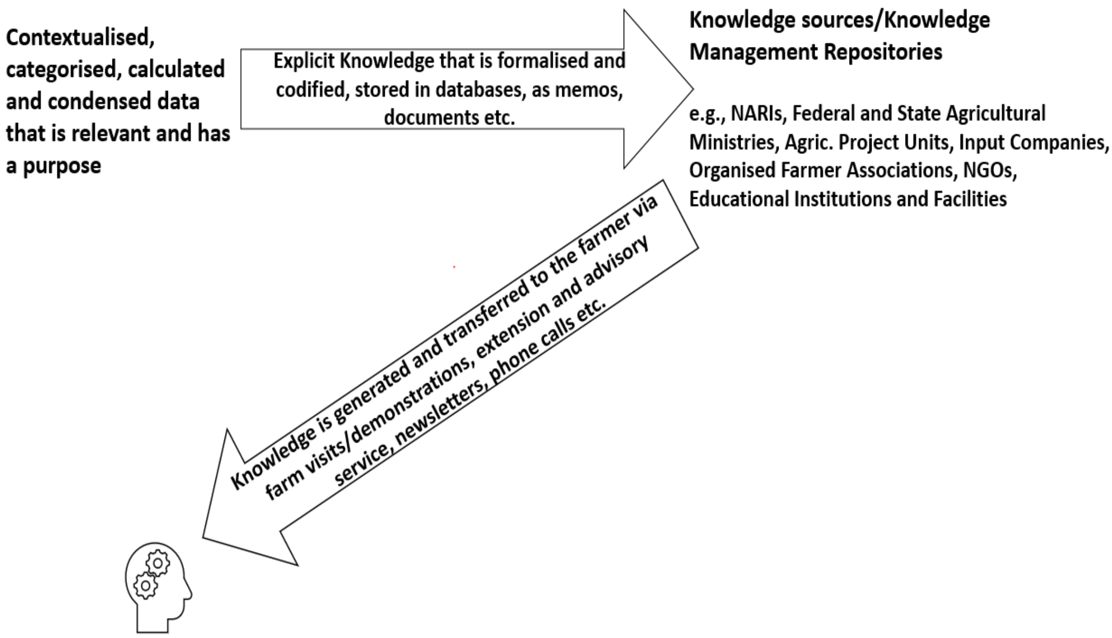

Figure 7.2: Knowledge transfer process (This is a top-down process where the information-rich sources and/or personnel perceive the farmer as one who lacks and needs the knowledge) (Author's compilation).

In a further explanation of these terms, Wang (2010) defined *knowledge exchange* as the process of both sharing and seeking for knowledge. Information and/or knowledge-seeking behaviour is the entire human behavioural action towards sources and channels of knowledge, which may involve both active and passive knowledge seeking and use (Wilson 2003). Knowledge exchange is a useful process in a knowledge and involves the producers, intermediaries and users of knowledge. Whilst knowledge transfer requires a one-way channelled communication, knowledge exchange requires more than a one-way communication channel, as well as involving both knowledge transfer and knowledge sharing (Mitton et al. 2007). Furthermore, knowledge exchange takes place when both actors (knowledge source and receiver) in the system are aware of their knowledge needs and decide to exchange and/or share knowledge between them (see further details in Figure 7.3). Hence, knowledge is transferred from a knowledge-rich source to a knowledge-poor receiver through the sharing process, but as this exchange is bilateral, the roles of source and receiver are not fix (Šūmane et al. 2016). Knowledge exchange aims at individuals and might occur in systems which are associated with increased interdependency and connection among the individual participants (Contandriopoulos et al. 2010). The means of knowledge exchange include the use of mobile technologies, face-to-face interactive communication, print and electronic media etc. (Global Forum for Rural Advisory Services [GFRAS] 2019). Thus, the involvement of varied agricultural stakeholders in the agricultural knowledge exchange is imperative in determining the knowledge needs of the target recipients to accommodate their daily agricultural activities. Additionally, a clear understanding of the sources and target destination of the knowledge and media used for the knowledge exchange is imperative to strengthen knowledge flows.

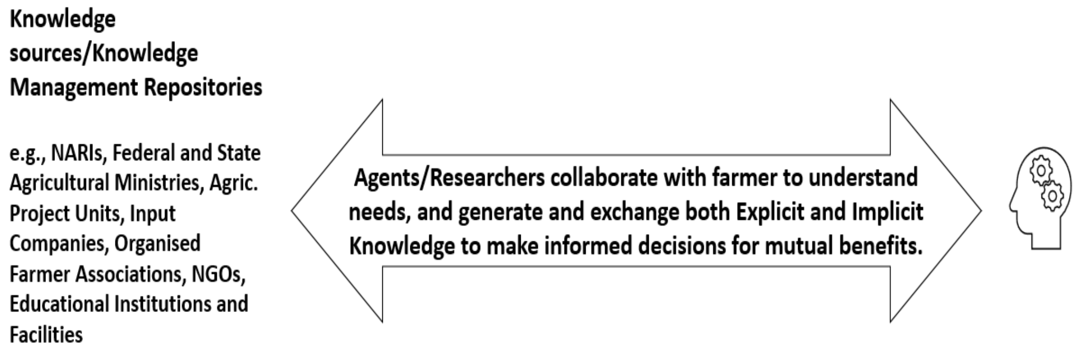

Figure 7.3: Knowledge exchange process (This process allows collaboration between the knowledge-rich sources and knowledge-poor receiver. However, being the knowledge-rich or poor entity could depend on the context and experience) (Author’s compilation).

Significantly, trust and social capital are necessities in knowledge exchange and/or sharing, with opinions showing that farmers are more likely to utilise knowledge when it emanates from trusted sources (Fisher 2013). Riley et al. (2018) attributed knowledge utilisation to the capital status of the farmer and how easy it is for his colleagues to observe his position. Albeit using slightly divergent terminology, Riley (2008) and Tsouvalis et al. (2000) noted similar views in their discussion of ‘knowledge cultures’. As such, the collaborative process should encourage credible[44], salient[45] and legitimate[46] exchange of information amongst the stakeholders (Ingram et al. 2016; Steingröver et al. 2010).

7.3 The evolution of innovation systems in agriculture

Frameworks and tools used to evaluate knowledge exchange in agricultural systems have seen major changes over the last decade, Nigeria included. These have evolved from the earliest approaches which followed the National Agricultural Research System [NARS] to the Transfer of Technology [TOT], through to Agricultural Knowledge and Information System [AKIS] and more recently to Agricultural Innovation System (AIS). The NARS perspective emerged in the late 1980s and involves a linear approach in which knowledge flows from a known source to the target end-users. The NARS concept was based on the assumption that agricultural research disseminated through technology transfer automatically leads to the adoption of such technologies by farmers and results in consequent growth in production (World Bank 2006). However, the effectiveness of the NARS concept depends entirely on how widely the innovations are taken up by practitioners. Furthermore, NARS relies on the role of the government in fostering technological change and the public nature of agricultural research, as well as assuming that the economic and social background of any technological change is exogenous and unchangeable. Hence, NARS as a concept is not specifically targeted at the technology users and other stakeholders and therefore does not always reflect the main stakeholders' needs nor take into account the changing circumstances of the research institutes (World Bank 2006).

In the mid-1980s to late 90s, the concept of technology transfer or transfer of technology [TOT] emerged. This concept focused on increasing the participation of farmers, as target users and involved extension personnel as the technology mediators. The process involved the technology mediators training the farmers and allowing them to practice the techniques on their own farms and then visiting these farms occasionally to ascertain the

[44] Credibility refers to whether the information is accurate, valid and of high quality.
[45] How relevant information is to a particular decision maker. Different actors have different knowledge interests and thus varied criteria for assessing the relevance of knowledge – in relation to timing, context and need.
[46] This shows the extent to which knowledge production has been respectful of the divergent views and values of stakeholders, unbiased in its conduct and fair in its treatment of opposing opinions and interests.

adoption of the technology (World Bank 2006). The TOT concept aimed at reforming and enhancing the efficiency of conventional agricultural extension for the development of agriculture (Pant and Hambly Odame 2009). The effectiveness of the TOT is also subject to technology adoption, which allows farmers' feedback with the aim of improving technology transfer and adoption. However, the limitations lie in the lack of interaction and involvement of other stakeholders in the network, as well as over-dependency on the extension personnel. Hence, criticisms emerged from this concept that gave rise to the development of the Agricultural Knowledge and Information System [AKIS] (Rolling 1988). In contrast to NARS and TOT, AKIS evolved as a more sophisticated approach, that links farmers with organisations such as the research, extension, education and market, so to generate, share and use agricultural knowledge/information or technology. A key aim is to promote mutual learning from various sources for improved agricultural productivity and well-being of the target beneficiaries (World Bank 2006). The AKIS concept places the farmers at the heart of the knowledge-loop formed by education, research, market and extension, as well as recognising them as the key actors in the process. However, AKIS's focus is limited to actors and process within the closest environment with reduced attention towards other organisational actors and external factors (Spielman 2005). Hence, in support of strengthening AKIS's limitations, the Agricultural Innovation Systems emerged. Agricultural Innovation Systems [AIS] involve an extended set of actors and/or stakeholders thereby building on the basic approach of including only the agricultural research, extension and education institutions and places more emphasis on the role of farmers and other relevant stakeholders (e.g. local markets). Furthermore, the AIS concept offers an opportunity for strengthening the capability to create, spread and use knowledge for solving agricultural problem (World Bank 2006). Thus, the concept is considered to improve on the previous concepts of agricultural research systems and development (Spielman 2005).

Crucially, later concepts i.e. AKIS and AIS, do not focus only on the transfer of knowledge, these approaches also consider the demand aspect as well as the complex nature of the innovation process. Using communication and networking mechanisms, relevant knowledge is collectively created, recognising and involving the farmers' contribution to knowledge (Assefa et al. 2009). Of these various ways of capturing knowledge exchange, AKIS and AIS are the most relevant for this study as they capture the complex relationship between varied stakeholders (farmers, research, extension, education and training, policy regulatory bodies, civil society organisations and others) for agricultural development.

7.4 A conceptual framework for this knowledge system study

This study drew strength from the AKIS and AIS perspectives with the emphasis on the interaction among multiple relevant stakeholders as shown in Figure 7.4. In shaping how the stakeholders interact in the innovation process, facilitation mechanisms are crucial (Devaux et al. 2011). The mechanism in this regard involves innovation or interactive platform that can enhance communication and information sharing and improved ability to make collective decisions (Aslam et al. 2013; Pyburn and Woodhill 2014). Mobile technologies such as mobile phones – smart and feature phones – that have built-in systems that can enhance collaborative knowledge exchange, have been credited with facilitating knowledge networks and platforms where diverse agricultural stakeholders can connect to share knowledge (FAO 2017c; FAO 2018a). Interactive mobile technological innovation can then challenge the dominant top-down agricultural knowledge system and seek to change it through the dissemination of fundamental ideas and practices through a horizontal approach which allows a contribution from all participating stakeholders (Ingram 2018). This means that knowledge generation and learning can be promoted through a collective process where production methods are proposed and discussed, ecological concepts are integrated, then practices implemented in individual farms and results are discussed in groups via a platform (Lamine 2011). In this concept, the role of the formal actors in agricultural development has to change from being considered as the sole drivers, originators and owners of agricultural knowledge or the process of agricultural innovation to contributors of knowledge. However, their services are considered relevant in relation to the roles of other relevant stakeholders (Gildemacher and Wongtschowski 2015). This interpretation encourages a pluralistic approach where the roles of the farmers evolve over time based on their specific environment, skills and competencies in convening their indigenous knowledge, while the roles of other stakeholders are negotiated to adapt to their [farmers] own system. Thus, the concept is aimed at enhancing agroecological/indigenous knowledge or innovation using the AKIS and AIS system thinking.

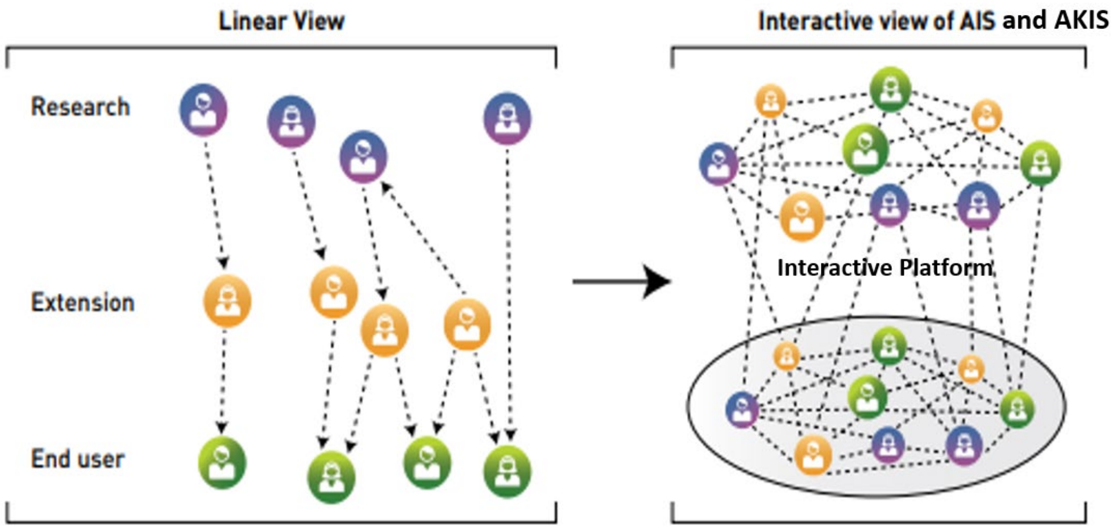

Figure 7.4: The concept for the flow of agroecological knowledge (Adapted from Klerkx et al. 2012; Pant and Hambly-Odame 2009; Tropical Agriculture Platform [TAP] 2016; World Bank 2006).

The application of these kind of initiatives that can promote agroecological practice is becoming popular and gaining recognition, particularly among policymakers in Latin America, some European countries, and even in some parts of Africa (Anderson et al. 2018; FAO 2015; FAO 2018 L'Ateleir Paysan 2016). However, such initiatives in Nigeria are likely to present major policy implications for agricultural research, extension delivery and utilisation. Government policymakers would need to consider how best to promote and support such changes. Supporting vigorous collaborative agroecological research among actors in the various sectors and sub-sectors would be best achieved using a horizontal framework which recognises the varied stakeholders' contributions to knowledge. It also requires an understanding of the strengths and weaknesses of these different sectors and actors and the provision of support for the institutions that would contribute to strengthening the agroecological knowledge and exchange system. However, in considering the applicability of this kind of initiative, it is also important to consider the relevant possible factors that can influence a persons' behaviour towards accepting or rejecting a particular initiative, especially within the smallholder farmers' context and conditions (Hall 2014; Mills et al. 2016; Padel et al. 2018).

For agroecological practice, it has been argued that a range of factors could affect farmers' attitudes. These factors include personal traits, social or cultural norms, knowledge regimes etc. could encourage both behaviours and attitudes that either constrain or support farmers' decision-making (Burton and Paragahawewa 2011; Meek 2015; Sutherland and Darnhofer 2012; Trevisan et al. 2016). Similar critics have also shaped the discourse about the use of mobile phone applications. Whilst mobile phone applications are acclaimed for facilitating interactive knowledge exchange, a number of studies have questioned their adaptability and sustainability (Bengtsson and Ågerfalk 2011; Heeks 2010; Remy et al. 2018). These issues are grouped into 1) access to use; 2) ability to use; 3) actual use; and 4) impact of use (Kleine et al. 2012; Singh 2010) and others have identified various ways such challenges can be ameliorated (see Danes et al. 2014; Emeana et al. 2020; GSM Association 2016).

7.5 Methodology

The study reported here is a qualitative research that was carried out in southeast Nigeria focussing on Imo state and Abia state respectively. Imo was purposively selected because of its high dependency on agriculture and it's diverse research and extension activities, whilst Abia was selected because both the National Agricultural Extension and Research Liaison Service [NAERLS] southeast zonal office and Federal University of Agriculture Umudike, are sited there. The study sought to explore farmers' information needs as well as how and where they access and source for agricultural information. Additionally, the structural flow of agricultural knowledge system in the area was ascertained. Prior to data collection, the study sought the approval of Coventry University's ethical regulatory unit (Appendix 14 for the ethical approval number).

7.5.1 Data collection strategies

A total of 30 participants comprising of 12 farmers, eight extension personnel and 10 agricultural university lecturers, were selected using purposive sampling technique. The farmers were selected from various family farm holdings from Umuakaobia, Ezinnachi and Eziala Enyiogugu, all in Imo state, while the extension personnel and university lecturers were respectively selected from NAERLS and Federal University of Agriculture Umudike, all in Abia State. In locating farmers for interview, initial contact was made with the Imo state Agricultural Development Programme Unit to gain access to the full list of their contact farmers. Additionally, both the extension personnel and agricultural lecturers were accessed through their respective heads of department – taking into account the demerits of confronting gatekeepers (Holloway et al. 2010). Subsequently, prior to the actual interview, the researcher contacted the potential interviewees via telephone calls to discuss the topic under study, gain understanding about their experience and assess whether the interview will be worthwhile (e.g., van Rijnsoever 2017). This sample was chosen on the rationale that rich data can be provided, and the sampling technique proved useful in reducing bias and enhancing credibility but does not substitute representativeness (Crabtree and Miller 1999; Patton 1990). The field extension personnel and agricultural university lecturers were selected because they engage in agricultural information creation and distribution. Generally, the study sample has common interest in agricultural knowledge for agricultural production and their varied experience allowed them to reflect on the motives for their activities in their various disciplines. Accordingly, Crabtree and DiCicco-Bloom (2006) and McCracken (1988) in their studies, argued that the selection of interviewees should be fairly homogenous and share critical similarities related to the research question. The interviews with the farmers were conducted on-farm to gain a better understanding of their agricultural practices, problems, motivations and adaptation strategies (Gliessman 2000). For other participants, interviews were conducted in their various workplaces. The study adopted a semi-structured interview format, allowing the researcher the flexibility to probe certain aspects of the interviewees' answers as well as share in their experiences and beliefs (Boyce and Neale 2006; Huston and Rowan 1998; Mack 2005). Questions were asked about where knowledge is sourced from, what type of knowledge (i.e. both explicit and implicit), how and through what channel, from whom (i.e. individual or institution), and why such knowledge is needed (see further details in the Appendix 7). Interviews lasted between 1 and 2 hours, where possible, the researcher took a walking interview approach, which helped to gain understanding and observe the features of the farms or nature of the job (Riley and Holton 2016; Kinney 2017). Additionally, official publications of the Federal Ministry of Agriculture and Rural Development and NAERLS, as well as the Agricultural Development Project documents, formed part of the secondary sources of data. All data were collected between December 2017 and April 2018.

7.5.2 Analytical process

The interviews were recorded using a handheld voice recorder and transcribed verbatim in a Microsoft Word by repeatedly listening to the recordings. Additionally, the researcher outlined her personal observations and related information that emanated during the interview process in a diary. This approach allowed the researcher to get acquainted with and derive meanings from the data (Bennett et al. 2019). Each of the interview transcripts was iteratively studied and relevant statements were manually labelled with different codes (descriptive phrases) using Microsoft Word highlighting tools. Moser and Korstjens (2018) argued that coding process allows the researcher to immerse him/herself in the data. Coding is important in noticing relevant phenomena, highlighting examples of those phenomena, and analysing them to ascertain similarities, differences, patterns, and structures (Basit 2003; Seidel and Kelle 1995). Consequently, the emergent codes were categorised into nine broader themes which were further summarised in five overarching themes that were fit to the study objectives. Creating categories prompts the construction of a conceptual scheme that matches the data. Additionally, it is useful to identify two different, although connected, phases to data coding such as: 1) addressing the meanings inside the research background; and 2) focussing on what may be meaningful to the intended audience (Saldaña 2013). In reporting the responses, the researcher linked the themes; copied verbatim, some of the interviewees' quotes that match each theme; and finally, outlined the outcomes. Additionally, in section 7.6.5, the study used Table 7.1 to summarise the sub-themes that were articulated as some of the reasons for maintaining some traditional farming practices.

7.6 Results and discussion

7.6.1 Participant characteristics

This section highlights the characteristics of the respondents such as their age, gender implication, literacy level and experience in their respective fields. While few farmers were above 60 years, the majority were aged between 30 and 59. The extension personnel and lecturers were also aged between 30 and 59 years.

This finding indicates that the participants were middle-aged and in their economically active stage. For the farmers, this could influence their knowledge about any innovation (Sillitoe et al. 2005) and their attitudes (Lawal 2017) towards such innovation. More so, the extension personnel's age is likely to influence their capacity to disseminate any available agricultural information to the farmers. This finding corroborates Idrisa and Ogunbameru (2008) and Olorunfemi et al. (2018) that individuals that are best suited for extension service delivery are those in their economically active age. In this same perspective, the age of the lecturers may impact on their research and/or lecturing activities.

The farmers shared their individual experiences about the impact of gender on their agricultural activities, indicating that have more influence on decision-making. Quotes from two female farmers read:

> "*We do the working in our own family portion together, the digging and …, but I mainly look after the maize and cassava, I mean the ones we eat [food crops], my husband sells the main crops [cash crops] and gets more money for himself to spend. You see, I can only sell when harvest is more, so I can get small money*" (Woman farmer 1).

> "*As a woman, it is difficult to say when to plant, ahh even to decide what to plant when the man is there. You are there to help take care of everything but not to plan everything*" (Female farmer 7).

This finding validates Enete and Amusa (2010) in their comparative study on gender involvement in agricultural decision-making amongst farm households in Ekiti state Nigeria, which indicated that, though some field activities may be gender-specific, women' contribution to farming decision-making is limited due to misconception that women farmers are supposed to be subordinates to men in farming. The role of women in ensuring food production cannot be overemphasised (FAO and ECOWAS 2018). Otaha (2013) in the analysis of food insecurity in Nigeria and the way forward, noted that women are often marginalised and deprived access to some of the agricultural assets when compared to men. This finding validates Otaha (2013) claim and further revealed that the women mostly engage in food crop farming than the cash crops as their male counterparts, which in most cases affect their (women) income as their harvest is mainly for household food supply and little for sale, while the men sold their cash crops which gave them more earnings. This situation may affect women's ability to cater to their other needs. Furthermore, the women are often marginalised in terms of land ownership and/or acquisition if they are widowed and/or do not have a male child that can inherit their husband's land. One of the interviewees commented thus:

"*One will not wish such to happen, because if a woman has no child and the husband dies, perpetually she has lost access to the family land*" (Male farmer 1).

This finding also corroborates Enwelu et al. (2014) in their study about women farmers' access and use of land for agricultural activities in Anambra state Nigeria which revealed that women own and access land in the name of their husbands. These present findings could be translated into unequal access to relevant agricultural information as well agricultural assets which could, however, inhibit women' access to agroecological knowledge and practice of agroecological approaches given that information and land are the most production factors for farmers.

In various studies across African countries such as Ethopia (Zewdu et al. 2016); Tanzania (Lwoga et al. 2011; Siyao 2012); and Mali (Sousa et al. 2016), farmers are reported to be illiterate with low educational status. However, this present study finding revealed that the level of academic attainment varied between the farmers and other participant groups, many farmers had tertiary education as their lowest educational qualification. This could indicate that presently Nigeria's farmers are becoming more literate than previously thought. Previous studies have considered that farmers are considered as non-literate, which limits their agricultural production and economic growth, as well as their ability to access relevant agricultural information (Obidike 2011; Soola 1988; Welfare Irivwieri 2007). The literacy profile of the farmer participants corroborates other recent studies regarding academic attainment and literacy levels. For example, some of the studies carried out in Nigeria showed a higher proportion of farmers who had formal education (Adesope et al. 2012; Asa and Daniel 2015; Asa and Uwem 2017; Nwachukwu 2010).

The respondents' level of experience in their various fields also varies, with the majority having more than 10 years of experience. This finding indicates that all the participants, have spent a relatively good number of years in the agricultural sector which is expected to have improved their capability in their service/farming activities and could impact their decision-making process for access and/or dissemination of agricultural knowledge. Similarly, Laki et al. (2014) concluded that level of experience is a significant factor for overall competency in agricultural activities. This could also influence farmers' choice of practice.

7.6.2 Farmers' information needs

Farmers seek agricultural information to help them improve their productivity and therefore, adequate interactive information exchange is needed to support them. This study finding revealed that the major information needs of the farming participants include: how to control plant pests and diseases (n=12); how to improve seed preservation (n=8); how to secure credit for their farming activities (n=8); how to sustain yield (n=11); how to manage livestock diseases (n=7); how to improve soil fertility (n=9); and access to market for inputs and produce sale (n=10). This finding indicates that the farmers in the area still seek for agricultural information that is relevant for improving their agricultural productivity. Similarly, Soyemi (2014) observed that female farmers in Nigeria seek access to pertinent agricultural information. However, a previous empirical study that involved subsistence farmers, observed that the main agricultural information and/or knowledge the farmers seek to access include crop improvement and management practices (Emeana et al. 2019). This could possibly imply that these farmers are more concerned with improving their productivity to enhance their livelihoods. However, during the interview, it was revealed that the male farmer participants needed information about access to market for inputs and sale of produce (n=7) and how to secure credit (n=7), while the female participants needed information about techniques for improving yield.

> "*You see, where to sale our produce to make more profit is important to us as where we can be buying the things we need for the farming*" (Male farmer 3).

Although this study observed a slight difference in information and/or knowledge needs of the farmers according to gender, a similar study by Adomi et al. (2003) stated that there was significant dissimilarity in the information needs of the farmers in the rural areas of Delta state Nigeria.

7.6.3 Exchange of agricultural knowledge and information among the stakeholders

The participants were asked about how the flow of agricultural information takes place amongst them. The findings revealed that the flow of agricultural knowledge in the area could be classified as top-down as well as horizontal in nature, such that the top-down is from the formal sources while the horizontal is from and within their local communities (see Figure 7.5).

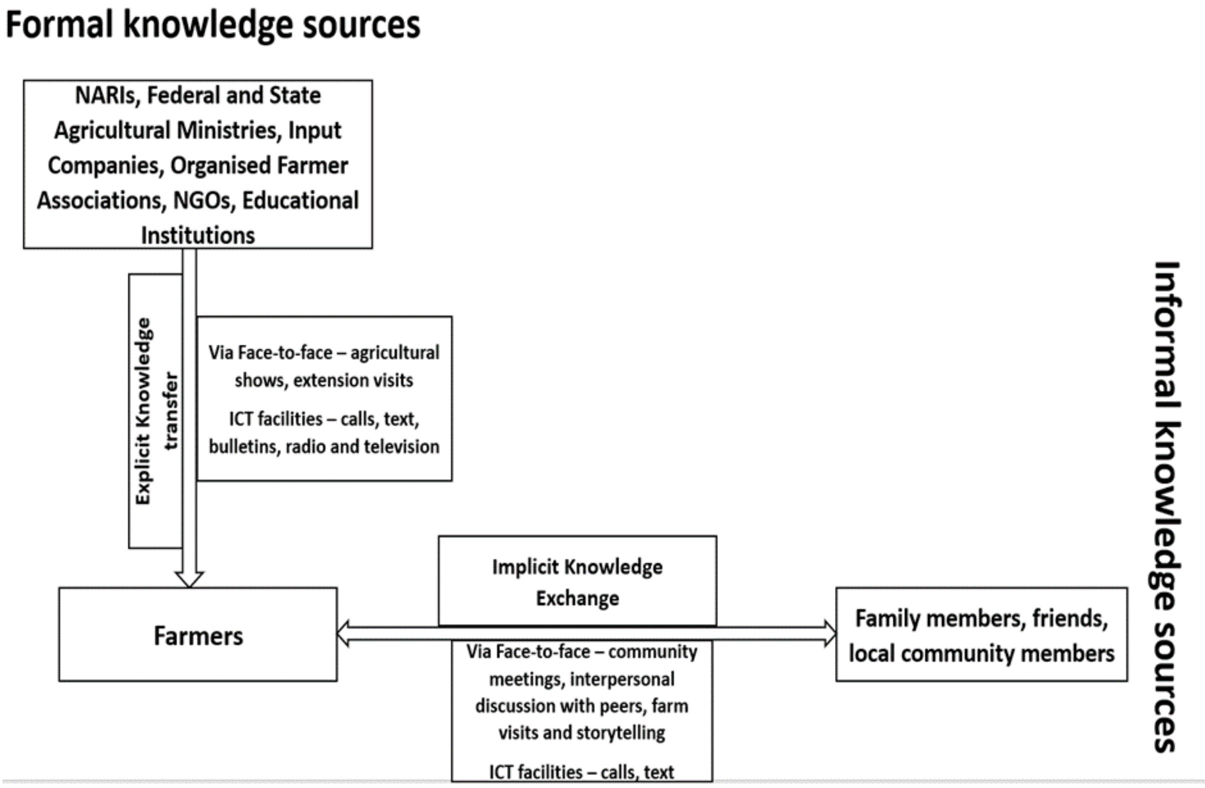

Figure 7.5: The flow of agricultural knowledge (Field survey 2017/18)

It appeared that the first point of contact for these farmers for problem-solving initiatives in their local setting is their local networks. As the multiple narratives revealed that the farmers shared their agricultural knowledge through local gatherings (village meetings), interpersonal discussions, phone calls, text messages, and visits to family members, agricultural shows and seminars and input supply shops and other farmer organisations. Most importantly, the agricultural shows and seminars are sometimes organised by Cooperative Farmer Organisations, input supply companies, NARIs, Agricultural Ministries and Agricultural Universities. A male farmer narrated an example:

> "*We relate more in our community; we learn from other farmers too. When we had cases of the maize attack by insects in our fields, we were encouraged by some other farmers who attended seminars on how to tackle it [insect pests' infestation]. So, they told us to start planting sorghum in the same field with maize and apply pesticides. Although we do not plant sorghum before, but because of this we have adopted it to reduce risk of*

loss and we share this information with other neighbouring communities too" (Male farmer 4).

However, the extension personnel and lecturers indicated that they shared knowledge through meetings with colleagues and farmers at agricultural shows and conferences, phone calls, text messages, bulletins and/or publications, and visits to farmers' farms. The extension personnel group indicated that they occasionally use the television and radio for the broadcast of agricultural information. All the participants mentioned the use of face-to-face meetings and mobile phones either through calls and/or text messages for agricultural knowledge exchange. This finding indicates that there is a similarity in the mechanism of agricultural knowledge flow among the various participant groups. Furthermore, the finding revealed that whilst all the extension personnel participants acknowledged the importance and need for face-to-face contact with the farmers, the majority preferred the use of mobile phone in contacting the farmers, especially farmers in the remotest part of their work jurisdiction. This finding is in consonance with Aker and Mbiti (2010) and Baumüller (2015) that increase in mobile phone ownership and internet penetration is creating significant opportunities for reaching remote and under-serviced farmers. The implication of this present finding is that it confirms the effectiveness of the use of mobile phone in agricultural extension and advisory services in Nigeria.

7.6.4 Access to and sourcing of agricultural knowledge via face-to-face and use of ICTs

The interview narrative from the farmers indicates that local community meetings (n=12), friends and family (n=10), public extension agents (n=8), and input suppliers (n=8) were the main sources of agricultural information through face-to-face communication. During the interview, the farmers echoed that although the extension personnel were an important source as the community meetings, the frequency of their visit is limited. These findings corroborate Adomi et al. (2003) and Sturges and Neill (2004). Accordingly, Sturges and Neill (2004) further noted that local community meeting as a source was rich in agricultural knowledge.

In addition, many farmers access agricultural knowledge using other media such as text messages and phone calls, acquisition of bulletins, and to a lesser degree radio and television. Mobile phones and their facilities [internet-assisted data sharing such as WhatsApp, text messages and calls were common channels used for accessing agricultural information and connecting with other relevant informants. Many farmer participants used such facilities for sourcing and sharing agricultural related information, as well as socialising with their peers and contacting extension service. This finding validates Asa and Uwem (2017) and Bolarinwa and Oyeyinka (2011) in their study carried out in Nigeria which reported that majority of the farmers owned and/or had access to mobile phone, and used mobile phone in accessing agricultural information, as well as contacting the extension personnel and sharing information with their counterparts. This present finding suggests that their literacy level and active age influenced their competency in the use of the mobile phone features. Furthermore, the findings corroborate Robert (2014) who reported a high level of farmers' access to mobile phones in Nigeria. More so, Aker and Mbiti (2010) observed that farmers' access to a mobile phone in sub-Saharan Africa dramatically increased over a period. The Pew Research (2017) similarly highlighted that internet facilities are increasing in Africa and the smallholder farmers are benefiting from the development.

This present finding also revealed that all the participants (farmers, extension personnel and university lecturers) accessed and sourced agricultural knowledge using mobile phone facilities. Although there were issues identified such as erratic power supply and internet availability, the participants echoed that they have developed varied strategies of managing the situation. The strategies highlighted include ensuring they have reliable power bank adaptor, access to a backup phone charger and owning more than one phone at a time. This finding is significant because mobile phone facilities can create opportunity for interactive knowledge sharing amongst the participants.

7.6.5 Diversity of access to and sources of formal/explicit and informal/implicit knowledge

It was observed that there are different sources of agricultural information, and that the explicit knowledge increased because of the presence of AVS programme activities in the area. The present findings also revealed that many other formal sources of agricultural knowledge such as input supply companies can now have access to the farmers through the extension agents assigned to their zone. The interview responses indicated that the research institutes generated knowledge such as; genetic modification of crop varieties; soil fertility and weed, pests and disease control techniques with agrochemicals; crop improvement and management practices; and livestock production with hormone therapies as well as fish production techniques. This finding supports that of Abbas (2017) which revealed a high generation of explicit knowledge in the research institutes in Nigeria. Furthermore, the knowledge generated is documented and presented through annual reports and conferences, transferred via extension service and sometimes trialled at the AV farmers' plot. However, during the interview, it was revealed that the AVS programme is confronted with various bottlenecks such as irregular attendance of the extension agents and lack of funds. A farmer participant commented on his experience thus:

> "*I am part of the adopted village scheme project which the government established where the agriculture people [extension personnel and researchers] come to our farmers to show us some of the farming techniques and allow us to manage by ourselves and give them feedback, but many a time they do not maintain follow up, so it ends there*" (Male farmer 5).

Moreover, the findings showed that while the farmers accessed agricultural information from varied sources, they also shared their own local knowledge assets with other farmers, family and friends in their community. The frequently included sharing of farming methods in informal meetings, interpersonal discussions, and storytelling or when they go to each other's farm to observe their activities. They also communicate their ideas using mobile phone facilities. The finding revealed that the farmers gain their indigenous knowledge through heritage and experience over time. The knowledge generated stays with them and is exchanged amongst themselves (within their local communities) and others who cared to learn as implicit knowledge. Some of such sustained farming traditions and/or local knowledge include: the use of charcoal and wood ash for soil fertility enhancement; use of neem leaf solution for disease and pest control; peppermint leaf solution for controlling stillbirth in ruminants; mulching with cassava peels; traditional fencing to control erosion; new yam festivals; crop rotation; mixed-cropping methods; organic composting and animal manuring; and shifting cultivation. The interview narrative revealed that there were several factors that motivated the farmers to share their implicit knowledge within their communities. Table 7.1 shows the various reasons descending from the most to the least articulated. These findings suggest that, though the influence of formal knowledge persists, smallholder farmers still have confidence in their local knowledge.

Table 7.1: Factors that contribute to farmers' decision to sustain and share their local agricultural knowledge

Motivating factors	**Most articulated**	**Least articulated**
Develop adaptive strategies in managing the changing local farming conditions	✓	
Maintain existing local knowledge and reduce local knowledge extinction	✓	
Form management strategies to control insects, pests and diseases infestation	✓	
Conserve local seed and domesticated animal varieties	✓	
Understanding and respect for communal farming values	✓	
Form communal decision-making in solving farming issues		✓
Form stronger network with other farming communities		✓

Source: (Field Survey 2017/18)

In addition, the interview responses from the lecturers revealed that there is still a lack of agroecological-based course(s) in the agricultural universities. The explicit knowledge passed down to the agricultural professionals is based on conventional agricultural practices in line with the knowledge generated by the research institutes. This finding indicates that the course(s) lack the integration of the local knowledge of the farmers as such, farmers' exposure to such knowledge does not impart any agroecological knowledge nor skill. Although an academic programme available between 2007 and 2010 did attempt to bridge the skill gap in agroecological approaches (Organic Agriculture) amongst prospective agricultural professionals particularly in Federal University of Agriculture Abeokuta – FUNAAB, in western Nigeria (Aiyelaagbe et al. 2009; Aiyelaagbe et al. 2010). However, this study observed that there is still a need for more of such programmes across the higher education sector. As such, programmes should incorporate the farmers' indigenous knowledge and collaborate with farmers especially for agroecology as there is no programme currently, so that they share their knowledge with the agricultural degree students.

7.6.6 The potential opportunities for the use of mobile interactive platforms for indigenous/agroecological knowledge exchange

The exchange of their (farmers) existing local knowledge and on-farm practice appeared the mainstay of the agroecological knowledge in the area. Thus, representing one of the aspects of agroecology knowledge innovation system which is characterised by practical learning and co-creation (Anderson et al. 2018). While people shared their knowledge amongst themselves, they tend to develop common interest, empowering them to experiment with varied practices which they thought might enhance their productivity. Such strategies helped them to form strong relationships and learn from each other on how to adapt to their changing environment as well as maintaining their existing local knowledge and practices. The findings corroborate Pimbert (2018) that agroecological knowledge is strengthened by collaborative efforts of local farmer groups at different scales. Indeed, these strategies are significant in progressing the current thinking about agroecological knowledge exchange systems. A quote from a farmer reads:

> "*You know, when there is any outbreak or problem, the first reaction is to ask your neighbours if they have experienced such and how they tackled it. We share ideas and go to observe better farms to know what they are doing, may be same or different*" (Male farmer 11).

Given that the findings of this study revealed that all the participants use mobile facilities for accessing and sourcing knowledge within their field, this identified an opportunity for using this technology for agroecological knowledge exchange amongst the participants. Although the respondents acknowledged the importance of face-to-face meetings such as facilitating on-farm training and trust, mobile phone facilities appeared useful in accessing both the formal and informal sources of agricultural knowledge. The interview responses revealed that the use of a mobile phone is; convenient (n=23) and less time consuming (n=21). A typical response from one of the interviewees reads:

> "*What I think is that it [mobile phone] helps us interact with each other and facilitate quick access to information, unlike the face-to-face one where you have to transport to the destination. I also think it is important we still maintain the face-to-face meeting approaches, so you know who you are dealing with*" (Extension agent 2).

The findings also show that the current formal agricultural knowledge flow in Nigeria appears to omit the important feedback circles and/or interactive loop that regulate and strengthen any knowledge generation and dissemination process. The respondents revealed that a more interactive approach will enhance frequent access to agricultural knowledge and further echoed the need to bring together the key actors in agricultural knowledge production. This finding supports Maurel and Huyghe (2017) findings that the increasing success of digitalising agricultural information enhances convenience, informal learning, easy and timely access to information. Using interactive platforms in this way enhances the exchange of knowledge amongst diverse communities (Maurel and Huyghe 2017). This present finding further indicates that collaborative agricultural knowledge exchange can contribute in creating social cohesion that brings about empowerment amongst knowledge producers and/or users in adapting to the complexity of agroecological knowledge and forming social movements. Anderson et al. (2018) noted that building social movements for transformative agroecological learning in Europe requires constructive dialogue amongst farmers' and other actors such as researchers and educators. This study, therefore, argues that an interactive platform and/or process can enhance agroecological knowledge exchange, while the connection can create opportunities for group learning and motivation as well as connecting them to other regional networks. It is also important to note that such platform can be used for non-agroecological knowledge as in the case of a dominant conventional agricultural systems, hence the proposed framework can also be used for implicit and explicit knowledge (See Figure 7.6). Although there may be a conflict of interests which may cause hegemonic struggle for knowledge ownership, the process can contribute to the integration of diverse knowledge (Šūmane et al. 2018).

Agroecological knowledge formation starts at the farm level and within the powers of the smallholders, and drawing upon this niche to develop agroecological knowledge requires the connective loop of knowledge brokering system and favourable agricultural policies. Hence, this study went on to design an interactive mobile phone-enabled initiative which can enhance agroecological knowledge exchange amongst the relevant stakeholders (see Figure 7.7 below). As illustrated in the diagram, the interactive platform will enhance frequent access/transfer/exchange of agroecological/implicit knowledge and documentation of implicit knowledge to represent explicit (i.e. a documented implicit knowledge) knowledge for overall national agroecological development. The concept support Abbas (2017) who identified the need to integrate indigenous agricultural knowledge in Nigeria's agricultural sector and the importance of establishing national agricultural database to enhance awareness.

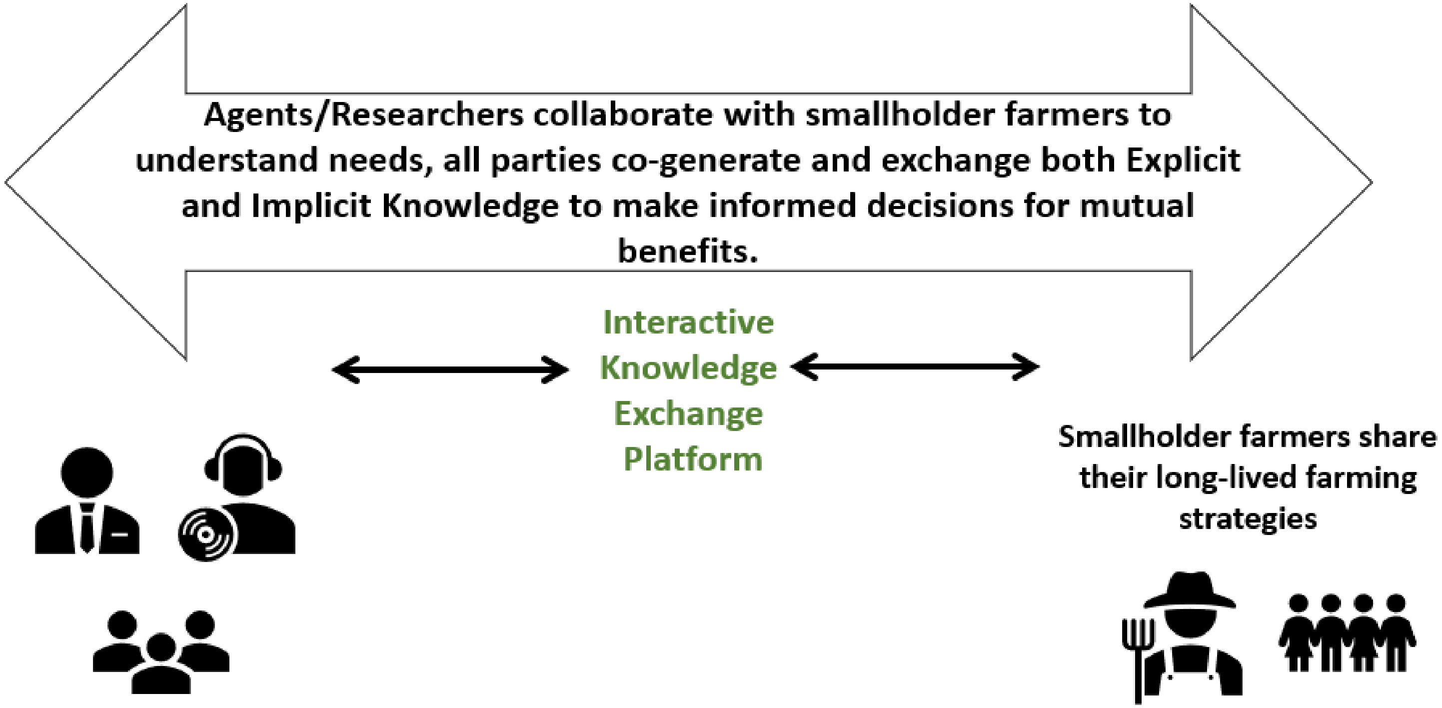

Figure 7.6: The proposed framework for the interactive exchange of both formal and informal agricultural knowledge for all stakeholders (author's insight)

7.7 Conclusion and recommendations

This study clearly demonstrated that formal agricultural knowledge is provided by existing extension organisations for farmers in a top-down approach and that this forms the dominant source of formal agricultural information in the study area. Although this system provided information for the farmers, the farmers still shared their own indigenous/informal knowledge within their informal networks. These informal systems create opportunities for bilateral sharing of agroecological/indigenous knowledge. Obviously, the flow of explicit agricultural knowledge does not include the interactive process and/or contribution from the target beneficiaries of the knowledge/innovation. However, the informal knowledge exchange of indigenous knowledge creates an avenue for farmers to learn from each other, form problem-solving strategies, and contribute to the knowledge generation because of their familiarity in the community. This is also important to impart agroecological knowledge which does not conform to the extension services' policy. Thus, this study concludes that the local knowledge and practices still avail smallholder farmers the ability to manage farming problems irrespective of their total dependence on agrochemicals.

This study also identifies that mobile phone facilities are important in helping to access and source for agricultural knowledge. While the face-to-face meeting approach is important, this study concludes that a common interactive platform through a mobile phone can enhance collaborative knowledge exchange amongst both formal and informal generators of knowledge. Hence, the platform may encourage ideological motivation for other farmers to transition to agroecological practice, whilst availing opportunities for farmers' own contribution to knowledge generation following the AKIS and AIS concepts. Although the integration and use of mobile phone-enabled facilities in agriculture has been contested, with concerns about the social, economic and environmental challenges especially in rural settings this present study revealed that the participants formed resilient strategies to manage some of the identified problems (Aker et al. 2016; Baumüller 2015).

Building upon this understanding, the study recommends the implementation of favourable and sustainable policies that will recognise all stakeholders in agriculture, especially farmers as co-developers of knowledge. Strengthening the role of the smallholder farmers in sustainable agricultural development implies that their knowledge should be valued and encouraged, as well as integrated into the agricultural innovation system. Significantly, investment in informal agricultural knowledge management, research and extension are required in making agroecology successful. Given that agroecological principles are part of smallholder farmers' ecologically-based local knowledge (Altieri 2017), this study, therefore, envisaged that a full incorporation of smallholder farmers' implicit knowledge can take the present AKIS in Nigeria to Agroecological Innovation System as in Figure 7.7 below.

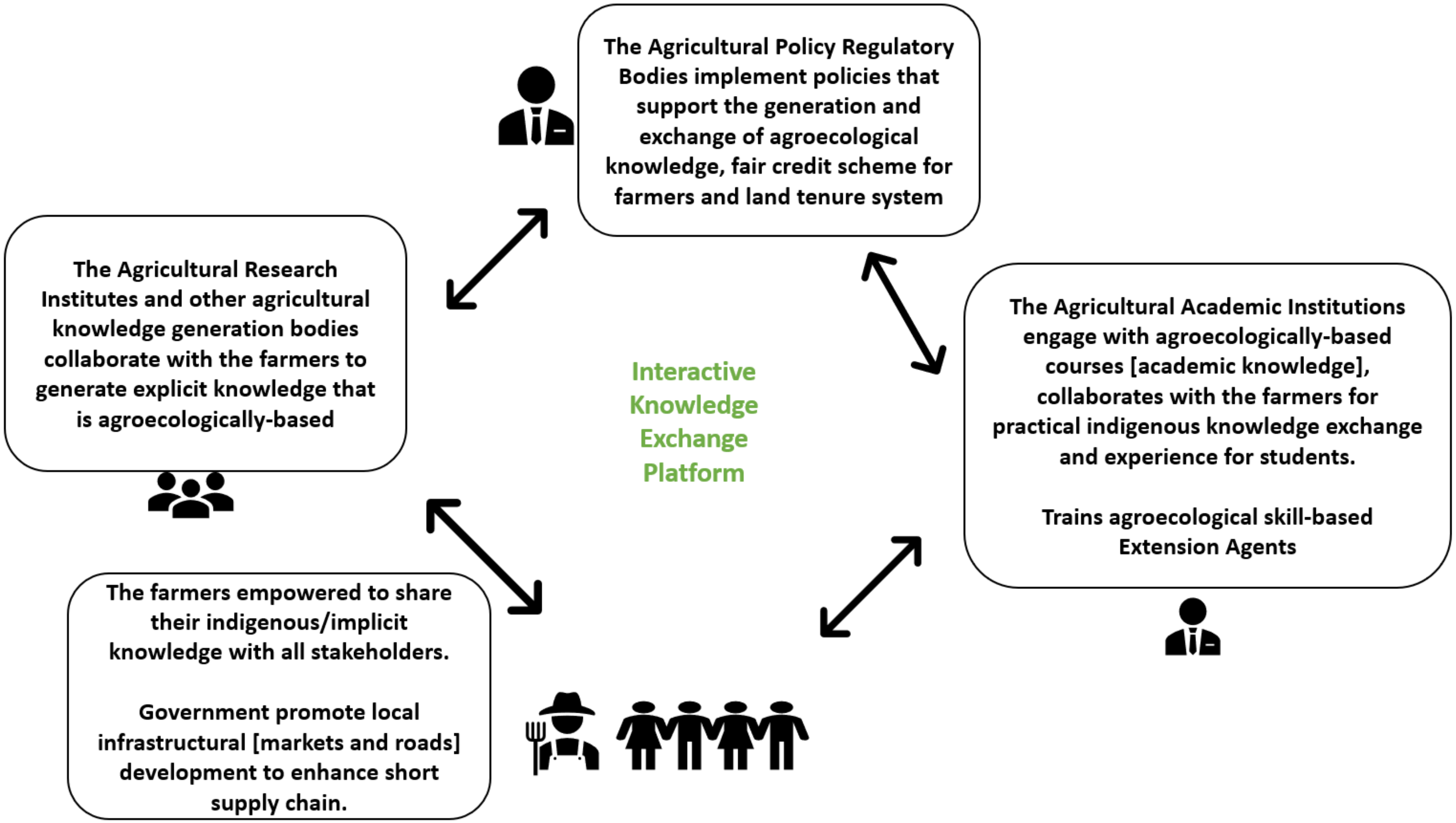

Figure 7.7: The expected outcome of the 'Interactive Knowledge Exchange Platform' an improved agroecological knowledge exchange system in an ideal transformed agri-food system (author's insight).

Chapter summary

This chapter has identified the agricultural information needs of the farmers in the study area and then verified the current sources of their agricultural knowledge. It revealed two distinct channels for knowledge transfer and sources of agricultural knowledge, which incorporated formal and informal methods. The chapter acknowledged that face-to-face methods of agricultural information/knowledge sharing is important for extension personnel to maintain the relationship with their clients (farmers) and vice versa. On the other hand, mobile phones were identified as a particularly useful tool, as they can facilitate access to farmers living in the remotest areas as well as enhance interactive flow of knowledge. Hence, this chapter concluded that the informal exchange of traditional knowledge within the communities could foster the development of agroecological knowledge from the grassroots. This conclusion thus revealed the need to further explore the trend and progress of mobile phone facilities for enhancing agricultural development specifically in Africa and to understand the challenges to their sustainability. Hence, the narrative of the impact and strategies for improving sustainability are all critically captured in the following chapter (Chapter 8).

Chapter 8: Exploring mobile phone-enabled initiatives for agricultural development in Africa: a review of their impacts and challenges to sustainability

This chapter builds upon the major themes that emerged from the existing literature and the empirical evidence about the potential of mobile phones for facilitating farmers' access to and sourcing of agricultural knowledge, as well as facilitating the reach of farmers by the extension personnel and the sharing of information amongst varied stakeholders. Following the in-depth discussion about how a mobile phone-enabled interactive application can enhance the exchange of indigenous/implicit knowledge amongst the relevant stakeholders, a framework was developed (Chapter 7). In this regard, this chapter (Chapter 8) reviews the trends and progress of mobile phone-enabled services/facilities (known as m-Agri services in this chapter) used for agricultural development and how such services have influenced the livelihood of the farmers. Furthermore, the chapter explores the factors that contribute to the successes of the m-Agri services and the challenges to their sustainability, as well as ways of improvement. This chapter intends to highlight strategies that have enabled the success of other existing m-Agri services.

This chapter is a peer-reviewed journal article published in a Special Issue ICT4S – ICT for Sustainability as:

Emeana, E. M., Trenchard, L., and Dehnen-Schmutz, K. (2020). The Revolution of Mobile Phone-Enabled Services for Agricultural Development (m-Agri Services) in Africa: The Challenges for Sustainability. *Sustainability*, 12(2), 485.

This chapter refers to mobile phone-enabled applications for agricultural development as m-Agri services and explores sustainability in ICT4D in line with the scope of the special issue. See the original title and abstract in Appendix 22.

8.1 Introduction

A digital revolution has helped to drive global development with technological progress, price reduction, and the infrastructural deployment has helped to improve access to and connectivity for people globally (ITU 2015; World Bank Group 2016). Although the equal impact is debatable, many studies have argued about the positive impacts and stress that these technological changes could have as well as their potential to enhance livelihoods in the global south (Avgerou 2008; Avgerou et al. 2016; Mansell and Wehn 1998; Walsham 2012). For example, in Africa, whilst some studies have highlighted the importance of these digital technologies (Donner and Escobari 2010; Heeks 2002), others question their impact and sustainability (Easterly and Easterly 2006; Harris 2016; Kleine and Unwin 2009; Qureshi 2015; Walton and Heeks 2011). Additionally, some scholars have also questioned how the development happens as well as whether such development is always good (Heeks 2010; Krauss 2016). Digital technologies popularly known as information and communication technologies (ICTs) are comprised of various technologies that are used to aid information exchange and communication. These technologies include hardware (e.g. computers and mobile phones), and software (e.g. internet facilities and media for information transmission) (Asenso-Okyere and Mekonnen 2012; Kaware and Sain 2015). The use of information and communication technologies for development or ICT4D for short, has continued to evolve (Avgerou 2010; Heeks 2010, 2014; Walsham 2017) with increasing attention on their use for agricultural development (Chavula 2014; FAO 2017; Nakasone et al. 2014; Zyl et al. 2014). ICTs' contribution to development varies according to the various disciplines and their intended aim (Avgerou 2010; Thapa and Sæbø 2014). Though, various reports about the benefits of the use of ICTs for agricultural development in Africa have continued to emerge (Aker and Mbiti 2010; World Bank 2016; Yonazi et al. 2012; Zewge and Dittrich 2017), improving the long-term impact of these technologies also requires an understanding of human-computer interaction (HCI) (Beale et al. 2009). HCI for development (HCI4D) is a sub-discipline of HCI, which focuses specifically on the relationship between humans and computers in the context of development (Anokwa et al. 2009). In essence, while both ICT4D and HCI4D are concerned with information technology and human development, ICT4D is concerned with the process of technology development and impact as well as the design of the technology (Avgerou 2010). Whereas HCI4D focuses on the interaction between humans and information technology and the improvement of this relationship (Anokwa et al. 2009). Beale et al. (2009) referred to this concept as using 'the techniques, approaches and mindset of who, what, when and how' or 'user-centred design' when developing such technologies for development. Hence, this present study sits between ICT4D and HCI4D and is concerned with the sustainability and long-term impacts of future agricultural development projects.

Farmers' increasing access to agricultural information in some parts of Africa has been linked to the evolution and uptake of digital technologies (Annan et al. 2016; Baumüller 2017; Schwab 2016). Because agriculture is location-specific, and farmers need advice on agricultural practices and input use, accurate local weather predictions, real-time prices and market information, harnessing the increasing growth of the internet and associated digital technologies is important. Such technologies, like the mobile phone, are contributing to helping farmers retrieve information they need, overcome constraints faced by the traditional agricultural extension advisory services and promote transformative agricultural development such as collaborative agricultural knowledge exchange and learning (Aker and Mbiti 2010; Donner and Escobari 2010; World Bank 2016).

The digital technology age has resulted in many accessible software applications aimed at farmers and other stakeholders in the agricultural sector (Dehnen-Schmutz et al. 2016). Although many digital innovations aimed for agricultural development and ones that can help improve the lives of rural people are developing rapidly, there is a lack of good evidence to support the impact of such technologies on development. What is needed is holistic, rigorous, and quantitative reports on the ways in which these initiatives aid development and sustainability (World Bank 2016). According to Yonazi et al. (2012), the strategic application of ICTs to Africa's agricultural sector offers the best opportunity for socio-economic growth of smallholder farmers. Although numerous ICT-based initiatives have been implemented in different parts of Africa for the uptake and improvement of agricultural practices, this present study is focused on the mobile phone-enabled application initiative(s) for agriculture known as m-Agri services. In the context of this study, 'm-Agri service' is used to characterise any mobile phone-enabled application targeted to the needs of the agricultural sector and its stakeholders. These m-Agri services include electronic information and/or functions that are accessed through mobile phones (be they feature or smartphones) (GSMA 2016). These services might include banking facilities, social networking platforms, or information such as market prices. Services can be delivered in a variety of formats including graphics, videos, images, audio recordings and/or texts. Smartphones specifically provide functionalities that enable users to access mobile and web applications, which can facilitate active engagement (GSMA 2017).

The increasing penetration of mobile networks as well as availability of mobile phones and their facilities have created significant improvements in the ability to reach remote, dispersed and under-served farmers irrespective of their environment and social status by facilitating access to extension services, agricultural information and financial services (Aker and Mbiti 2010; Baumüller 2015, 2017; Heeks 2008; Kleine and Unwin 2009; World Bank 2016). A wide range of agricultural information can be provided includiing data on inputs, best agricultural practices, transport and market prices (World Bank 2011). Baumüller (2015) identified two key areas that are impacted upon by m-Agri services. These are information and learning (e.g., through stakeholder networking platforms) and mobile payments (e.g., virtual markets and supply chain management). Various m-Agri services have been developed in the African region with the support of international donor agencies such as the World Bank, FAO etc. These have targeted areas that are characterised by weak infrastructure, limited access to market information and poor transportation systems (Danes et al. 2014). While the developers of these m-Agri services and their funders have often believed that these services hold great promise for enhancing target users' livelihoods by helping them to improve yields and provide fair market pricing opportunities, often their financial and infrastructural stability are questionable and only a very few are able to stand the test of time (Baumüller 2018; Danes et al. 2014; Qiang et al. 2012).

The reasons and remedies for this gap are still yet unclear, with the factual evidence of their (m-Agri services) sustainability and long-term usage by the target users still rare. Although many m-Agri apps are created, many are short-lived, and a few become financially self-sustaining or widespread (Danes et al. 2014). Some studies have focused on the impact, effectiveness, farmers' attitude, empowerment and challenges farmers face in using m-Agri services (Balraj and Pavalam 2012; Fadairo et al. 2015; McCole et al. 2014; Misaki et al. 2018; Nwaobiala and Ubor 2016). Others focus on the technical or funders' perspective (Baumüller 2018; Danes et al. 2014; FAO 2015). Baumüller (2018) reported that the developers' failure to understand the context in which the farmers use these m-Agri services results in underutilisation of such services. Danes et al. (2014) acknowledged that the number of successful m-Agri services is limited in Africa. In their report, the authors argued that a successful m-Agri app is one that empowers smallholder farmers to increase their agricultural performance, is user friendly, beneficial and interests the users as well as reaches a certain scale in subscription and viability (Danes et al. 2014). Thus, their definition supports the long-term impact of a given m-Agri service. Meeting such criteria requires that concrete information is needed about the lessons learned, to inform the design and techniques of future efforts (FAO 2015). Furthermore, Danes et al. (2014) recounted the willingness amongst agricultural stakeholders and application developers to collaborate more and exchange ideas on best practice. Danes et al. (2014) also propose that developers should consider projects with open software, set up learning communities, develop indigenous scaled agricultural content, make existing data available and connect the poorest to mobile networks. However, addressing the sustainability challenges requires a holistic understanding of the social, economic and environmental impact and/or sustainability of the m-Agri services with a focus on the wider problems of designing, developing and deploying the service(s) to the disadvantaged (i.e., the rural or underserved) areas (Winters and Toyama 2009). Considering this approach, more attention needs to be given to the target users' context and aspirations (e.g., their needs, social and physical constraints, etc. (Brynjarsdottir et al. 2012; Steyn and Van Greunen 2014; Winters and Toyama 2009). Efforts to design, produce and evaluate appropriate m-Agri services for developing countries are naturally multidisciplinary, therefore, the research identified in this present study is obtained from a wide range of disciplines including sustainable agriculture, international development and ICT for development (ICT4D) (Best and Bar 2009; Burrell and Toyama 2009; Danes et al. 2014; Dearden and Rizvi 2008; Heeks 1999, 2008; Kolko and Rose 2007; Shneiderman 2002; Winters and Toyama 2009).

While other authors have also raised concerns about the environmental sustainability (e.g., the energy demand, material resource use, and emissions) of such initiatives (Blevis 2007; Lundström and Pargman 2017], this present review explores the challenges that can impede the long-term sustainability of m-Agri services, in terms of their longevity, financial stability, and relevance, which are key issues to be addressed when scaling up from the pilot stage of pilot projects (Baumüller 2018). Additionally, the review identifies opportunities for policymakers to enhance the sustainable development of m-Agri initiatives in Africa. By so doing, this review answers the following research questions:

- What are the current trends and progress in the use of m-Agri services for enhancing agriculture and smallholder farmers' livelihoods in Africa?

- How can all relevant stakeholders involved in design, development, deployment and use, approach the challenges of m-Agri service(s) for sustainability?
- Are there specific functionalities for the m-Agri services that can enhance sustainability?
- What should the role of the policymakers be in promoting m-Agri sustainability?

Having outlined the specific aim and objectives of this review study, the remaining sections describe the conceptual background to the study including the concept of sustainability, the methodology adopted to identify relevant materials for the review, a summary of the key findings of the literature surveyed and conclusions which includes recommendations for future designs.

8.2 Conceptualising sustainability in this review

Sustainability is a widely used but contested term that has gained notable attention in recent times especially in social and technological science sectors such as policy-oriented research, human computer interaction, ICT for development, and business development (Blevis 2007; IFAD 2009; Roedl et al. 2017; Thomson et al. 2011; Winters and Toyama 2009). The use of the word 'sustainability' as a broader concept implies '*meeting the needs and aspirations of the present generation without undermining the ability of nature to regenerate for future generations' needs*' (Brundtland et al. 1987). In this context, sustainability refers to the environmental, social, cultural, technological, political, institutional and economic consequences linked with the way development-based projects are designed and implemented (Blevis 2007; Hazas and Nathan 2017; Roedl et al. 2017; Winters and Toyama 2009). Hence, looking at sustainability from the m-Agri services' developer, funder and target users' perspectives implies that they (as the actors) must ensure to enhance the socioeconomic and environmental sustainability of the given project. Additionally, the continuation of the benefits of m-Agri services after the implementation or launching need to be ensured. Accordingly, funders should be concerned about the underlying cost (social, economic, and environmental) of any intended m-Agri service and fund the services that have a well-defined sustainability plan in place. This means that integrating sustainability principles in any ongoing m-Agri project can be an efficient way of ensuring long-term impact. However, from the implementers or developers' point of view, this means that they will need to continue to perform and deliver services to the target users (farmers and other agricultural stakeholders) even after assessing the impact of the project. In other words, from the perspective of this review, sustainability requires all stakeholders involved to continuously maintain ownership and hosting of the m-Agri services especially services that have a significant positive impact on smallholder farmers' livelihood even after the funding and other forms of intervention have ended.

Initially, this review was conceived as an overview of the literature associated with the development and use of m-Agri services for sustainable agriculture such as agroecology and developing/African countries such as Nigeria. Additionally, the review was concerned with the challenges to sustainability of m-Agri services in terms of their continued functioning, their longevity, and usefulness. The interaction between humans and interactive technologies in the developing world is also a discipline in its own right, known as human-computer interaction for development (HCI4D). The literature associated with HCI4D and ICT4D (information and communication technology for development) in many respects comes to the same conclusions regarding the need for better technically and culturally appropriate designs as the literature on m-Agri apps for sustainable agriculture (Ho et al. 2009). However, it also raises further questions about what is meant by sustainability and how the impacts of interactive technologies on sustainable development should be evaluated (Remy et al. 2018; World Bank 2011).

In this context, sustainability can be understood in two different ways (Brynjarsdottir et al. 2012; Remy et al. 2018). First, is the m-Agri service in itself sustainable? This is described by Remy et al. (2018) as 'sustainability in design' (SiD). For the m-Agri apps identified in the review the discussion of m-Agri app's sustainability was often framed in terms of its longevity, financial stability, and options for scaling up (Baumüller 2018). Software such as m-Agri services can be described as 'weightless.' This means they do not themselves have a direct impact on the environment, but they can be designed to be efficient for users, i.e., to work offline in regions with poor mobile coverage and power networks (Ho et al. 2009). The second way in which sustainability should be considered is the effect or impact that an m-Agri service can have on sustainability (Blevis 2007; Remy et al. 2018). Does it encourage more sustainable behaviours? Is there any impact on the sustainability of real-world practices in the agricultural system targeted (Brynjarsdottir et al. 2012; Remy et al. 2018)? This is described as 'sustainability through design' (StD) by Remy et al. (2018).

Although sustainability should be evaluated in a holistic manner incorporating environmental, economic, and societal impacts, this is not often the case (Bengtsson and Ågerfalk 2011). Incorporating these three pillars into an evaluation is time-consuming, and, more often than not, evaluations focus on one pillar only, and most frequently on environmental sustainability (Roedl et al. 2017). Although several authors including Toyama (2015) and Remy et al. (2018) have produced frameworks for evaluating the sustainability of ICT interventions, there is still considerable debate on the approach to evaluation in a human-computer interaction for development (HCI4D) (Brynjarsdottir et al. 2012; Remy et al. 2018; Roedl et al. 2017). One of the key issues with evaluating sustainability of ICT in the developing world is the question of who decides which criteria should be used for evaluation and which values are important. Ideas and interpretations of sustainability depend on culture and context (Thomas et al. 2017). This may be why evaluation of impact on sustainability is often missing in HCI4D/ICT4D research (Remy et al. 2018). In their review, Brynjarsdottir et al. (2012) found that almost half of the HCI studies included no evaluation whatsoever.

8.3 Methodology

This analysis adopts a scoping review methodology as described by Arksey and O'Malley (2005) and focuses on published literature that relates to mobile phone-enabled applications for agricultural development and smallholder farmers' livelihood improvement in Africa. The scoping review method is less restrictive than a systematic review and allows the redefinition of the literature search criteria as the researcher becomes familiar with the existing literature on the subject area (Arksey and O'Malley 2005). During the review process, searches were made through the Web of Science, Scopus, AgEcon, JSTOR, Science Direct, ASSIA, Google and Google Scholar to identify relevant publications. The key search terms were based on mobile phone services that used for agricultural development in Africa. Terms such as 'ICTs', 'agriculture development', 'ICT4D', 'HCI4D', 'mobile application* apps for agriculture' etc. were inputted in the databases. The searches also included Boolean search strings combined with other search terms as listed below.

- 'mobile phone application' AND 'agriculture development' OR 'digital innovation';
- 'smartphone application' AND 'sustainability' OR 'agriculture';
- 'mobile' OR 'smartphone' AND 'farmers' OR 'smallholder farmers' livelihood';
- 'agriculture information' AND 'farmers' livelihood development';
- 'smart farming' AND 'smallholder farmers' OR 'm-Agri';
- 'mobile application' AND 'm-Agri finance' AND 'services';
- 'mobile application' AND 'm-Agri' AND 'challenges'.

- ‘ICT for sustainability’ OR ‘ICT4S’ AND ‘ICT for development’ OR ‘ICT4D’;
- ‘Human Computer Interaction’ OR ‘HCI’ AND ‘sustainability’;
- ‘HCI4D’ OR ‘HCI for development’ AND ‘sustainable design’.

After skimming through the published titles and their abstracts, only relevant articles published in English within an African context were selected for further review. Articles that excluded human interaction and focused on non-human involvement such as management of equipment, connecting to the internet of things were not included for detailed review. Articles included were published after the year 2000 with the criteria that, that was when mobile and internet facilities began to expand significantly in Africa. Furthermore, articles that specifically cover m-Agri services that disseminate agricultural information, provide financial services as well as facilitate access to input and output market for agricultural stakeholders in Africa were included. In addition, a snowball strategy based on a thorough review of each article’s references was used to identify other relevant peer-reviewed literature. However, because of the limited number of relevant peer-reviewed literature, none covered the sustainability aspect of the m-Agri services. Grey literature was also included as long as they presented m-Agri services that have impacted on farmers’ livelihoods, provided they were within the year of publication range and geographic coverage. Publications that detailed ICT4D and HCI4D reports in the context of agricultural development were selected for further review. While the review focus is specifically on m-Agri services, references were made to some of the general concept of design theories (e.g., see Bidwell 2009; Bidwell et al. 2014; Biljon and Renaud 2016; Chaudry et al. 2012; Heeks 1999, 2002a, 2002b, 2009; Jones and Marsden 2006; Kleine et al. 2012; Tucker and Blake 2010).

In reporting these review findings, the information retrieved from the literature was grouped into themes that correspond to answering the research questions. After the inclusion and exclusion exercise, a total of 64 relevant artefacts were identified. They include 26 journal articles, 29 reports (grey literature), and 9 webpages as listed in Table 8.1. To complement this literature search, a search for m-Agri services currently available in Africa was also carried out using the main iOS and Android app stores. This first aimed to authenticate the m-Agri services reviewed in the literature search and also retrieved other English language applications targeted for farmers and agriculture. The m-Agri services identified are shown in Table 8.2. Each application’s platform was searched to identify the specific location of such an application and the user reviews were checked to determine whether or not the application was still functioning. Those m-Agri services that appeared to be functional were compiled in Table 8.2 with a summary of their purpose and their location indicated. Although the two most popular app stores were investigated, this list may not be exhaustive as there may be other applications available which were not present in the databases accessed. Examples of m-Agri services from Table 8.2 discussed in the text are shown in italics.

Table 8.1. List of materials accessed

Materials used	Number of materials	References
Peer-reviewed journal articles	26	Aker 2011; Aker et al. 2016; Asenso-Okyere and Mekonnen 2012; Baumüller 2013, 2015, 2017; Bedi 1999; Brugger 2011; Courtois and Subervie 2014; David-West 2010; Davis and Sulaiman 2014; Demenongu et al. 2018; Emeana et al. 2019; Ezezika et al. 2012; Godson-Ibeji et al. 2016; Henze and Ulrichs 2016; Ifeoma and Mthtwa 2015; Joshi 2009; Kikulwe et al. 2014; Lamptey et al. 2016; Lawal-Adebowale and Akeredolu-Ale 2010; Milovanović 2014; Morris et al. 2005; Nneji et al. 2015; Rashid and Elder 2009; Sekabira and Qaim 2017
Reports/Grey literature	29	African Union Convention on Cyber Security and Personal Data Protection 2014; Betterplace Lab 2017; Bothwell et al. 2014; Châte 2018; Chetty and Grinter 2007; GIZ 2018; Grevendonk et al. 2013; GSMA 2013; 2015; 2016a; 2016b; 2017; 2018; IICD 2012; Kedja 2016; Laureys 2016; Mercy Corps 2013; Odhiambo and Tabitha 2016; Omolayo 2015; Rioba 2018; Tricarico and Loukos 2017; United Nations Global Pulse 2015; USAID 2018; van Schalkwyk et al. 2017; Wacksman and Sultan 2016; Waldron and Amusin 2017; Woodard et al. 2014; World Bank 2011, 2016
Webpages	9	AgroHub 2018; Code Innovation 2015; Dimagi 2019; European Union General Data Protection Regulation 2018; Gro Intelligence 2018; Hello Tractor 2018; MERL Tech 2017; Senekela 2018; WeFarm 2018

Scoping survey 2018/19

8.4 Results and Discussion

This review explored the progress of m-Agri services in contributing to the improvement of livelihood of smallholder farmers and the challenges to their sustainability in Africa. In this section, the findings that answered the fundamental questions that emerged from the study's aim and objectives are outlined into four overarching themes and discussed accordingly.

8.4.1 An overview of current trends in m-Agri services

The increasing expansion and use of m-Agri services have created a trend in the agricultural digital ecosystem, which consists of software platforms, thousands of developers and millions of users. Some of such m-Agri services are available and distributed through platforms such as the app stores for mobile and web apps and databases for short message and other related services. Table 8.2 below highlights existing functional m-Agri services in the African region. The list was correct at the time of writing, even though it is acknowledged that in the time taken for publication, some of the available applications may no longer be fully functioning.

Table 8.2: Survey of currently functioning mobile phone-based m-Agri services available in Africa in 2018

Mobile Apps	**Inventor/ Founders**	**Country/ Location of Use**	**Description**
iCow	Kenyan farmer, Su Kahumbu	Kenya	SMS and voice-only mobile app. Farmers are sent information on the best dairy practices. Allows farmers to register their cows, and to receive individualised text messages on their mobile phones, including advice for veterinary care and feeding schedules, sends prompts to farmers to collect and store milk within the days of a cow's cycle, a database of experts, and updated market rates on cattle prices (Baumüller 2013; Omolayo 2015).
Vet Africa	A Scotland based tech company – Cojengo, founded by Craig Taylor and Iain Collins in partnership with Microsoft	Kenya, Ethiopia, Uganda and Tanzania	An image-based user interface app provides diagnostic tools and disease surveillance data for livestock disease and recommends appropriate medications for farm animals. Helps farmers monitor and record animal data (Omolayo 2015).
M-Farm	Kenyans: Linda Kwamboka, Susan Oguya and Jamila Abass are co-founders	Kenya and Ghana	Delivers price transparency and access to markets. Provides updates to farmers on current prices of goods across the country and a networking platform for farmers to sell their produce wholesale. Connects local farmers directly to suppliers and provides the best access for farm inputs (Omolayo 2015).
Esoko	A team of local and international professional in Ghana	Nine African countries	Connects projects, Non-Governmental Organizations (NGO), businesses and government to farmers. Formerly known as TradeNet provides agricultural content,

			marketing, advisory and monitoring services for farmers and potential investors (David-West 2010; Ifeoma and Mthitwa 2015).
Agro-Hub	Agro-Hub was developed by a Cameroonian business venture	Cameron	Agro-Hub employs social network, SMS and the internet to source, manage and disseminate information on all areas of agriculture (AgroHub 2018; Lamptey et al. 2016).
Agri-wallet	Dodore Kenya Ltd founded by Ad Rietberg and Sijmen de Hoogh	Kenya	Agri-wallet is a mobile purse that smallholder farmers use to manage their business finances and can borrow money to spend on agricultural inputs such as fertilizer and seeds (Omolayo 2015).
Cocoa Link	Developed by Farmerline which promotes entrepreneurship in partnership with Hershey and World Cocoa Foundation	Ghana	Delivers farming practice information from agricultural experts to farmers in English and local languages at no cost (Asenso-Okyere and Mekonnen 2012).
Kilimo Salama	Syngenta Foundation for Sustainable Agriculture and Kenyan telecom operator, Safaricom	Kenya	Provides up-to-date and full climate and weather information to farmers and sustainable agricultural practices to increase productivity, ensure food security and protect their crops during bad weather (Brugger 2011).
Kuza Doctor	Backpack farmers in Kenya	Kenya	Provides access to information on crop growth, soil and answer to general farming questions to help farmers grow better crops by employing environment-friendly (Omolayo 2015).

Modisar	Agric Software Development Start-up Company located in Gaborone, Botswana	Botswana	Enable farmers to keep and access their farm records, cattle herds, farm costs and sales. Provides advice to farmers on animal vaccinations, feed and nutrition and finance (Omolayo 2015).
Hello tractor	A team of business entrepreneurs	Nigeria	Provides access to low-cost tractors that farmers can buy or rent using their mobile phones (HelloTractor 2018).
Haller app	Haller foundation	Kenya	Provide farming instructions to the farmers on how to manage soil fertility and maintain beehives (Henze and Ulrichs 2016).
M-Shamba	M-shamba social enterprise	Kenya	Provide information about crop and poultry management practices for the small-scale farmers and allows farmers to track farm activities such as their revenues and expenses (Henze and Ulrichs 2016).
WeFarm	Originally created by Kenny Ewan, Claire Rhodes and Jim Rhodes, and was developed as a pilot project from within the Cafedirect Producers' Foundation (now called Producers Direct)	Kenya, Tanzania and Uganda	Provides free crop and livestock management practices. Especially advice on how to manage diseases and new practices (Henze and Ulrichs 2016; WeFarm 2018).
M-Samaki		Kenya	Provides advice on fish farming about how to manage pond health and feed as well as harvest and marketing (Henze and Ulrichs 2016).

Senekela	Established by Orange-Mali	Mali	Provides advice on available agricultural products and market prices which allow farmers to market their produce in better conditions and improve their productivity (Senekela 2018).
e-Wallet	Established by the Federal Ministry of Agriculture and Rural Development	Nigeria	Provides information about where and how to buy fertilizer and the exact amount sold, which allows farmers to compare prices (Demenongu et al. 2018).
Tigo Kilimo	Provided my mobile network operator Tigo	Tanzania	An agricultural value-added service that provides information for 10 crops through unstructured supplementary service data (USSD), SMS, voice, and helpline for the farmers.
EZ-Farm	IBM Research—Africa Dr Kala Fleming	Kenya	Provides farmers with information on facilities for remote farming water management.
AgroTech	A programme run by Grameen Foundation and its partners Digital Green	Ghana	Enables the government and private company field personnel to understand and analyse farmers' needs and crop history quickly and timely, to deliver agricultural advice, and to procure loans to purchase farm supplies such as fertilisers and seeds.
Lima Links	SANGONet, a South African NGO, and International Development Enterprises (iDE), with $200,000 in initial funding from the Gates Foundation.	Zambia	Provides a sort of 'live' market price information on horticulture and connections to markets for smallholder farmers.
AGMIS (Infotrade)	Infotrade	Uganda	Aggregates market price information from 35 major districts in Uganda for 48 agricultural products, trends, and price movements. Price data is collected three times a week, analysed, and disseminated to the farmers.
Crowdyvest (Farmcrowdy)	Team of individuals with experience and expertise in information technology management, e-commerce and financial management supported by Syngenta and ASTC	Nigeria	Supports small farm sponsorship, provides improved seeds, farm inputs, training on modern farming techniques, and also provide a market for the sale of farm produce for farmers.

	(Agricultural Training Centre), Vom and Plateau State Notore Seeds		
Crop Monitoring Service (CROPMON)	Developed by Geodata for Agriculture and Water Facility, Netherlands with four Dutch and five Kenyan partners	Kenya	CROPMON develops and makes available information that help farmers to make improved farm management decisions during the growing season. The information given is based on real-time satellite imagery informing them of the growth and growth status of their crops.
FarmDrive	Rita Kimani and Peris Bosire	Kenya	Connects smallholder farmers to loans and financial management tools through their mobile phones. Closes the critical data gap that prevents financial institutions from lending to creditworthy smallholder farmers.
MyAgro (One Acre Fund)	Anushka Ratnayake, One Acre Fund	Mali, Senegal	Helps the farmers save money gradually in smaller amounts to cover the cost of their basic farm needs such as buying seeds, fertiliser, and training.
Fertiliser Optimiser Tool (FOT)	CABI's OFRA programme, funded by the Alliance for a Green Revolution in Africa (AGRA)	13 countries in Africa	Provides free access to advice on fertiliser use for farmers and extension workers. The app runs in an offline mode allowing users to perform optimisation calculations in the field and utilises data on crops grown, area planted, fertiliser cost, management, and expected crop sales, etc. to calculate the most profitable combinations of fertilisers to use.
NARO beans, Common Cassava Diseases & Control, NARO Maize Production	National Agricultural Research Organisation (NARO)	Uganda	Provides information on: (1) bean cultivation, (2) common cassava diseases and control, and (3) maize production for the farmers.
Pannar Sprout	Developed by Pannar Seed, a South African seed group founded in 1958, which is one of the largest field crop seed producers and suppliers in Africa	South Africa and some other African nations	Provides technical advice for grain farmers. A new function has been added, which is known as PlantDr for help with crop diseases.
Khula	South African digital company in Randburg	South Africa	Provides mentorship for farmers and connects them to customers, better access to logistics, and source for low cost farm inputs through a group purchase.

Agripredict	Developed by three individuals (Patrick Sikalinda, Cassandra Mtine, and Mwiza Simbeye)	Zambia	Provides information that help farmers to identify crop diseases, predict pest infestations, and weather conditions.
uLima	uLima Limited	Kenya	Provides access to crop and livestock management information, weather and market price information, and customised crop and livestock calendars for farmers.
AgTag	Magazine app	South Africa	Provides written articles, videos, and audio on crops, livestock, equipment, water, and soil management as well as agro-processing.
Nuru (Plant Village)	Developed by Penn State University researchers in collaboration with UN FAO and Consultative Group of International Agricultural Research (CGIAR). Nuru is incorporated into the Plant Village app.	Many African countries	Helps farmers to diagnose crop diseases of crops like cassava, maize, wheat, and potatoes in the field without an Internet connection. The app interfaces with the FAMEWS app to upload data collected from the field. For example, the app help farmers to validate data on fall armyworm to the national fall armyworm focal points and database.
RiceAdvice	Developed by AfricaRice and CGIAR under the name RiceAdvice.	22 African countries	Provides farmers with field-specific crop management guidelines for rice production
Agrix Tech	No details	Cameroon	Detects crop diseases at a primary stage and proposes treatment with the use of artificial intelligence.
Labaroun Kassoua	Labaroun Kassoua in Niger is one of the mAgri services supported by Orange in Africa	Niger	Offers information and advice on agricultural techniques, weather, and access to markets and financial services for farmers.
mAgri, Côte d'Ivoire	mAgri in Côte d'Ivoire is one of the mAgri services supported by Orange in Africa	Côte d'Ivoire	Provides information and advice on weather, agricultural approaches, access to markets, and financial services.
Naafa Buudu	Supported by Orange in Africa	Burkina Faso	Offers farmers advice on weather, market prices, financial services, and agricultural techniques.
Cow Tribe	Cow tribe technology company based in Ghana	Ghana	Provides subscription based and on-demand animal vaccines and other services to last mile farmers.

Connected Farmer	Produced by the Connected Farmer Alliance, a public-private partnership between U.S. Agency for International Development (USAID) and Vodafone	Kenya, Tanzania, and Mozambique	Targets to address the value chain management inefficiencies and increase productivity of both the agribusinesses and the smallholder farmers who supply them.

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Globally, m-Agri services' contribution has been to enhance the efficiency of the agricultural value chain, as information delivered through m-Agri services can help farmers' access to new technology or inputs and assess its suitability, as well as facilitate farmer-to-farmer/buyer relationships, help manage financial and production risk and identify where best to sell their produce (Baumüller 2015; World Bank 2011). Similarly, the m-Agri services identified in this review had a positive contribution to improved smallholder farmers' livelihood by facilitating their access to financial services, which enables them to access and source for agricultural information as well as input and marketing services (Bedi 1999; GSMA 2015; Mercy Corps 2013; Milovanović 2014). Thus, the following sub-sections highlight the trends and progress made in these categories. The key trends include m-Agri financial services, information and sharing; and input and marketing services. These are discussed in more detail below.

M-Agri financial services

According to Mercy Corps (2013), the transitioning to and use of m-Agri financial services by smallholder farmers has increased safe and convenient transactions in many African countries. These kinds of services open up opportunities for many smallholder farmers who are excluded from mainstream financial services such as banking and insurance. Furthermore, the availability of loans and repayment via such platforms increases farmers' ability to manage their finances and investment in agriculture, as well as improve their relationship with bankers and other relevant agricultural stakeholders (Baumüller 2017; Nneji et al. 2015; Tricarico and Loukos 2017). For instance, farmers in Western Kenya with the help of One Acre Fund can access *Agri-Wallet*, which is an m-Agri financial service that allows them to borrow money to spend on their agricultural inputs and pay back their loans digitally. Thus, saving travelling costs to extension offices and banks, as well as improving time management and reduced cash-carrying (Waldron and Amusin 2017). Significantly, digitising agricultural payments via mobile phones has the potential to improve security, efficiency and transparency. Particularly, there are increasing number of initiatives, which aim to enhance the m-Agri financial services' value chain, especially in sub-Saharan Africa with major attention in Kenya, Rwanda, Tanzania and Uganda, and other dynamic markets such as Ghana and Ivory Coast (GSMA 2017). Other examples of m-Agri apps include *Labaroun Kassoua* in Niger and *FarmDrive* in Kenya. Accordingly, Mercy Corps (2013) reported that over 46% of farming households use an m-Agri financial service product in Uganda and attested that this had resulted in an increase in household incomes. This service can support the creation of economic identities for the farmers through the transactional reports and records from their produce sales as well as for geolocations and farm size, creating full financial inclusion to their access to credit, savings accounts and insurance facilities (Tricarico and Loukos 2017).

M-Agri information and knowledge sharing services

According to Bedi (1999), m-Agri services play a significant role in enhancing farmer access to information because of their ability to support the retrieval of information from its repository at the farmers' convenience. Specifically, information and knowledge sharing can support better agricultural practices and skills development among farmers, which results in increased productivity as well as enabling easier access to product certification requirements (Emeana et al. 2019; Tricarico and Loukos 2017). Baumüller (2017) pointed out that advice on farming practices is the most easily provided agricultural information for farmers through mobile phone services. In addition to this, information on the weather forecast, monitoring and crop diseases and monitoring can then better equip them in understanding and managing risks. Thus, this helps the farmers save and improve their productivity. For instance, the *Senekela Orange* initiative is a service established in Mali that provides farmers' access to updated agricultural advice such as stock availability, product market prices and weather predictions. Crowdsourcing information through mobile phone application, such as that provided by *Nuru*, a digital early warning network is helping farmers to prevent the outbreak of cassava diseases in Tanzania (Laureys 2016). In a Technical Centre for Agricultural and Rural Cooperation (CTA) report, a similar service allows farmers to access real-time, location and specific information regarding their farming queries and providing advice regarding crop and livestock management during the critical stages of development which also aids learning (Rioba 2018). Training is the cornerstone of future agriculture and capacity building for farmers, with training information content and research contributing to a rise in agricultural innovations. Potentially, innovations can be disseminated and promoted among farmers more rapidly through m-Agri information and knowledge sharing platforms (Baumüller 2017; Châte 2018). In an evaluation of the m-Agri service, *Tigo Kilimo* in Tanzania, carried out by GSMA (2015), the attitudes and behaviour of users were compared to non-users. The results showed that *Tigo Kilimo* users were more willing to change their farming practices by shifting from one cropping system to adopting diversification approaches in growing more varieties of crops.

M-Agri input and marketing services

Increasing globalisation and market deregulation in developing countries often results in pressure on many smallholder farmers to lower their prices. For these farmers, greater awareness about the politics of agricultural products' pricing, marketing and trade allows them to better deal with these pressures. M-Agri services can provide them with timely access to information and better access to input and output services (Milovanović 2014). Basically, farmers tend to be more receptive when information that is tailored to specific contexts to support their needs with the view of reducing cost, as well as increasing efficiency and productivity (Davis and Sulaiman 2014; Milovanović 2014). M-Agri services can facilitate the dissemination of information about input suppliers and input prices as well as provide platforms for input trading and bargaining, which can help farmers evaluate the profitability and obtain higher prices for produce (Baumüller 2017; Courtois and Subervie 2014). Furthermore, access to market pricing information is helping farmers improve their harvest planning. For instance, the app *m-farm* helps farmers in Kenya to make informed decisions about the best harvest, selling times and pricing (Baumüller 2015). Besides allowing farmers to obtain market price information, the *m-farm* app also enables suppliers to publicise product information on special offers to the farmers (World Bank 2016).

Some studies in the African region affirmed that m-Agri interventions led to greater savings, increase in produce sales, increase in household income, farmers' confidence and trust, financial security, farm management, increased access to inputs, increased bargaining power and social cohesion for smallholder farmers (Baumüller 2015, 2017; Courtois and Subervie 2014; Kikulwe et al. 2014; Sekabira and Qaim 2017). However, the type of solutions, range and complexity vary, as some providers offer complete platforms with multiple functionalities and others target single or specific issues with the aim of improving smallholders' livelihoods. The maintenance of these acclaimed positive impacts requires a consistent and unified approach by the project initiators, service developers, funders (public and private investors), implementers, researchers, internet providers, non-government agencies, policymakers and the farmers. Hence, it is imperative to understand the challenges that affect such initiatives as well as to comprehend the strategies that can improve their sustainability.

8.4.2 The challenges for m-Agri services in Africa

This review further revealed that, despite the positive impacts and opportunities for m-Agri service initiatives towards the enhancement of smallholder farmers' livelihoods in Africa, the reality is that not all of these are sustainable in the long term. According to Laureys (2016), lessons show that exaggerated expectations placed on such services can lead to frustration and abandonment. If they are not well designed, clearly integrated into, and adapted to their prospective users' life processes they will not survive. Laureys's findings corroborate other authors in the field of HCI4D who have argued that, the design of a usable mobile phone interface in Africa is an important task, especially when it is intended for use by people with specific needs. When designing such services, various additional challenges beyond the technical aspect, need to be considered (Bidwell et al. 2014; Biljon and Renaud 2016; Chaudry et al. 2012; Jones and Marsden 2006). In an empirical study, Bidwell et al. (2014) argued that applications designed to widen access to information must respond to the complex interaction between social structures and types of communication. Furthermore, complementary investments in electricity and literacy programmes can affect the scaling up of initiatives for smallholder farming. For example, the adoption and use of the *e-Wallet* service that enables farmers to make more informed farm management decisions (where and how to buy fertiliser and seeds) in Nigeria were constrained by a poor electricity supply resulting in many farmers abandoning its use (Demenongu et al. 2018; Godson-Ibeji et al. 2016). See Chapter 9 for a further analysis on the effect of irregular electricity supply and how agricultural actors are adapting to the challenges in Nigeria. Applications that failed to consider their target users' literacy level were also likely to be abandoned, where the target farmers have low literacy level and struggle to interact with the app. A text-based application may be severely limited to succeed, despite the good intentions if the target users find it difficult to read and understand the content (GSMA 2015). An example is n'kalô in Côte d'Ivoire, which provided market information to cashew producers. This was forced to close down eventually because the target users found it difficult to engage with the content (Kedja 2016). Farmers are likely not to engage in a particular practice if they perceive that such initiative will require a lot of effort to use (Dillon Morris 2001). Beyond basic literacy, skills such as the internet skills needed for some of the m-Agri services are sometimes lacking, it was estimated in 2016 that 7 in 10 people in Africa who do not fully utilise their internet account affirmed that they do not know how to use it effectively, while 4 in 5 mobile phone owners have simple phones that are not capable of browsing the internet (World Bank 2016), bearing in mind that farmers are among these people. As such, lacking the required skills to use technology to access and express information effectively, impacts people's self-efficacy, which is in contrast with the ICT4D emphasis on designs and services that allow people to harness technology for their own objectives to change their situation and/or circumstances (Heeks 2009; Tucker and Blake 2010).

The one-size-fits-all approach can sometimes be a distraction that can cause the implementers to focus more on the technology and ignore the specific demands and priorities of the proposed users (Aker et al. 2016; GSMA 2016a). For instance, *Tigo Kilimo* provides agronomic information on ten particular crop varieties and market price information on such crops, however, many users reported that there was limited information on a wider variety of crops that were most important to them. In addition, they echoed that financial support information should be incorporated into the service (GSMA 2015). This, therefore, re-emphasises the notion in the field of ICT4D that access to technology and use strengthens people's advantages and ability to change their situation (i.e., self-efficacy) (Heeks 2009; Toyama 2011). Failure to integrate a deep understanding of the target users' culture when designing or adapting m-Agri initiatives is one of the challenges to sustainability of the service as users tend to lose interest in such initiatives (GSMA 2016a). Scaling-up the initiative can be challenging when there is a lack of relevance in the content for the target users or the effectiveness of the communication style (Rashid and Elder 2009). For example, the use of foreign languages such as English in non-English speaking countries may neglect the appropriate cultural context of the host community (Ifeoma and Mthitwa 2015). This aligns with more general insights in the ICT4D field of study that the modes and types of communication supported by technologies could be ill-suited to certain social situations, which might mean that such technologies are incompatible with the settings in which they are targeted at (Bidwell 2009; Heeks 2002). M-Agri services may also be doomed to fail if the implementers do not consider the cost for sustainability right from the beginning of the project. Services provided free of charge to farmers in the pilot stage could prove difficult to continue after the donors leave without a further source of revenue. A typical example is the M-Kilimo, a Kenyan farmer helpline (no longer functioning), where the service aimed to address the weaknesses in the availability of extension services using available networks in Kenya, which charged a standard network rate. The service was initially successful after the first three years (2009–2011) but was abandoned due to the high cost of the operation as farmers found it difficult to bear the cost for a longer time (Odhiambo and Tabitha 2016; Rioba 2018).

Trust has proven to be a critical factor in determining the success of any given project. The farmers tend to be sceptical with trusting external organisation such as the government or those in the private sector (Ezezika et al. 2012). As Baumüller (2015) and Aker et al. (2016) point out, getting the farmers to trust the information provided to them can be difficult. This can affect the progress of such services as well as the contents and could present a suspicious notion in a way that is either reliable or understandable. In addition, given that smallholder farmers' income is often low especially among farmers living in the rural areas, such farmers can be unwilling to pay for m-Agri services as well as pay for the costs associated with using the application (Aker et al. 2016; Qiang et al. 2012). A comprehensible business model both for-profit and non-profit m-Agri services, which can guarantee such services to exist independently of external funding in the future is sometimes ignored. By so doing, it can affect the development (Baumüller 2015). In addition, data security and privacy, i.e. the fear of digital crime and identity theft can be a concern for the farmers in their continuous use of m-Agri initiatives, especially where the services are supported by smartphones, which have the tendency to collect more sensitive or personal data. Moreover, poor commitment and collaborative efforts of the government in implementing adequate policies that support the varied stakeholders poses a significant challenge to such initiatives (van Schalkwyk et al. 2017).

Certainly, some of these challenges to m-Agri services are more difficult to overcome than others. However, many of these issues can be addressed by taking a more participatory approach, in which key stakeholders combine forces to identify and adopt strategies that can support the development and design of m-Agri initiatives. Some of the strategies that were adopted by various m-Agri services to improve their relevance, longevity and sustainability are discussed below.

8.4.3 Strategies adopted by some of the existing m-Agri initiatives

Although agricultural development activities continue to focus on more technologically advanced systems, which are knowledge-intensive, there is also demand for more sustainable initiatives. For smallholder farmers who are the target users of many such interventions sustainability for them means placing their needs at the centre of every m-Agri service initiative (Chetty and Grinter 2007; Henze and Ulrichs 2016). Some of these m-Agri service providers have already begun to implement some strategies that can enhance the sustainability of their project. In the situations where digital literacy may be low among the target users, the developers and their funders may have to work directly with the target users to enhance their skill in using the application. For instance, *m-farm*, which is a Kenyan m-Agri service co-opted a team of content managers who directly work with the farmers who do not fully understand the use of the application. They act as mentors to the farmers and teach them the step-by-step process of the application so that they become conversant with it and are able to use it independently in the future. Where the main issue is an unreliable electricity power supply, the One Acre Fund provided the target users with solar-powered phone chargers on credit to help address this (Gro Intelligence 2015).

Similarly, *WeFarm* which operates in Kenya and Uganda adopted the strategy of using crowdsourced knowledge through a message service to give remote farmers access to agricultural information without using internet facilities (WeFarm 2018). This method has enabled the application providers to connect to more than 1.1 million users across Kenya and Uganda. This service also allows the farmers to ask questions in any language, and therefore, directly addresses one of the barriers to long-term usage by the farmers. This is where the farmers are not conversant with the language used for the service.

The sustainability of a given project also needs to consider the economic aspects. The question of whether or not to charge end users fees is the subject of debate and depends on the business model (Aker et al. 2016). Many m-Agri services take a business-to-customer approach with a business-oriented perspective, this is where charging the end-users a fee for a given service seems reasonable to maintain the initiative. Services that rely on direct revenue from target users can only attain fiscal sustainability by scale (Joshi 2009; Morris et al. 2005). Some of these m-Agri services adopted this strategy to enhance the sustainability of their service. For example, the *Connected Farmer* that operates in Kenya, Tanzania and Mozambique, which offers combined services such as agronomic information, a weather forecast and marketplace services, adopted the service bundle model through the generation of income from selling products and services for agribusinesses as well as selling data and market research survey. In this case, the agribusiness clients pay a monthly charge to access farmer data (GSMA 2016b). Similarly, *iCow* charges its users KES9 ($0.09) to receive three short message service tips per week. This means that the service's fiscal sustainability is ensured with regular recurring revenue of $150,000 from regular users (GSMA 2018). In this case, the higher the number of users, the more the service becomes financially sustainable. However, the business-to-customer approach can be difficult to achieve in practice as many farmers have low disposable incomes. Many times, their ability and willingness to pay does not always translate into real payment (Aker et al. 2016). An example of such dilemma is the *Tigo Kilimo's* experience when new users and repeat users of the service increased after their short message service fee was removed. Even though the farmers who used the service expressed their willingness to pay a small amount in a survey, as the majority did not sign up not until the fee was removed (GSMA 2015).

Given that m-Agri services can be a complex system of technologies, it is important to clearly and distinctively define the design and management of the technologies. It is often difficult for implementers of these m-Agri services to understand the exact needs of the farmers and to assess how best is best enough for the applications' everyday use. This may, in the short-term, lead to advances that fail to tackle the major areas of farmers' need or deliver over-performing interventions that may be unnecessarily exorbitant (Aker et al. 2016). Therefore, a closer relationship and continuous communication with the end-users and other key stakeholders will help to ensure that the most value is gained from the initiative. This can be achieved by drawing insight from the principles for digital development and adapting to the following strategies and functionalities as discussed below.

8.5 Strategies and functionalities that can enhance the sustainability of m-Agri services

8.5.1 Designing with the users in mind

The success of m-Agri services should be deep-rooted in a clear understanding of the user characteristics, their needs, dynamics and challenges, as well as potential changes in future. This could be achieved by getting to know the target users or potential users through dialogue, observation and collaboration, which aligns with what Kleine et al. (2012) referred to as participatory approach to technology design. During the engagement process, the information gathered is, therefore, used in building, testing and redesigning the service until it effectively meets the users' need. In their study, Kleine et al. (2012) applied the capabilities approach and argued that the approach challenges researchers and/or developers to co-design with users in a way that expands the freedom of the users to live the life they value. The capabilities approach proposed by Sen (2001) views development as '*the expansion of human capacity to lead lives they* *value*' and m-Agri applications should be seen as means to achieve this objective. The approach of co-designing the intended application with the users can address the specific context, culture, behaviours and expectations of the users who will directly and basically interact with the service. This means that the service providers will continue to partner with the target users throughout the lifecycle of the project, co-creating solutions for identified problems as well as continuously obtaining and incorporating the feedback from the users (Aker et al. 2016; GSMA 2016a, 2016b, 2018; IICD 2012; Laureys 2016). The m-Agri implementers should focus on engaging the farmers at all stages of the product development, from identifying the opportunities and generating concepts during the early stage, to developed stages of product realisation, execution and scaling-up (Godson-Ibeji et al. 2016). The m-Agri initiatives can be impeded if the perceived problem that the service aims to address, the availability, affordability and accessibility of such services, are not thoroughly analysed or evaluated before creation and implementation (Aker et al. 2016; GSMA 2016a). This strategy could answer the question of whether the application should be free, text-based or internet connection free (Aker et al. 2016; Van Schalkwyk et al. 2017).

8.5.2 Analysing and understanding the existing environment

In maintaining a given m-Agri service, the initiators need to consider the structures and needs that exist in the target community, country or region. The time and resources set aside to understand the culture, political environment, technological infrastructure, gender norms, economy of the target location and other factors that can influence target users' ability to access and use the service, can enable the implementers to ensure that a relevant m-Agri service that will attract long-term use is chosen. This recounts that the m-Agri services that do not account for the ecosystem challenges are more likely to fail to achieve the desired objectives or become sustainable (GSMA 2018; Laureys 2016; USAID 2018; Wacksman and Sultan 2016; Woodard et al. 2014). This may imply that the implementing organisations must identify whether the target community have significant experience in a certain mobile device to be used for the m-Agri service rather than creating and imposing it on them. Furthermore, implementers need to understand the socio-cultural circumstances of the female target users and design m-Agri services that aim to close the digital gender divide (Betterplace Lab 2017; GIZ 2018). This could mean that m-Agri services that consider women's lived realities and working conditions should be encouraged and supported. As such, this strategy is in tandem with the general belief that ICT interventionists should work with the community to promote social inclusion and avoid abuses of power, and aim to develop people's own skills and abilities to manage their needs and mobilise resources for their benefits (Heeks 1999).

8.5.3 Designing for scale and sustainability

Achieving scale is an objective that always seems ambiguous for many m-Agri service developers. That is the practitioners' inability to move such initiatives beyond the pilot stage, such that requires the adoption of the initiative beyond the pilot's population. Designing the m-Agri services for scale means planning beyond the pilot and considering the factors that will enable the extensive adoption later as well as proposing what will be affordable and useable beyond the pilot group. The design for the scale of an m-Agri service project from the onset can guarantee that the project will expand more easily to markets, new users or locations, if the service meets target users' need and has an impact. In addition, ensuring that the m-Agri services are embedded in the existing policies, users' daily activities and workflow, can help to improve the services' sustainability (Woodard et al. 2014). Additionally, institutionalising such a service with a private company, government or non-governmental organisation, as well as incorporating a business model that has a sustainable revenue generation strategy can enhance the ultimate achievement of a sustained positive impact (Dimagi 2019; GIZ 2018; GSMA 2013; Woodard et al. 2014). Seeking for scale and sustainability requires that implementers should ensure they understand their target users' changing behaviour, expectations and willingness to pay for the m-Agri service.

8.5.4 Addressing privacy and security through collaboration

This approach implies that the m-Agri service providers need to ensure individual users' sensitive information is secured while adhering to strict transparency of how data will be collected and used as well as minimising the amount of personal and sensitive information collected. As such, all related data policy should be followed stringently. The m-Agri service providers have the duty of care to ensure that they define data ownership, declare who has access to the data and who decides what to do with the data, and determine the use and where the data will be stored before embarking on the data collection process. A risk-benefit analysis should be carried out throughout the data collection cycle to identify the individuals who benefit from the process and who are at risk (United Nations Global Pulse 2015). The initiators or implementers should consider the impact of data theft or inefficient data management to ensure they assess the risks of leakage and unauthorised access to any stored data (European Union General Data Protection Regulation 2018).

Furthermore, it is imperative for the implementers to work collaboratively with the target users to ensure that they (target users) understand the risks associated with sharing their data to enable them to make an informed decision about whether or not to participate (MERL Tech 2017). At the same time, the users need to be made aware of what their data will be used for, how it will be stored, for how long it will be stored, and who can access the data. The best practices for security and privacy protection may include encryption of files, secure cloud storage services, use of two-factor authentication, validating data-sharing agreements with all the potential data-sharing associates (African Union Convention on Cyber Security and Personal Data Protection 2014). The adherence to these principles is vital to uphold the ethical implementation of m-Agri services and prevention of negative outcomes that may result from security breaches. Hence, this; will help to secure the interest of the users/participants and, at the same time, promote trust between all the stakeholders (end users, implementers, funders and others).

8.5.5 Reusing and improving on the existing initiatives

Innovation does not only mean to build something new, but rather it can also mean repurposing an existing initiative/tool in a new way and/or adding more features or functionality. This strategy, therefore, means that the implementing organisations can explore ways of adapting and improving on the existing m-Agri services. The term ‘reuse’ in this perspective means evaluating the resources that are currently available and using them the way they are to meet the aim of any proposed initiative, while ‘improve’, means modifying the existing resources to improve their quality, applicability and impacts. This approach could be achieved by identifying the relevant methods, software platforms or codes, digital content, technology tools and standards that have been tried and tested (Bothwell et al. 2014). As such, the implementers should learn about m-Agri initiatives that have been piloted or scaled through blogs, conferences, project evaluations and digital development community. This can be realised by collaborating with other digital development practitioners and partaking in technical working groups and other knowledge-sharing events to be informed of the existing services and to establish relationships that could lead to the future improvement and/or reuse of the proposed one (Grevendonk et al. 2013; Roedl et al. 2017). Although, an existing initiative may not exactly fit all the requirements for reuse, improving and upgrading it rather than creating an entirely new one should be considered. It is also important to identify what works and what does not work before embarking on a given project. Hence, this approach can reduce the amount of time needed for the development and testing, as well as reducing the costs of the m-Agri service.

8.5.6 Open and data driven

An open approach to m-Agri services can help to increase collaboration among the relevant stakeholders as well as help to reduce the duplication of initiative that is already in existence. Many times, huge resources are spent on investing in new tools, content generation and developing of software codes for specific m-Agri solutions that are locked away under licensing fees with restricted access to data. Moreover, programmes can judiciously use their resources and achieve impact by being open. However, what being open means for a particular initiative may depend on practical or technical limitations, privacy and security concerns, as well as the dynamics of the stakeholders and networks in the target environment. Being open in this perspective means that the implementers need to adhere to publicly available standards and policies such as the Open Data Commons licence, Open Source licence, and Creative Commons licence, which allow them to freely share their data, while maintaining users' privacy protections and acknowledging intellectual property rights (Code Innovation 2015). For instance, the extent to which m-Agri service providers use any open source software is dependent on the needs identified within the context and assessment of the available options that fit the needs. Hence, it requires that the implementers/developers need to collaborate with their counterparts who have created similar initiatives and identify opportunities for making such initiatives more open. Moreover, no amount of data collected will manifest an accelerated impact if not used to inform a decision-making process. When an m-Agri service is data driven, quality information is made available to the right target users when it is relevant and when they can use it to solve their perceived problems. The users should drive the process of determining which is the best data needed for their decision making, appropriate time and in what format, such that continued use of the applications is ensured (Heeks 2002b).

However, dealing with these approaches and concepts for ensuring m-Agri services' sustainability requires good governance and the active involvement of the policymakers to facilitate the process. The following section, therefore, highlights some of the perceived role appropriate policy and governance can play in promoting the sustained long-term impact of m-Agri services.

8.5.7 Policy and governance

This review suggests that policymakers and/or government/non-government organisations can play a key role in enhancing the sustainability of m-Agri services in Africa by creating an enabling environment for all the stakeholders through the implementation of favourable policies or programmes. Thus, this could be achieved by supporting affordable access to mobile handsets, networks and internet facilities, and promoting universal digital literacy as well as grassroots innovation skills (Aker 2011; Aker et al. 2016). Furthermore, it requires that security policies should be implemented to protect individuals' data and uphold their privacy and dignity, as well as instituting an end-of-life post-project data management policy and ensuring that the implementers abide by strict data protection policies. Given that agriculture is increasingly becoming knowledge-intensive and technology-driven, a key task for the government and policymakers could be to enact policies that support m-Agri services that enable illiterate farmers to interact with such services using analogue components. The government can also support to host m-Agri services at subsidised rates or free for the target users and, by so doing, ensure improved long-term impact (Aker et al. 2016).

8.6 Summary of key findings and recommendations for the future

This review set out to examine the current landscape of m-Agri app use in Africa, and to provide an overview of the challenges that currently impede the establishment and sustainability of m-Agri services and identify opportunities for policymakers, designers and developers to enhance the development and sustainability of m-Agri apps in Africa. Smallholder farmers in Africa produce the majority of food consumed. For many of these smallholder farmers, m-Agri services could revolutionise their access to information and extension services, and, ultimately, improve their livelihoods (Lawal-Adebowale and Akeredolu-Ale 2010). Currently, these smallholder farmers are not always best served by the m-Agri services available and this should be improved. This requires input from policymakers and government to improve provision. The questions posed at the beginning have been addressed in detail in the previous sections, the key findings are summarised, and recommendations based on these findings are presented in Table 8.3.

Table 8.3: Key challenges for wider m-Agri use, opportunities for improvement and policy recommendations to improve m-Agri provision for smallholder farmers

Challenges to wider use of m-Agri services	**Opportunities/Potential Remedies**	**Policy Recommendation**
Uneven and unsteady electricity power supply for charging mobile phones and internet access	Infrastructure improvements and deployment	• Provide support for infrastructure development in rural areas (e.g., internet or Wi-Fi deployment) • Subsidise electricity tariff to encourage more household subscriptions
Uneven network coverage	Support for network providers to improve access in rural and distant regions	• Implement more nationally backed network coverage, financial or legislative incentives for food producers
Cost of subscription to m-Agri services	Free access, low-cost access, sponsorship by NGO, Business, or Government	• Government support for service start-up and maintenance of service
Cost of equipment	Low-cost handsets, or free handsets	• Provision of free handsets to disadvantaged users (women farmers, isolated villages) • Subsidy for low-cost handsets
Failure to understand farmers use of m-Agri services results in underutilisation	Understand the needs of users, content and language, engage in development needs analysis	• Encourage developers to engage with end users • Provide access through extension services • Engaging the extension agents may result in cost savings for extension services
Accessibility, language and skills needed for smartphone access	Provide training, understand user's language, education and technical skill levels	• Provision for the training of users, options for peer-to-peer learning and mentorship

Bridging the research-farmer disconnect	Encourage participatory research involving farmers	• Provide facilities for knowledge exchange • Provide extension agents with funding and facilities to engage • Policy to require researchers to engage with end users • Funding for research to bridge this disconnect
Trust issues on privacy and data security	Ensuring standards for data privacy and protection	• Privacy and data protection policy that can ensure that data subject has a right to access and understanding of what his/her data is used for and how long the data is stored • Democratisation of knowledge and sensitisation on procedures guiding intellectual property rights
Unsustainable business models	Diversified income sources to maintain a long-term impact of the service Revenue models that involve institutions covering the cost of marginalised users' [e.g. smallholder farmers, women and young people] access to the m-Agri service	• Provide facilities for maintaining a user feedback loop • Provide standards for business models to adapt to users' needs and expectations
Digital gender divide	Identify and engage with the gatekeepers (husbands, parents) Encourage services that are tailored to the needs of women	• Provide facilities that promote women and girls' participation in m-Agri services • Funding for an e-skill acquisition
Unsustainable practices towards m-Agri service(s)	A sustainable approach to the design, development, deployment and use Participatory approach to understand specific and genuine problems	• Regulatory policies that can ensure sustainable practices

Source: Author's compilation

8.7 Conclusion

M-Agri services have proven to bring significant benefits such as access to financial facilities, agricultural information and sharing, supply and marketing services to smallholder farmers with the enabling penetration of mobile phone and internet facilities. Despite the documented impacts, such initiatives can face challenges for sustainability. This review identified that some of the m-Agri services in Africa encountered challenges such as lack of trust in the content by the target users, the one-size-fits-all approach by the service initiators, and lack of necessary infrastructures before embarking on the development of the initiatives by the developers/implementers. The infrastructure required includes appropriate contents, sustainable business models, provision of mobile and internet skills and investment in grassroots assessment to understand specific users' need. However, it was revealed that there were various strategies adopted by some of the existing m-Agri services to overcoming such challenges which include reasonable service charges, offline messages that use no internet for delivery, providing alternatives for grid electricity-powered mobile phone chargers, as well as co-opting intermediaries between the providers and users to help improve users' skills. Following the review of literature and available m-Agri services, this study highlights that, to enhance the sustainability of m-Agri services, the initiators/implementers should adapt with the various functionalities which include designing with the target users in mind, understanding the target environment, and planning and executing the service beyond pilot stage. They should ensure the users' privacy and data security and explore other innovative strategies such as reusing and improving existing initiatives, operating within open data and open source policies/standards, and utilising a user-led initiative approach. It is also important that m-Agri service(s) providers ensure truly sustainable initiatives by adopting a holistic approach for sustainability in the design, development, deployment, and evaluation of any m-Agri service(s). This should consider the long-term social and economic impact as well as efficiency for the users and encourage sustainable behaviour through the design. This can be achieved through a participatory approach to identify the needs of the target users and requirements for sustainable m-Agri service(s). A peer-to-peer model among implementers and users should be encouraged to enhance share of ideas and initiatives. As such, these recommended strategies for improved long-term impact of future m-Agri projects are derived from the key findings of this review. Hence, each country's government and policymakers can enhance the actualisation of these recommendations.

Chapter summary

Given the clear understanding of the attributes of the mobile phone-enabled services, the challenges to their sustainability and the strategies that can improve the challenges, the narrative therefore drew the attention to the second aim of this whole thesis, which is to evaluate the potential impact of mobile phone-enabled application/services as an interactive initiative for enhancing the co-creation, learning and dissemination of agroecological knowledge in Nigeria. The following chapter (Chapter 9) explores some of the strategies for the purpose of realising the aim and objective of this thesis.

Chapter 9: Demonstrating the potential for mobile phone-enabled services to enhance collaborative agroecological knowledge exchange

This chapter discusses the potential impact of interactive mobile phone-enabled services, principally SmartAgroecology, detailing the process involved in the design, development and demonstration. Reconnecting back to the Chapter 7 of this thesis which proposed a framework for interactive exchange of agroecological knowledge amongst the relevant stakeholders, this present chapter, therefore, seeks to evaluate the perspective of the participants towards the use of an interactive m-app (SmartAgroecology) for this purpose. The chapter also explores whether the m-app can facilitate co-learning about agroecological approaches and exchange of agroecological information amongst the participants. This chapter involves the use of participatory action and design science research approach which utilises focus groups and workshops for data collection. The participants include smallholders and extension agents.

This chapter was originally published in a conference proceeding as:

Emeana, E. M., Trenchard, L., Dehnen-Schmutz, K (2018) The potential impact of mobile phone application in agroecological transitioning in southeast Nigeria. *In 13th European IFSA Symposium: Farming systems: facing uncertainties and enhancing opportunities*

However, after revision and incorporation of feedback from the conference, the chapter has now been modified to a manuscript in preparation for journal publication. See the proposed title and abstract in Appendix 23.

9.1 Introduction

Agroecology offers a sustainable alternative to conventional farming and food systems. In Africa, agroecological approaches can easily be adapted to local conditions for the sustainable management of small landholdings at low cost whilst protecting the environment (AFSA 2016; De Schutter, 2010). Additionally, agroecology improves and sustains on-farm fertiliser production, which in turn reduces farmers' reliance on external inputs and government subsidies, in addition to making vulnerable smallholder farmers less dependent on loans and retailing. Although agroecological methods can require much labour especially during the early implementation stage. This is due to the complexity of managing different plants and animals, and other farm activities such as recycling of farm waste, Ajayi et al., (2009) concluded that the higher labour-intensity of agroecological practice is a reality especially in the short term; however, it creates job opportunities in return. Agroecology also contributes to nutritional diversity as a result of the diversified plant and animal species managed under agroecological principles on farms (DeClerck et al. 2011). Furthermore, the agroecological practice can significantly remediate the negative effects of climate change by boosting soil organic matter and, in turn, improving soil carbon-sequestration capability (Mijatovic et al., 2010; Hoffman, 2011; Aguilera et al., 2013). Despite these potentials, agroecological techniques have not been widely adopted in African countries such as Nigeria.

Nigeria is currently faced with a food security crisis with her growing population becoming increasingly dependent on imported processed foods (Okafor, 2011), in addition to the gradual marginalisation of the subsistence-oriented farm system, and insecure land tenure (Nwajiuba, 2011). The country is among the African countries that embraced the Green Revolution (GR) strategy, which improved her cereal production but at considerable cost to human and ecosystem health (Adeola and Oluwafemi 2014). The GR approach influenced the intensification of agricultural land by reducing the fallow periods, increased mono-cropping and use of agrochemicals (Akinwumi 2014; Enete et al. 2011; Oguamanam 2015; Pingali 2013). As such, the agricultural activities have harmed the environment, affected human health, exacerbated climate change, increased the distortion of ecosystems, polluted the natural water systems, and rendered many soils infertile (Adomako and Ampadu 2015; Wallinga 2009). Agriculture in Nigeria is faced with rising temperatures, desertification, rise in sea levels, and changes in rainfall patterns (Nwaiwu et al. 2013). Aikhionbare (2015) further noted that agricultural activities in Nigeria are posing a continuous devastating effect on the farming system. The agricultural activities and the highlighted issues draw attention to the transitioning towards agroecological approaches as it can no longer be claimed that Nigeria's agricultural activities are ecologically sustainable.

Farmers' transition to agroecological approaches is a challenge because agroecological farming systems are knowledge-intensive which require farmers to learn how a landscape operates as an agroecosystem, combining their observations, predictions, and experiments with ecological principles that are improved by scientists who study the farming intricacies (Gliessman 2014; Pimbert 2011). It is a challenge therefore to find an effective way of delivering agroecological knowledge. Current agricultural extension services are underfunded, farmers who can access extension services often find them inadequate, but many more farmers are unable to access these services altogether. Unavailability and inadequacy of extension services hamper farmers' training and programmes designed to enhance the adoption of agricultural initiatives (FAO nd). Poor adoption of agricultural innovations especially in Nigeria has been blamed on poor agricultural information delivery systems (Anaeto et al. 2014). Obiora (2013) observed that organisational issues such as poor funding and low extension agent to farmer ratio are impeding extension services for effective agricultural information delivery in Nigeria. Okeke et al. (2015) noted that effective information communication to farmers is vital in attaining efficient agricultural extension practices in Nigeria. Emeana et al. (2019) also suggested that a participatory approach in information dissemination can strengthen the agricultural dissemination structure in Nigeria. Hence, the need to establish effective agricultural information delivery approaches that can boost interactive processes amongst farmers, extension personnel and all stakeholders that are involved in enhancing agricultural innovation and adoption.

The role of effective agricultural information systems aided by ICTs in agricultural development and the positive impact on the enhancement of adoption of agricultural innovations is established in the literature (Baloch and Thapa 2016; George et al. 2011; Kuehne et al. 2017; OECD 2001). ICTs could serve as a means of stimulating farmers' interest in new ideas and practices as well as provide useful information that could enhance farmers' decision-making including adoption of farming methods that improve farmers' livelihoods and promote rural development (Ani et al. 1997; FAO 2012; Lwoga 2010; Masuki et al. 2010; Nazari and Hassan 2011; Omotayo 2011). Agu (2013) suggested that ICT could support Nigerian women farmers by delivering basic education, information on food security, markets, improved farming techniques and food conservation. Support they find difficult to obtain through traditional means. Other communication channels used for agricultural information dissemination in accordance with the national policy on agriculture in Nigeria (Ariyo et al. 2013) include newsletters, radio, newspapers, farm magazines, television, leaflets, and many others (Dare, 1990). Of these, radio and television were reported as the major sources of agricultural information from agricultural agencies as they are presumed to reach large audiences and messages can be transmitted in the receivers' own language (Omenesa, 1997; Nwuzor, 2000; Ariyo et al. 2013). Both though share common features of the one-way mode of information transmission in that they do not support feedback or in-depth training (Mittal and Tripathy 2009).

On the other hand, the mobile phone and its applications have made a remarkable increase in the rapid exchange of information amongst farmers and extension agents (Aker 2011; Tali 2016), thus, creating opportunities for peer-to-peer knowledge sharing and feedback. Smartphones and basic-feature phones with internet connection capability and touchscreen interface are now widely used globally (Dehnen-Schmutz et al. 2016). The usefulness of the mobile phone in enhancing farmers' livelihoods, agricultural extension services and agricultural development in Nigeria has been established in the literature (Asa and Uwem 2017; Egbule et al., 2013; Haruna et al., 2013; Ogbeide and Ele 2017; Ogunniyi and Ojebuyi 2016). In a study on farmers' perceptions of organic farming in Ekiti state Nigeria which involved 160 smallholders, Oyesola and Obabire (2011) observed that a majority of the farmers preferred mobile phones for their source of agricultural information. Fasola and Adewumi (2011) also concluded in their study of 170 randomly selected farmers, that farmers use mostly mobile phones for their daily farming operations due to inadequate extension services. Furthermore, Bolarinwa and Oyeyinka (2011) noted increased farmers' access to extension services by the use of mobile phones. Similarly, Banmeke et al. (2017) observed that extension agents in Nigeria consider mobile phones as a capable means of dissemination of information to farmers. Using mobile phones for agricultural information delivery may contribute to interactive exchange of knowledge, thus making agroecological knowledge exchange amongst farmers and other stakeholders a reality.

Most significantly, mobile phone companies are increasingly playing major roles in making mobile connectivity more accessible. These industries have invested extensively in Nigeria's telecommunication facilities to promote affordability (Worldometers.info, 2019), resulting in improved access to mobile and internet facilities. In a report by Jumia Mobile Report Nigeria (2018), mobile connectivity has become the major driver of innovation and contributes to economic growth. The report noted that the penetration of mobile phones in Nigeria has rapidly increased and is still increasing. The number of subscribers grew exponentially, reaching an estimated 84% penetration in 2017. Further innovations mean that mobile applications require less data and are therefore accessible to more users who have poor internet connections (Jumia Mobile Report Nigeria 2018). Mobile operators and innovators are already using mobile applications and short message services to deliver information such as health advice, education, agriculture and government services (GSMA 2015). Presently, there are fewer agricultural mobile phone-enabled products and/or services developed in view of promoting farmers' access to agricultural information in Nigeria compared with other African countries such as Kenya and Uganda, see Figure 9.1 below.

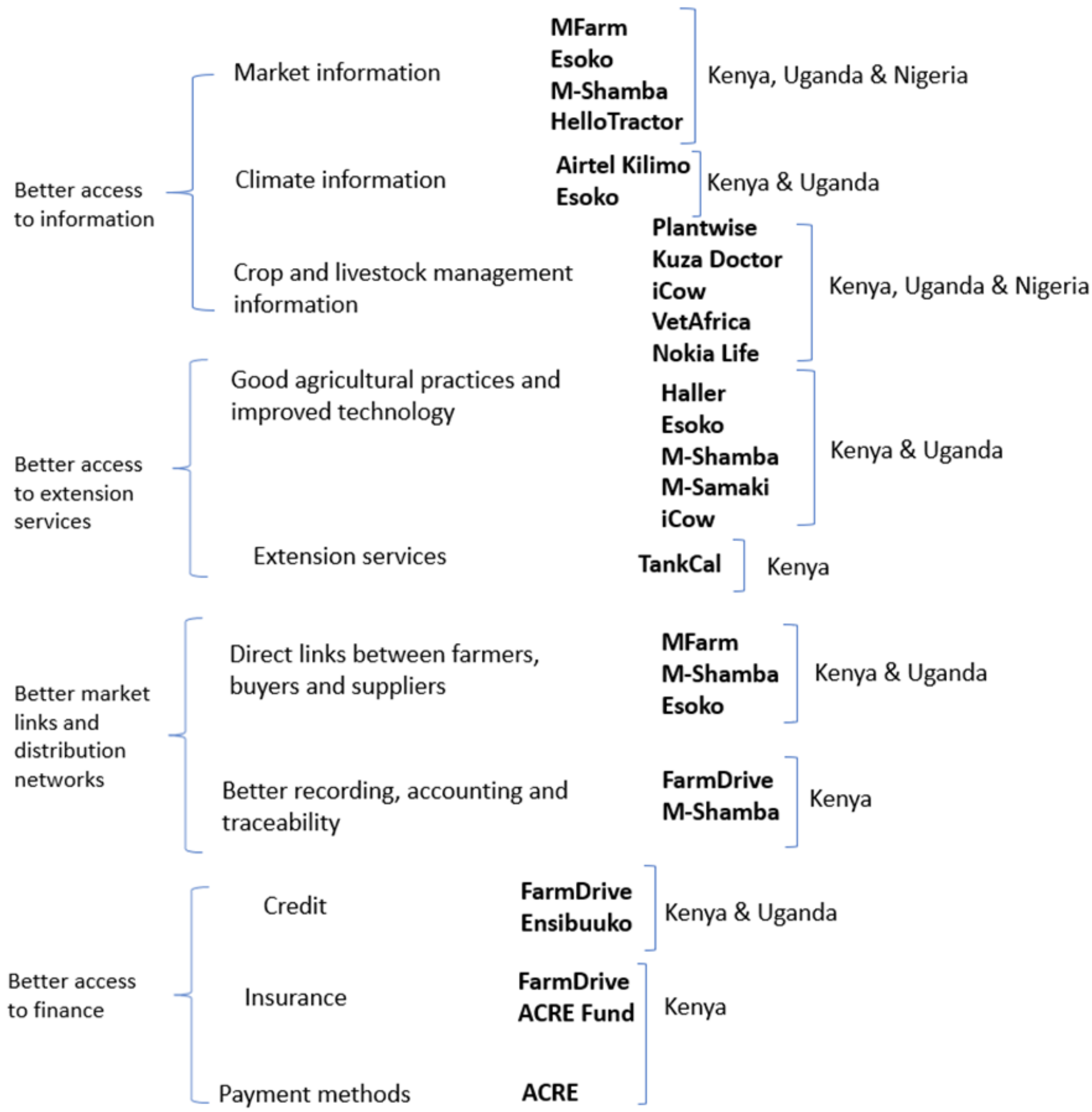

Figure 9.1: The mobile phone-enabled services for enhancing access to agricultural information in selected African countries (Adapted from Henze and Ulrichs 2016; Qiang et al. 2011).

There are a number of examples of mobile agricultural applications available in Nigeria. These include Hello Tractor which provides access to low-cost tractors that farmers can buy or rent using their mobile phones via short message service. Another app called Nokia Life sends information about crop management, weather forecasts and market prices to the farmers through their mobile phones. The Nigerian government also provides access to information about fertiliser and seed availability to farmers through their mobile devices as part of the Growth Enhancement Support Scheme under the

Agricultural Transformation Agenda (NADS report 2011). Present in Nigeria are the apps Farmcrowdy and e-Wallet, which support farmers' access to improved seeds and fertiliser as well as information on crop planting and markets (Demenongu et al. 2018). Beyond Africa, especially in Asia and the pacific region, many ICT-based agricultural development services have been developed for the benefit of farmers and are well documented in literature (Christensen et al. 2018; Hazelman and Attaluri 2011; Patel et al. 2010). There are also a number of such initiatives recorded in Europe (Benyei et al. 2020; Calvet-Mir et al. 2018; FAO 2018m; Leveau et al. 2019). The wide range of agricultural focused mobile applications, and their popularity with farmers suggests that this is a useful channel for providing information on agroecological techniques and practices. There are however, only a few web-based services which are currently focused on agroecological knowledge management at the time of writing, no mobile phone-enabled service is available to promote agroecological techniques nor any developed for collaborative agroecological knowledge exchange particularly in Nigeria.

In order to achieve sustainable advancement and/or adoption of any agricultural innovation or indigenous knowledge, an interactive process is required where information and skills relevant are shared among all agricultural stakeholders (FAO 2009). This can give the participants the opportunity to become the innovators, receivers or intermediaries. Uphoff (2014) noted the opportunities for farmers to become prime developers and evaluators of knowledge when they are actively involved, as they must ultimately make decisions concerning adoption or rejection of the initiative. The approach can allow farmers to decide and participate in the development of ICT based initiatives (Barakabitze et al. 2017). Barakabitze et al. (2017) further observed the effectiveness of embedding participatory approaches in developing ICT based agricultural information delivery strategies in Tanzania. In a similar study, FAO (2009) reported that farmers' involvement in the development of ICT based agricultural solutions can enhance their productivity. Therefore, in order to enhance the transition to agroecological approaches in Nigeria, farmers need support and access to agroecological information, as well as participate and contribute to the knowledge and design of the initiative. This could be achieved by developing and adapting an effective interactive agroecological information channel that allows regular contact with extension, research, support and collaborative contribution to knowledge. Accordingly, the information should be relevant, on time, accurate, reliable, usable, exhaustive, and complete. It is envisaged that improved access to information about agroecological principles, techniques and practices through mobile phone applications, farmers' participation and collaboration of researchers and extension personnel would encourage agroecology transition.

This study investigated the farmers' and extension agents' perceptions of agroecology and the potential for mobile phone-enabled applications, principally SmartAgroecology (i.e., a mobile application or m-app designed for knowledge interaction), to enhance the effective collaborative exchange of agroecological knowledge. Currently, the effectiveness of using a participatory approach in designing mobile phone-enabled applications for enhancing agroecology transition in Nigeria is yet to be explored. Hence, the principal objectives were:

- To develop, test and validate a mobile application that can enhance access to collaborative agroecological knowledge exchange using a participatory approach;
- To evaluate whether farmers' access to agroecological knowledge through the application can influence their transition to agroecology;
- To assess whether the application influences the extension personnel's information delivery approach;
- To evaluate the barriers to the application's wider use in Nigeria.

9.2 Methodology

This section describes the study area and how the data was collected and analysed. It also outlines the steps involved in the design of the m-app, as well as the activities carried undertaken during the fieldwork.

9.2.1 Study area

This study was carried out in the south-east region of Nigeria. After the second stage of data collection activities described in Table 5.3, Chapter 5, the researcher went back to the same study area to design, develop, and demonstrate the m-app (third stage). This was important because it allowed access to the smallholders and extension agents who participated in this study. The study considered the two states because they are among the regions with fairly good mobile coverage and increasing numbers of mobile and internet users (National Bureau of Statistics 2019).

9.2.2 Techniques used for data collection and analysis

Data was generated through focus group discussions (FDGs) with 50 respondents (see details in Table 9.1). The study adopted Pretty's (2005) approach of interactive participation which gives the participants control of the study outcome. The participants comprised of 30 farmers and 20 extension personnel purposively sampled (see further details in Chapter 5 above). The 30 farmers were contacted through their field extension contact person from the Imo State ADP office, while 12 extension agents were contacted from Imo state ADP office and eight from the NAERLS zonal office in Abia state, respectively. The farmers rely on the field extension personnel for agricultural information and advice on access to farm inputs and other related advisory services through the state ADP. The study adopted Minkler's (2000) strategy of the cyclical process of evidence finding, action and reflection, which leads to further inquiry and action for change. Gillis and Jackson (2002) opined that this approach allows for a systematic collection of data through the generation of practical knowledge for the purpose of taking action and making a change. Furthermore, the FGDs facilitated the emergence of rich data through interaction and collective opinion and further exploration of the general nature of the individual's comment. Additionally, the approaches helped to ensure that the m-app's design considered the technological accessibility needs of the participants given their location, experience and technical skills. Prior to the FGD sessions, the researcher conducted several informal home, farm and office visits to understand the lived experiences of the participants and build relationships.

In ensuring a suitable environment for the participants, the researcher facilitated the FGDs in a public office space that was familiar to the respondents, whilst also ensuring equal opportunity for each participant. Prior to the data collection, written informed consent was obtained from each participant as required for ethical approval of the study by Coventry University, United Kingdom. The researcher acknowledged some of the demerits of FGD approach opined by various authors (Freitas, 1998; McNiff and Whitehead, 2006) and adopted the open-ended and guided discussion approach by ensuring that the objectives of the research were explained. The themes of the discussion/questions were worded to suit the varied level of English proficiency of the participants. The themes were predetermined by the researcher, deliberated and accepted by the participants to cover the knowledge inquiry. The participants used post-it notes in elucidating their views, whilst verbal contributions were audio recorded. Data were analysed manually using hand-coding and the sources are coded to identify individual response by labelling each participant as Farmer 1-30 and Extension 1-20 within their representative group. To resonate meaning from the themes that emerged from the coding process, verbal quotations were used to support the four different themes.

Table 9.1: The overview of the focus groups for knowledge inquiry, design and demonstration of m-app

Date	Duration		Participants	The theme of the discussion
March – June 2017	Day 1 – 3 (6th, 10th, and 15th of March)	3 sessions, 2 hours per session	Farmer group (10 participants per group)	The existing agricultural practices and any issues involved. The benefits of agroecological practices. The type of information available. The medium of communication and knowledge exchange and preferred means of communication.
	Day 4 – 5 (27th March 4th April)	2 sessions, 2 hours	Extension personnel group (10 participants per group)	The benefits of agroecological approaches and perception about the knowledge exchange. The type of information delivered. The medium for agricultural information delivery to the farmers and preferred means of communication.
	Day 6 – 8 (13th, 18th, and 20th of April)	3 sessions, 2 hours per session	Farmer group (10 participants per session, same group formation)	The ability to use mobile phone-enabled services. The perception of collaborative knowledge exchange. The perception about contributing their indigenous knowledge towards the improvement of agroecological transitioning.
	Day 9 – 10 (26th of April 5th of May)	2 sessions, 2 hours per session	Extension personnel group [10 participants per group, same group formation]	The ability to use mobile phone-enabled services. The perception of collaborative knowledge exchange.
	Day 11 – 13 (8th, 10th, and 16th of May)	3 sessions, 2 hours per session	Group 1 and 2, 8 or 9 participants per group (mix of farmers and extension personnel)	How to design a user-friendly m-app The features required and platform presentation/outlook Incorporating feedback and reconfirmation
	Day 14 – 15 (25th of May 7th of June)	3 sessions, 2 hours per session	Group 3 and 4, 8 or 9 participants per group (mix of farmers and extension personnel)	How to design a user-friendly m-app The features required and platform presentation/outlook Incorporating feedback and reconfirmation
November 2017 – April 2018	Day 1 – 6 (27th and 30th of Nov, 8th Dec 2017, 23rd of Jan, 6th of March and 2nd of April 2018)	6 session, 2 hours per session	Group 1 – 6, 8 or 9 participants per group (mix of farmers and extension personnel)	Validation of individual experience and their perception about using the artefact (SmartAgroecology) for collaborative knowledge exchange. The barriers that could affect the application's wider use Measures to promote agroecological knowledge Measures to enhance the application's reliability (i.e., strategies that can ensure that the aim of the m-app is achieved and maintained).

Source (Field survey 2018)

9.2.3 Designing and developing mobile phone-enabled application known as SmartAgroecology using PADR framework

The PADR approach (see Chapter 4) was adopted to design the m-app to suit the need of the participants and enhance farmer-to-farmer and farmer-to-extension personnel interaction about agroecology. The study adopted the six steps of the design science research method as proposed by Peffers et al. (2008) and grouped five of the six steps into three stages. Each step is linked to the corresponding activity carried out by this study (see Figure 9.2 below).

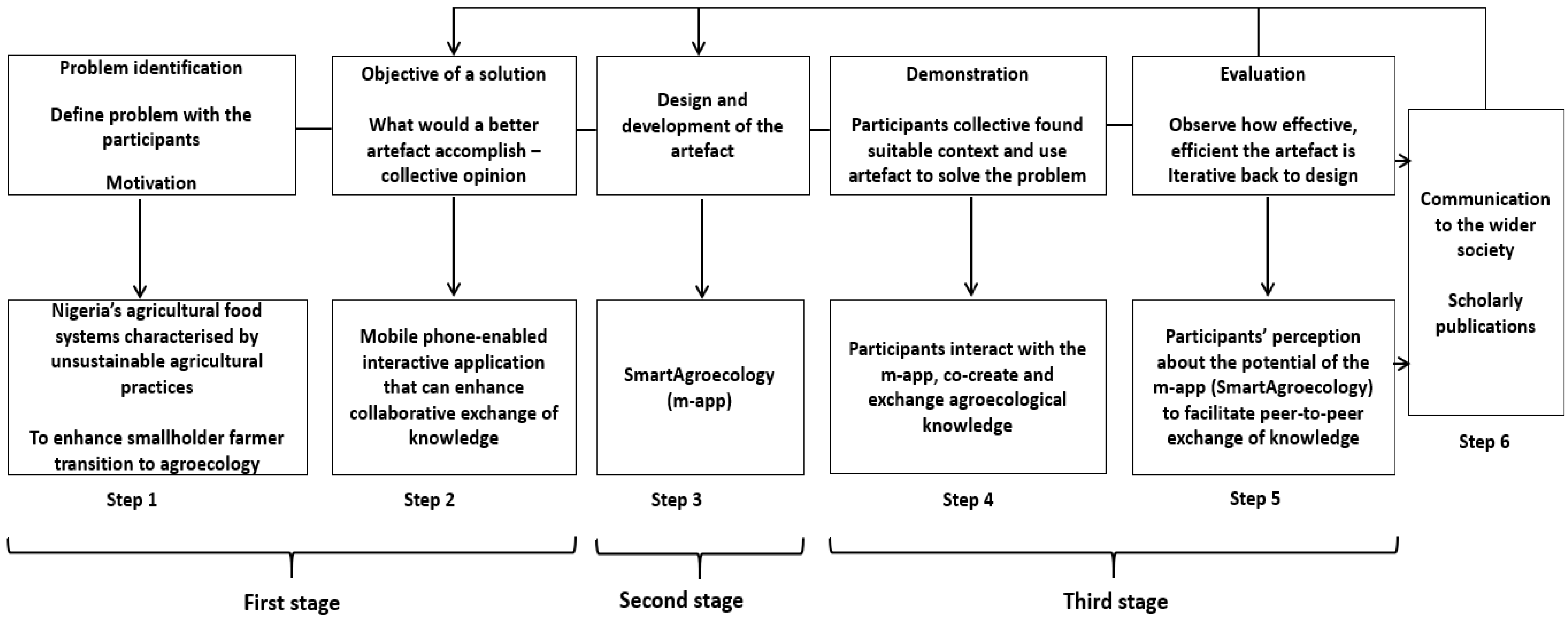

Figure 9.2: This study design science research methodology process (Adapted from Peffers et al. 2008)

A more detailed description of the different activities of the three stages is presented below.

The first stage involved deliberating and understanding the current perceived problem as well as spending time and establishing common relationships with the participants of the study. This stage helped to clarify their initial viewpoints about their current agricultural activities, channels of access and sources of agricultural information and associated issues. Discussions also helped to envision ways of tackling the problems. Home, farm and office visits, as well as FGDs with the participant groups (detailed in Table 9.1), proved to be valuable strategy in achieving the intended aim.

In the second stage, the focus shifted toward a more experimental design and development process with the participants. The aim of this stage was to gain insight about the possible solutions to the identified issues. At this stage, it was collectively agreed with the participants that the m-app will be suitable in exploring interactive ways of peer-to-peer knowledge exchange. After the design workshops, the developers made quick adjustments of the essential requirements of the m-app following the participants' feedback. Finally, the potential of the m-app in providing an interactive platform for collaborative exchange of knowledge about agroecology and agroecological approaches was demonstrated and evaluated. The third stage helped to gather a more nuanced perception of utilising ICTs such as mobile phone-enabled application for agroecological knowledge development in the study location. These processes are very important aspect of any given design science research (Helfert and Curley 2012) as they help capture the views and capability of all stakeholders involved as well as the applicability of the artefact (Cleven et al. 2009; Hevner et al. 2004; Kleine et al. 2012; Pries-Heje et al. 2008; Sein et al. 2011). Additionally, Woodard et al. (2014) suggest the importance of assessing the capability of the end-users of a given development project in order to minimise the challenge of abandonment after the project implementation. This is ideal for an agroecology development project in order to maintain sustainability and/or long-term use. Figure 9.3 illustrates the design framework of the application.

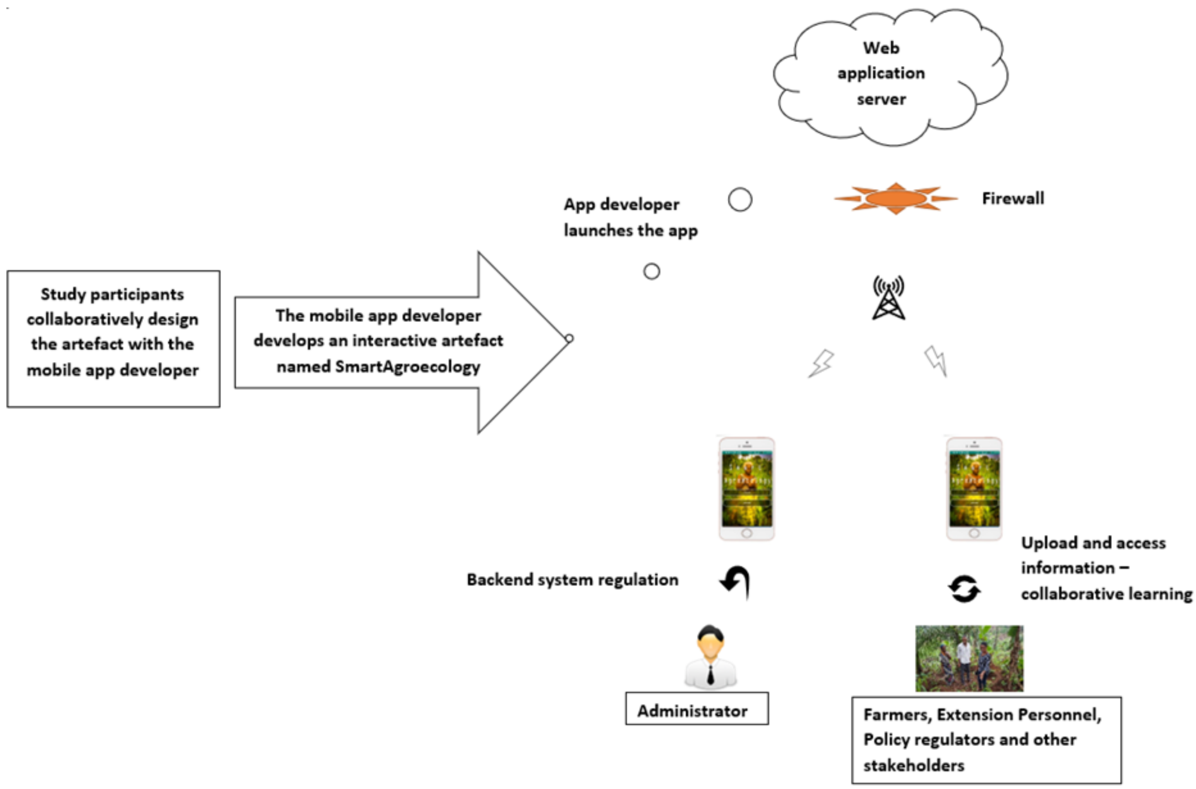

Figure 9.3: The design framework of the application (Field survey 2018).

9.3 Results

This section describes the general characteristics of the respondents and their ability to use mobile technology-assisted interactive platform and the varied responses of the respondents which are grouped into themes that address the study objectives.

9.3.1 Profile of the participants

Table 9.2 shows the participants' demographic data, highlighting their age, gender, level of education and level of experience in agricultural activities. The participants' ages ranged between 30 and 69 years with the majority being male. Their level of academic attainment varied with few farmers having tertiary education while the majority had secondary and primary education and all the extension personnel having tertiary education as their least qualification. The participants had varied years of experience in agriculture and agricultural activities. These results are equally important as they could imply that farming activities in the area are still mainly in the hands of the older male adults. Oseni et al. (2013) and Obayelu et al. (2019) in their respective studies, also confirmed that women farmers in Nigeria are less likely to engage in agricultural activities due to their limited access to land, labour, inputs and extension and advisory services. Similarly, Mohammed and Abdulquadri (2012) observed the gender inequality in the agricultural sector in Nigeria and called for a review of agricultural policies that currently place women at a disadvantage. All study participants have access to and/or own a smart or feature phones. There was no difference in their capacity to use mobile phones as well as the amount spent on airtime. A majority of the participants spend at least an hour per day using internet facilities for social interaction. Furthermore, the use of mobile phone for calls and texts appears common amongst the respondents. This is also significant as it could facilitate collaborative knowledge exchange.

Table 9.2: The demographic characteristics of the participants

Demographic characteristics	**Farmers (n=30)**	**Extension (n=20)**
Age (years)		
30 – 39	6	7
40 – 49	8	5
50 – 59	11	8
60 – 69	5	-
Gender		
Male	19	15
Female	11	5
Years of experience in agriculture		
1 – 9	3	7
10 – 19	7	6
20 – 29	20	7
Level of education		
Primary	9	-
Secondary	15	-
Tertiary	6	20
Competency in the use of mobile technology		
Basic	5	2
Proficient	17	8
Advanced	8	10
Average airtime cost used per week by each group [₦]	2586	2790
The range of airtime cost used per week [₦]	5500	4000
Hours spent using internet facilities in a day		
1 hour or less		
2 hours	3	2
3 hours and above	18	7
	9	11
Using mobile technology and internet facilities for		
Information seeking and sharing	8	6
Agricultural purposes	8	4
Socialising	5	3
All the above	9	7

Source (Field survey 2018).

9.3.2 Farming practices

The researcher’s aim was to understand the existing farming practices and explore ways to support farmers' learning and access to information on agroecological practices. The farmers were asked to describe their farming practices and the majority echoed that they use simple manual tools such as hoes, machetes, diggers etc. for cultivating their local fields/plots of land inherited from their grandfathers. These plots are located within their villages/communities and can be variety of shapes and sizes. An average landholding per household is generally between two to three hectares. Cultivation of crops generally commences after the first rain, however replanting of some crops can be continuously done throughout the planting season. While the farmers depend on external inputs for their agricultural production, only a few (20%) still maintain some of their traditional methods such as mixed cropping, crop rotation, seed selection and storage as well as intercropping which could be considered to be agroecological. On the other hand, there were issues raised in the use of external inputs such as the inputs being expensive and sometimes not effective, as well as the hybrid seed being damaged even before the next following planting season or after proper storage. Narratives from some of the farmers:

> *You see I use fertilizer and buy maize and cassava from the agriculture people, ehmm, the improve variety, but the maize does not germinate at times, and the cassava easily rotten in the soil*” (Farmer 1, Group 2).

> *I use fertiliser in my farm if stopping to use it will improve the yield, I do not mind stopping because the fertiliser and pesticides are very costly and you spend a lot of money to buy them*” (Farmer 7, Group 1).

During the discussion, all the extension personnel explained that the basic agricultural information available to the farmers is based on conventional techniques and knowledge where the farmers are encouraged to use the ‘best’ agrochemicals to improve yield. Thus:

> *We advise farmers to use these improved crop varieties and agrochemicals to increase their yield because most of these local varieties, especially maize, the sizes are small and yield is poor*” (Ext. personnel 16, Group 1).

The extension agents' promotion of farming practices that are contrary to agroecological principles is confirmed by Ajala et al. (2013) study which revealed that access to agrochemicals is the most agricultural information available to farmers through the extension services.

9.3.3 Participants' perception of agroecological practices

In order to determine the participants' perception of agroecology and agroecological practices, the researcher stimulated debates on the demerits of conventional agriculture as adapted from (FAO 2015; Kremen et al. 2012). During the discussion, it emerged that most participants, both extension personnel and farmers, have read and/or heard about the negative effects of agrochemicals on human health and environment but appeared not to be worried about it as they believed it is better to produce more food for the growing population. However, most of the farmers recounted that the effect of the agrochemicals on the soil is increasing and visible as many macro-organisms are becoming extinct on site. A narrative from one of the farmers read:

> *You know before we used to see the millipedes, even wild mushrooms and other organisms, but now is rare you see them in the farms*" (Farmer 9, Group 2).

Building on this debate, the researcher stimulated the discussion on the benefits of agroecological practices as opined by non-governmental organisations (De Schutter 2010; FAO 2015; 2018), scientists (Altieri et al. 2015; Altieri 2017) and civil society groups (AFSA 2017; La Via Campesina 2014; Nyeleni 2015). The fewer farmers who still maintained some agroecological approaches, were more vocal about the benefits and encouraged others to consider such practices. Furthermore, it was observed that most of the farmers are willing to practice agroecology, however, they emphasised the need for continued agroecological knowledge exchange among all stakeholders. On the other hand, most of the extension personnel emphasised that agroecology is still a developing concept that requires vigorous awareness to enhance its extension and/or knowledge exchange in Nigeria. They believed that the agricultural policy is yet to capture agroecology in the farming system. Additionally, it was observed that the extension services are faced with many challenges most important of these are a lack of funds and incentives for staff which ultimately affects the quality of service rendered to farmers. The farmers noted that the extension personnel rarely visit them. Most farmers indicated that they are eager to join online groups where they can share and receive information. These are typical narratives from the participants:

> *We face too many problems both administrative and welfare, so it is difficult to do your job if you are not motivated. Meeting with the farmers requires a lot of commitment so that will be difficult to achieve if the authorities care less about you*" (Ext. Personnel 16, Group 2).

> *It will be good if we have platforms or forum we can join to interact and gain information from others and not solely relying on the extension personnel. We can also recreate our own knowledge with others*" (Farmer 2, Group 3).

In understanding how the mobile phone-enabled application influences the participants' decision and choice of agricultural activities, they were asked to explain their thoughts about the initiative as well as the factors that can affect the application's wider use. The question further sought to understand if such interactive technology can be used for agroecology knowledge exchange and/or extension, hence their perceptions are highlighted below.

9.3.4 Perceptions about interactive agroecology knowledge exchange using mobile phone-enabled application

The participants' perception of the mobile phone-enabled application (m-app) was generally positive with the majority expressing interest in the potential benefits for agroecology knowledge exchange. The participants agreed to name the m-app 'SmartAgroecology' which in the participants' understanding, agroecological knowledge can be accessed through such mobile application. They expressed their satisfaction about the m-app as they collectively noted that it can raise awareness of agroecology practices as well as encourage transition. The farmers particularly highlighted that it can contribute to researchers' and extension personnel' awareness of farmers' needs as such enhance their livelihoods. However, there was considerable discussion around the receptivity and ability of the older stakeholders to continue to use the m-app beyond pilot. Some participants, particularly, wondered whether older adults would have the intellectual and attention capability to navigate through the multiple menus and icon options of the application platform in addition to comprehending the knowledge shared. This general discussion reflected the participants' perceptions about other potential older adult users. More than half of the farmers noted that they find the m-app easy to interact with and further emphasised that it can encourage collaborative knowledge exchange as illustrated by these farmers' comments:

> *"Collaboration is important and sharing our own knowledge is very necessary as many of us have limited clue about agroecology generally while others seem to be knowledgeable in the approaches, so it will be a good platform to engage with everyone including the extension personnel*" (Farmer 11, Group 1).

> *"I see the demonstration of this application as something that is in existence already. The fact that it is allowing everyone to contribute to whatever the issue is, is worthwhile. You feel you are part of the knowledge expert not seen as someone who does not have anything to offer but waiting to be fed with information"* (Farmer 9, Group 4).

Also, the extension personnel seemed interested in innovations that can enhance their agricultural activities as well as reduce the cost of operations and travel. Some of them expressed their willingness to adopt the collaborative approach for knowledge sharing Thus:

> *"The app will help us understand the fundamental principles of agroecology and being able to effectively integrate them into our practices and especially the information we share with the farmers. It can facilitate our innovativeness in the face of challenges and to be able to share best practices*" (Ext. Personnel 7, Group 2).

9.3.5 The perceived barriers to the application's (i.e. SmartAgroecology) wider use

Although some of the participants emphasised imperativeness of integrating mobile technology to facilitate agroecological knowledge exchange, there were other factors which they highlighted that can affect the wider implementation. The participants reaffirmed that some of the rural communities still have erratic electricity supply which could limit the use of the application. A general concern was also raised about the literacy level of future users to smoothly operate the app. The participants also echoed that there may be a lack of trust among users in terms of data protection as well as individuals' scepticism about the risk of malware and/or data theft. An excerpt from the discussion:

> 'Y*ou know people may be uncomfortable registering their presence on the app because they feel unsure about the genuineness of the app, even people that may not know much about how to operate it can be worried too'* (Farmer 8, Group 2).

> '*Regular electricity is still an issue, even some times in a week, one has not seen light, though people have resorted to using generator for their individual households and a lot people have more than one phone to keep up. Or even the internet to use the app, so it means that we have to be using the mobile subscription which is what some many of my people do now to get on*' (Farmer 25, Group 3).

Another concern raised was the degree of poverty among the Nigeria populace. The participants reflected that, this may affect other potential users' access especially in affording feature and/or smartphones, which may hamper their adoption of the use of the mobile phone-enabled application.

9.4 Discussion

The interactive exchange of agroecological knowledge proposed by this study in the area was well received as most of the farmers who expressed their willingness to transform their existing agricultural practices to agroecological practices so long as they have access to expert skills. Farmers are often characterised as being creative in recreating their traditional knowledge (FAO 2007), however, in the case of these farmers in this study, their traditional methods are almost extinct with only a few still maintaining the practice. The findings also support Amujoyegbe et al., (2016) that most farmers in Nigeria use agrochemicals for productivity.

The results further show that the extension personnel and farmers are aware of the negative effects of agrochemical and other unsustainable agricultural practices on human and ecosystem health but appear to be more interested in increasing food production. This corroborates Mgbenka et al. (2015) who opined that most farmers in Nigeria seem to be more interested in high productivity and not the benefits of sustainable practices such as organic farming. This study further reveals that many farmers are beginning to experience the impact of extensive agrochemicals on biodiversity as some of the natural macro-organisms that are supposed to be present in the soil are nearly extinct. For example, one of the farmers said that they no longer see millipedes in the soil. This finding, therefore, supports several mainstream institutions and scientists (FAO 2018; Gliessman 2014), that state that extensive use of agrochemicals can destroy soil biodiversity and the ecological complexes within the ecosystem.

This study provides insight that the use of mobile technology such as a mobile phone-enabled application can facilitate interactive agroecological knowledge exchange. The application can support farmers' self-efficiency and ability to succeed in learning new practices collectively. The study also reveals that collaborative exchange of knowledge on research about ecological principles and local knowledge amongst farmers, extension personnel and other relevant stakeholders can enhance co-creation of agroecological knowledge. Hence, the farmers can contribute their traditional or local expert knowledge and the researchers can contribute their agroecology-based research knowledge, as well as the extension personnel, bring in their expert skills to enhance farmer-to-extension personnel relationship. As such, the interaction can improve collaborative agroecological knowledge exchange and transition.

This study joins Altieri (2015) in advocating for respectful collaboration among relevant stakeholders that recognises farmers' indigenous knowledge, however, using a mobile phone-enabled interactive application such as SmartAgroecology in facilitating the collaboration. The PADR framework proved to be a valuable technique in creating the application. Although the use of such initiative has shown the potential for enhancing farmers' interest in agroecological practices, there were factors that could affect the wider use. These factors include unreliable electric power supply which may affect the individuals' mobile phone operation and poor communication technology skills amongst prospective participants as well as trust issues regarding data protection and risk of malware. Among the identified factors is poverty which has been reported to be common in the rural areas of Nigeria, affecting smallholders (Otene et al. 2017). These findings are similar to other mobile technology studies relating to the use of mobile applications (Kang 2014; Malik et al. 2017). A survey carried out by the Gillwald et al. (2018), indicated that only 66% of Nigerians are connected to the main electricity grid. It also recorded that a significant number of Nigerian households (22%) do not have an electricity connection. In addition to household access to communications services still low, recorded at 3% of all households in Nigeria having working internet (Gillwald et al. 2018). Unlike her West African counterparts, such as Senegal and Ghana, Nigeria does not have a nationally backed network[47] through which high-speed internet can be made available to the entire households, businesses, individuals etc. in the country (Ajimotokan 2017). Although, various factors attributed to the poor penetration of household internet including, collapse of companies which supplied fixed wireless communication to homes and individuals, as well as privatisation of network providers, this could hamper the use of existing and/or future applications in the country. So, people or individuals mostly access internet via mobile subscription (Rimi and Chudi 2017), and the poverty situation could also affect ownership of feature or smartphones. This study further acknowledges that some of these factors can limit the use of mobile phone-enabled initiatives in many developing and low-income nations (Akpabio et al. 2007; Otene et al. 2017; Rimi and Chudi 2017).

Finally, the opportunity for farmers to share knowledge and access necessary information with the confidence that extension personnel are always available on the platform to attend to their information needs can promote their commitment. Accordingly, Bandura (1997) noted that observing peers promotes individual capabilities. Therefore, the integration of the mobile phone-enabled application opens more innovation within the agroecological farming system.

The m-app can offer an interactive platform for the farmers, extension personnel and other relevant stakeholders such as the agricultural policy regulators. All the involved individuals in the framework are required to use a mobile phone – be it a feature or smartphone, to communicate within the platform through a mobile telecommunication

[47] The National Government announced plans in November 2017 to develop an 18 000 km fibre network, but it is unclear how, if, or when this would be done (Ajimotokan 2017).

network facility. Through the mobile phone, the user can share and/or access information on the platform. Where there are agroecology-based skilled extension personnel, they can respond to any query raised on agroecological practices. The policy regulators can adjust policy structures and respond to queries from the farmers. The researchers can provide agroecological-based research that can inform farmers' practices. The data transmitted by these stakeholders will be secured such that any sensitive information transmitted from the various mobile application installed from the cloud will be encrypted including their passwords. Moreover, this type of technological initiative has the ability to promote democratisation of agroecological knowledge in the area and could be maintained by ensuring a revenue model that involve institutions covering the potential cost of access to the service. As such, a decentralised, bottom up, and participatory process of knowledge creation tailored to the unique local contexts of the farmers can be improved through the application. These identified barriers could be overcome by providing subsidies for smallholder farmers to get a smartphone and training for digital illiterate participants on how to use such initiatives, however, this may require the intervention of government and willing NGOs. Although the participants in this survey were able to use the m-app irrespective of their age and varied level of proficiency in English, as well as competency in the use of mobile technology, this may not be same with other potential users elsewhere in Nigeria given that this study only took place in the southeast and with fewer participants. As such, it is imperative to consider sustainability in design for future initiatives (see Remy et al. 2018).

9.5 Conclusions

The study explored the farmers' and extension agents' perception of agroecology and the potential of a mobile phone-enabled application to enhance the transitioning to agroecology. The study elucidated the importance of applying participatory action design in the development of agricultural information enhancement initiatives and maintained that the process will encourage collaboration amongst farmers and all actors in the agricultural value chain and specifically for agroecology. Instead of depending on the conventional extension service delivery method that is still in practice in Nigeria, farmers' learning needs can be embedded within the learning environment alongside other experts in agriculture. The study observed that farmers are willing to adopt agroecological practices that are sustainable and capable of ameliorating agriculture induced environmental issues. Though this study's findings cannot be generalised due to the methodological processes i.e. purposive sampling and non-representative sample, the study suggests that a mobile-enabled application such as the SmartAgroecology application has the potential to enhance agroecological practices in Nigeria and could impact positively on agricultural policy for the benefit of farmers and the country's agriculture.

Agroecological transition in Nigeria requires awareness to hasten and this study has demonstrated that a mobile phone-enabled interactive application has the potential to contribute to the required action needed to achieve the objective. Nigeria is well-positioned to pioneer revolutionary agricultural developments based on agroecological techniques which would improve productivity, improve farmers' livelihoods, the rural economy of rural households as well as care for the environment. The mobile phone-enabled application can provide direct access to agroecological information to farmers. By so doing, it can reduce or even remove the limitation of dependency on government-run extension services and institutions which are prone to bureaucracy, politics, poor funding, insufficient manpower, and maybe propagate agroecological policies. The study acknowledges the factors that could hinder the use of the initiative beyond the pilot and recommends that a further investigation is needed to understand how to enhance collaborative agroecological knowledge. It also recommends that agricultural knowledge and innovation system in Nigeria should be assessed for improvement in favour of enhancing agroecological transition.

Chapter summary

This chapter has explored the potential of the mobile phone-enabled application principally SmartAgroecology in enhancing the interactive exchange of agroecological knowledge. Accounting for the strategies that can enhance the sustained positive impact of such initiatives, this study confirmed that understanding of target user's needs and skills and respectful relationship between the implementers and users can facilitate knowledge exchange as well as trust on the initiative. The chapter concludes that such m-app would provide opportunities for agroecological knowledge improvement in Nigeria.

The demonstration and conclusion that mobile-phone interactive initiatives can facilitate the exchange of agroecological knowledge and collaborative learning brought the research activities to the end. Hence, given the nature of this thesis (thesis by publication), the following chapter (Chapter 10) considers the chapters together as a whole by critically analysing the entire outcome of the aims and objectives of the study and outline the key research findings, as well as knowledge gaps and future research direction.

Chapter 10: Discussion and Conclusion

10.1 Introduction

This chapter discusses the overall findings of the study. At the outset this study had three broad aims: firstly to understand how agroecology is practised and understood in Nigeria; secondly to evaluate the opportunities for wider adoption of agroecological techniques and thirdly to understand the challenges to transitioning from the current conventional farming system to a more agroecological approach. As the research developed, the broad aims were developed into five objectives, each of which aimed to tackle a particular aspect of the study in more detail. Given the pragmatic view of the researcher and agroecology being transdisciplinary in nature, a multi-method approach was adopted. As a result, the study examined an innovative way of delivering this transition to agroecology by exploring the potential use of mobile phone-enabled applications or m-apps to enhance the interaction and exchange of agroecological knowledge between farmers, extension agents, and other agricultural stakeholders.

Initially, the study findings were planned to be presented as a traditional thesis. However, early findings written up as articles were accepted for publication in conference proceedings and peer-reviewed journals. Therefore, the decision was made to present the final thesis as a thesis by artefacts (also known as a thesis by publication). The general discussion at this point presents a critical analysis of the themes that arose from the primary data and relates them to the existing literature.

This chapter begins by presenting the study aims and objectives in Table 10.1. This table also includes the various individual sub-objectives that emerged from each of the main study objectives, indicating where they were addressed in the thesis and also gives an evaluation of their achievement (see Table 10.1). After critically discussing the key findings, the chapter then comments on the contribution to knowledge, limitations of the overall study, followed by a critical reflection of the implications of the study findings, recommendations and suggestions for further research are also included. It finally concludes with the researcher's self-reflection and an overall appraisal of the entire study outcome.

Table 10.1: How the study methods meet the aims and objectives, key findings, the chapters where they were addressed, and evaluation of the achievement

Study objectives (1 -5) and Sub-objectives/ research questions		**Methods used**	**Outcome or Key findings**	**Chapters where aim and objectives are addressed**	**Achieved?**
Contextualise the importance of the study by exploring the current state of agroecology in Africa and ascertain the opportunities and challenges in the region (**Objective 1**)	What is the effect of agroecological practice in Africa? What are the drivers and challenges to the transition towards agroecology? Are there opportunities for policy contribution towards agroecological development?	Secondary literature (scoping review) Problem identification and motivation Defining the objective for the solution	Identified the positive impacts of agroecological approaches on smallholder farmers' livelihoods Agroecological approaches enhance farmers' productivity, health and nutrition as well as improve their farm biodiversity, soil health and yield Limited support for transitioning farmers and agroecology development mainly from agroecology movements such as AFSA, Groundswell etc. Limited research and available information about agroecology and agroecological approaches Agroecology is gaining prominence in the African region	Chapter 2, 3, 4, 6 and 7	This first sub-objective was achieved by proving that agroecology and the practices contribute to the 17 SDGs, promote social, economic, and environmental conditions of smallholders (see sections 3.2.1 – 3.2.3). The second confirmed that the transition towards agroecology is driven by its affordability, profitability, and viability in improving productivity and ecosystem restoration (see section 3.2.4). Policies that are not in favour of smallholder farming, lack of required information on agroecology and the

					resources, and other intrinsic and extrinsic factors such as personal traits, agency influence, perceived required labour hinder the transition towards agroecology (see section 3.2.5). The third confirmed that agroecology is gaining increasing attention and fewer African countries like Tanzania, Uganda etc. have begun to support agroecology through policy reforms and NGOs support, but in Nigeria agroecological approaches is in infancy and no agricultural policy yet for the development (see sections 1.1 -1.2; 6.3.2).
Investigate the role of public agricultural extension and advisory services in enhancing agroecological knowledge and farmers' transition towards agroecological	What are the agricultural activities in the study area? What are the extension personnel activities? What are the factors that influence the extension activities?	Problem identification and motivation Defining the objective for the solution Secondary literature	The existing agricultural regime in Nigeria significantly influences farming activities and does little to support the dissemination, knowledge, and skill acquisition of agroecology and agroecological approaches in the area The challenges confronting the progress of transitioning towards agroecological practices in the area include the perceived labour-	Chapter 1, 2, 6, 7 and 9	This first sub-objective was achieved by confirming that the agricultural practices in the area are subsistence, smallholder farmers depend exclusively on agrochemicals for yield maximisation and only a few farmers maintained a few of their

practice in Nigeria (**Objective 2**)	How do extension activities influence farming activities? What are the key constraints to the wider adoption of agroecological and/or organic farming methods?	Semi-structured individual in-depth interviews Participant observation	intensive nature of agroecological approaches, poor access to required resources, and perceived unfavourable environmental conditions. Other factors influencing farmers' perception of agroecological practices include the concept that conventional methods require less labour and that they lack agroecological expertise due to a lack of formal agroecological-based information Although most of the surveyed farmers depend on the use of agrochemicals for production, a few still maintain some of their traditional practices such as the use of neem leaf solution for biological control of pests and diseases, crop rotation, mixed cropping, shifting cultivation etc. The surveyed farmers showed a general willingness to adopt or transition to agroecological approaches as they expressed concerns about the negative impacts of conventional methods		traditional farming methods (see sections 1.2 – 1.2.2; 2.1.4). The second confirmed that the extension agents' activities improved in the area due to the presence of AVS programme (see sections 6.3.1 – 6.3.2; 7.6.3 – 7.6.5). The third established that the extension services in the surveyed area include providing crop and livestock management initiatives that are based on the current agricultural policies that are characterised by conventional methods (see sections 6.3.1; 7.6.2 – 7.6.5). The fourth noted that smallholders are inclined by the notion of yield maximisation (see sections 6.3.2; 7.6.2). Key constraints to agroecological transition include lack of awareness on agroecology, lack of access to and available agroecological

					information, lack of system support – that is in terms of institution and policy (see sections 3.2.5; 6.3.1 – 6.3.2; 7.6.4)
Evaluate farmers' knowledge of agroecology and understand their information needs and sources of information (**Objective 3**)	Evaluate the agricultural information needs of the farmers Consider how agricultural knowledge is exchanged among the stakeholders Evaluate the relevant structures in place for knowledge exchange Determine the factors that contribute to effective knowledge flow Propose a knowledge exchange/transfer framework that integrates mobile technology to enhance agroecological practices.	Defining the objective for the solution Secondary literature Semi-structured individual in-depth interviews Participant observation	There is formal knowledge transfer which is delivered top-down from the agricultural knowledge institutions and informal systems which are shared within the farming community The informal system creates the opportunity for farmers to share their knowledge and learn from each other, as well as form problem-solving strategies The indigenous or traditional practices help smallholder farmers to manage their farming issues even though they practice conventional farming Identified that mobile phone facilities can facilitate access to and source for knowledge, be it agroecological or conventional A mobile phone-enabled interactive platform can improve the collaborative exchange of knowledge amongst agricultural knowledge actors and especially ones living in remote areas	Chapter 3, 6, 7, 8 and 9	This first sub-objective confirmed that smallholders require information about how to improve production, financial procurement, and access to market (see sections 6.3.2; 7.6.2 – 7.6.4). The second established that smallholders share and access knowledge informally within their communities and receive a top down delivery of information from extension service (see sections 7.6.4 – 7.6.5). The third confirmed that structures such as community meetings, communal networks and mobile phone communication facilitate exchange of knowledge (see sections 7.6.4 – 7.6.6). The fourth ascertained that the use of mobile phones and face-to-face

			Face-to-face methods of agricultural information sharing are equally important for agricultural knowledge development.		communication are efficient for an interactive knowledge exchange (see section 7.6.6). Fifth established that incorporating an interactive mobile phone-enabled initiative can improve access, sourcing and exchange of knowledge and information (see section 7.6.6).
Evaluate the landscape of mobile phone-enabled services in Africa and ascertain the challenges for sustainability (**Objective 4**)	What are the current trends and progress in the use of m-Agri services for enhancing agriculture and smallholder farmers' livelihoods in Africa? How can all relevant stakeholders involved in design, development, deployment, and use, approach the challenges of m-Agri service(s) for sustainability? Are there specific functionalities for the m-Agri	Problem identification and motivation Defining the objective for the solution Secondary literature (scoping review)	Mobile phone-enabled applications or m-Agri services are contributing to the improvement of smallholder farmers' livelihoods in Africa generally such that they can access financial, marketing, and advisory facilities Identified challenges to the sustainability of m-Agri services which include the service developers not considering the target users' digital competence and literacy skills, one size fits all strategy from developers, target users' wavering trust in the service either on the content or for their data protection and security The strategies that can enhance the sustainability or long-term use of the m-Agri services include that the design should incorporate target users' situation and their	Chapter 1, 4, 7, 8 and 9	The first sub-objective confirmed that the use of mobile phone application in agricultural development and smallholders' livelihoods improvement is increasing generally in Africa (see section 8.4.1). The second and third established that the initiators of such mobile applications relevant for smallholders' use can enhance their long-term use through ensuring that the target users are involved, and security and fairness guaranteed in the design, development, and

	services that can enhance sustainability? What should the role of the policymakers be in promoting m-Agri sustainability?		environment, reusing and improving any existing initiative or perfect their imperfections to serve the purpose (e.g. rewriting their code, upgrading the software etc.), as well as maintaining an open-source and data-driven approach		implementation processes see sections 8.4.3 – 8.5.6). The fourth ascertained that policy reforms that will support both initiators and users can help to promote long-term use and impact (see section 8.5.7).

Develop, demonstrate, and evaluate the potential of interactive methods, principally a mobile phone-enabled application '*SmartAgroecology*' for enhancing agroecological transition (**Objective 5**)	To develop, test and validate a mobile application that can enhance access to collaborative agroecological knowledge exchange using a participatory approach To evaluate whether farmers' access to agroecological knowledge through the application can influence their transition to agroecology To assess whether the application influences the extension personnel's information delivery approach To evaluate the barriers to the application's wider use in Nigeria	Problem identification and motivation Defining the objective for the solution Focus group discussions Design and development workshops Demonstration workshops	Identified that the mobile phone-enabled initiatives such as SmartAgroecology can improve the interactive exchange of agroecological knowledge and information as well as other relevant agricultural information Continuous collaboration with all relevant stakeholders, as they co-create, co-validate and co-share agroecological-based knowledge, with the farmers having more knowledge generation and decision-making power influenced by their traditional knowledge, can promote agroecological knowledge and transition Factors such as erratic electricity supply and sparsely situated internet facilities, as well as fear of sensitive data insecurity on the side of the potential users, were identified as the strain that may affect the wider use of the application.	Chapter 1, 4, 6, 7, 8, and 9	The first sub-objective established the design and development of an m-app; however, the completeness and impact were not fully confirmed (see sections 7.6.6; 9.3.5. The second and third confirmed the potential of such m-app to enhance interactive exchange of knowledge and was not particularly tested for only agroecology knowledge exchange, however, the idea of incorporating an interactive m-app for extension services was well received (see section 9.3.4). The fourth ascertained that economic, social and environmental factors can hinder the wider use of such m-app (see section 9.3.5).

Source: Author's compilation

10.2 Overall study key findings

This section discusses the overall key findings and their relationship with the existing literature.

10.2.1 State of agroecological practices in Africa

Of the various strategies available that can ameliorate the negative effects of conventional agriculture and curb food insecurity, agroecology is gaining support worldwide and there are many calls for the adoption of agroecological practices and a transition towards agroecology (HLPE 2019, 2020; De Schutter 2011; FAO 2018). Agroecological practices have proven viable in contributing to the improvement of smallholder farmers' livelihoods in Africa and have contributed in various ways to achieve the 17 United Nation's Sustainable Development Goals (AFSA 2017; FAO 2018; Millennium Institute 2018). This present study's review outcome confirmed Didarali and Gambiza (2019) study that agroecological practices amongst smallholder farmers in South Africa and Zimbabwe are beneficial and helped them to improve their health and wellbeing. Reporting on the general impact of agroecology, Nyantakyi-Frimpong et al. (2016) concluded that HIV-affected farming households that engaged in agroecological practices in northern Malawi recorded an improvement in meeting their food, nutrition, labour and income needs, while also sustainably managing their natural resources. Similarly, Namululi (2011) reported that agroecological practices helped farmers in Uganda to become more food secure than other farmers who do not practice agroecology. However, in the part of Nigeria as an African country, this present study contributed to the claim that agroecology as a set of practices is still developing at different regional levels, with the majority of the organised activities in the form of organic agriculture taking place in the south-western region (Adebiyi 2014; Mgbenka et al. 2015). Certainly, this has been observed by different studies as they argue that Nigeria compared to other African countries is lagging where agroecology related practices are concerned (Mgbenka et al. 2015; Olaito 2014). Moreover, this study confirmed that although smallholder farmers in this study were in tune with conventional systems and depend more on improved seeds and agrochemicals, they still maintain some of the traditional practices that are widely accepted as agroecological practices. A similar observation was made by Ajibade and Shokemi (2003) and Olatokun and Ayanbode (2009) in earlier studies that smallholder farmers in Nigeria still practise some of their traditional practices which could be classified as an agroecological practice by default. This study further corroborated the fact that the integration of livestock into crop production can enhance agroecological practice such as composting or green manuring (Reents et al. 2008).

The present study also demonstrated that the smallholder farmers in the study area who maintain agroecological by default practices attested to the viability of such practices in improving crop yield and soil health. This finding validates Adebayo and Oladele (2014) in their findings that smallholders in southwestern Nigeria began to adopt cover cropping, composting and animal manuring due to their positive impact on soil nutrients. In an experimental report, Ibeawuchi et al. (2007) noted that intercropping with land-race leguminous plants in a small plot cassava-based farm in Owerri south-eastern Nigeria resulted in higher yields. A similar report in the same region confirmed that such approaches can improve soil fertility maintenance, biodiversity, and yield (Nweke 2018). This is a confirmation that agroecological approaches are viable and can uphold the positive impacts on smallholder farming in Nigeria as in other African countries where such practices are gaining more recognition.

Furthermore, the impact of agroecological practices on smallholder farmers' income as a result of diversification of crops and animal production, and their reduced or zero dependence on agrochemicals etc. as found in the scoping review is an important driver of transition towards agroecology. This study further recorded that the viability of agroecological practices in enhancing crop yield resulting in food security, also contribute to farmers' transition. In another perspective, Conrad (2014) contested this to argue that agroecological practice has a limited positive impact on food security amongst smallholder farmers in Malawi. It is therefore important to acknowledge that food security can also be influenced by increased income (FAO 2015). Despite these positive impacts and the driving factors, this study revealed that smallholder farmers' transition towards agroecology in Africa is lagging due to a lack of appropriate information for farmers who wish to practice agroecological practices and support for the transitioning. It was also recognised that agroecological practices have lots of potentials in the African region but require a different type of government support that goes beyond helping farmers' access to external inputs to one that encourages farmers to use on-farm inputs. In addition to a government that provides incentives to farmers who contribute to lowering the effect of climate change through their various environment-friendly practices such as agroecological practices. Despite these challenges facing African smallholder farmers, the transition towards agroecological farming systems is gaining a foothold in the region, although, in the case of Nigeria, the progress is still in the early stages.

Transitioning to agroecological farming practices requires that the farmers need access to agroecological information and learning (De Schutter 2010; Herren et al. 2015). Though equipped with their traditional farming knowledge, farmers look to agricultural advisory experts for information that fits their local context (Lwoga et al. 2011). However, one of the key challenges outlined by the present study has been that smallholder farmers have limited access to agroecological information due to the extension and advisory support for conventional agriculture. This continues to be largely reflected in the current agricultural policy in Nigeria (FMARD 2016), where the support for conventional farming practices remains dominant and the traditional practices are seen as primitive, inefficient, and unproductive (Olatokun and Ayanbode 2009; FMARD 2016; Iyegha 2000). This was also echoed in this current study, where farmer participants who practice some agroecological practices were encouraged by the extension agents to substitute practices such as the use of local varieties for improved varieties managed with extensive use of agrochemicals. Although the farmers surveyed in this present study were more inclined to use conventional methods to increase their production, they all expressed their willingness to adopt agroecological farming systems' values. The smallholders' expression of interest could be motivated by their perceived usefulness of agroecological practices and capacity to implement such practices (Ajzen 2011). The farmers' willingness to adopt agroecological approaches is important, however, actually changing their practices requires: 1) access to information; 2) opportunities to learn new skills; 3) incentives for a change; 4) favourable policies; and 5) an understanding of how social and/or personal traits can also influence their behaviours towards change (Davis et al. 2002; Fishbein and Ajzen 2010; Venkatesh et al. 2003). This, therefore, signifies the importance of ascertaining the impact of institutions such as extension and advisory services, research, policy, and education on the development of agroecological practices in the area.

10.2.2 The influence of institutions on agroecological development

Nigeria's agricultural extension system underwent several reforms which included the establishment of an adopted village scheme [AVS]. Sani et al. (2015), confirmed that farmers' access to extension services improved as a result of the AVS. This present study validates Sani's study and further confirmed that the extension agents' activities in the study area, influenced the smallholder farmers' farming activities. It was also observed that, although direct contact with farmers has been established in the area through the AVS, the system still encounters challenges such as lack of budgetary allocation for the extension agents' transportation resulting in irregular visits and/or no show after few contacts with the farmers. Previous studies also concluded that the AVS had little impact on the poor extension agent to farmer ratio, currently estimated at around 1:5,000-10,000 (Huber et al. 2017; Ogbe 2016). These challenges could further hinder the development of agroecological systems generally in Nigeria and especially in the study location should such scheme be adopted for agroecology, therefore, alternative approaches such as the use of interactive m-apps can be used to ameliorate such issues.

Agricultural activities in Nigeria have not proved productive as reflected in various studies that outlined the challenges facing smallholder farmers in the aspect of their economic, social, and environmental conditions (Aikhionbare 2015; Nwaiwu et al. 2013; Oguamanam 2015). The current study confirmed that smallholder farmers are faced with purchasing external inputs at exorbitant rates, changes in weather conditions, consistent replanting of improved seeds due to seedlings failure, soil infertility, increasing infestations of pests, diseases, and insects, as well as health issues. This could be the reason behind the type of information they seek, as it was highlighted that information on how to control diseases and pests, improve seed preservation, sustain yield, and enhance soil fertility were the key information needs (see Fishbein and Ajzen 2010). These challenges could be a drive to encourage them to engage in agroecological practices while expecting improvements in their livelihoods through various agroecological practices. As Meijer et al. (2015) pointed out, intrinsic and extrinsic factors can influence farmers' decision-making towards sustainable practices like agroecological practices.

An effective agroecological farming system for smallholder farmers demands agricultural information that is compatible with their existing traditional knowledge, thereby helping them to develop agroecological approaches that are adaptable to their local context (see Altieri 2017). However, actualising such a system could be challenging and difficult in Nigeria as this study revealed that the agricultural information available to the smallholders in the area is based on the use of intensive or conventional systems for crop and livestock management. The study further demonstrated that farmers' access to agroecological information through the extension agents is limited because the extension agents' mandate does not include agroecology and agroecological practices. Even the surveyed farmers who were not under the AVS attested that the agricultural information available to them through the extension agents is characterised by conventional systems (see Appendix 24). Detailing the role of the agricultural extension and advisory services, this study identified that the extension agents do little to enhance the exchange of agroecological knowledge due to lack of institutional extension system for agroecology and agroecological knowledge and practices as well as poor agroecology research and lack of presentation of any case studies.

Critical to achieving agroecological development at the farm level and associated livelihoods improvements for the smallholder farmers is the institutional environment available to support them in the process of transition. Having examined the role of the extension agents which is of particular importance for smallholder farmers' transitioning towards agroecology as they are directly involved with them, this study highlighted that the existing federal agricultural promotion policy, i.e. the agricultural transformation agenda, appears to be more agribusiness focused. This is because the policy encourages the use of agrochemicals, more research in genetic modification of organisms, irrigation practices and the use of hybrid or improved seeds, which in turn influence the agricultural information available to the farmers. Under the influence of this agricultural policy, farmers are encouraged to purchase new improved seeds every planting season and are discouraged from using their local varieties because the local varieties are perceived as low quality by the extension agents. This implies that to situate an agroecological system in Nigeria requires grassroots awareness on the importance of agroecological-grown or local varieties and more scientific and social research to continually prove the viability and sustainability of such varieties in improving yield within the farmers' local context. Even a report by the AFSA and GRAIN (2018) noted that farmers' rights to their seed systems are being increasingly weakened with various restrictive laws, protocols and trade agreements (e.g., include the Arusha Protocol for Protection of New Varieties of Plants, UEMOA [Union économique et monétaire ouest-africaine] etc.). Notwithstanding denials by the advocates of industrial seed systems and widespread government supposed ratification of global agreements to safeguard agricultural biodiversity. This situation, therefore, requires strong collaborative and political will to influence the existing agricultural policy in favour of agroecology. Although this could be a challenge, as the present policy regime in Nigeria is agribusiness focused, hence, achieving any form of change may require grassroots movement that can lobby for agroecological agenda at the policy level. The majority of the smallholder farmers surveyed including ones not directly under the AVS depend on agrochemicals for yield enhancement and a few still incorporate some of their traditional methods in their small farm holdings with little or no advice from the agricultural extension agents. While few farmers practise some of the traditional methods but lacked expertise in management, the extension agents also expressed a lack of agroecology extension skills to assist the farmers in managing their traditional knowledge-based activities. Although change takes time and can be very uncertain (Dwyer et al. 2007), these findings suggest that the situation is a high-level policy issue within the agricultural institutions, which requires a fundamental change in the existing agricultural policy. While this is important, it is also critical to recognise that any structural change involving food systems might be faced with push back by the existing model or political interests (see Magrini et al. 2019).

This study also demonstrated that the majority of the surveyed extension agents are yet to participate in any training on agroecology and agroecological practices. This means that the majority have not had the opportunity to undergo the requisite training required for the efficient dissemination of agroecological approaches to the farmers. The findings validate Edeoghon and Idele (2012) that the extension agents in the south-eastern region of Nigeria are yet to be exposed to adequate training on environmental sustenance strategies. Similarly, Okwoche et al. (2011) claimed that the majority of the extension agents in the north-central states of Nigeria had inadequate in-service training on climate change adaptation strategies. In a similar study carried out in Delta state Nigeria, Ajieh and Okoh (2012) stated that farmers in the area had a low level of awareness and knowledge of locally adapted soil recovery strategies due to lack of access to the required information from the extension agents. The implication of these empirical findings is likely because of the lack of adequate training and enlightenment on the side of the extension agents about the benefits of agroecology and related practices and the need for a shift to adopt the practices. These findings imply that the agricultural and extension activities in Nigeria are largely dependent on conventional systems. This could also suggest that using the extension agents to actualise agroecological knowledge extension would not be effective in the short term, as the current situation needs a change in policy and training provided for the extension agents.

Remarkably, the lecturers surveyed in this study echoed that there was no established agroecological-based course(s) in their institution. Moreover, it was further noted that the explicit knowledge available for the agricultural professionals are based on conventional agricultural practices that are the same as the knowledge generated by the research institutes. The findings validate a narrative study by Aiyelaagbe et al. (2009) which stated that many Nigerian tertiary institutions lacked relevant expertise in agroecological related courses and most staff in such institutions were trained exclusively in conventional farming. The situation requires greater awareness about agroecology, benefits of agroecological practices, and extensive agroecological skills' training for all relevant field-based stakeholders (e.g., extension, researchers, market actors etc.). Institutionalising agroecology in Nigeria requires the collective efforts of all stakeholders including academic, research and policy institutions as well as the farmers. It is important that the extension agents are trained on agroecological approaches, agroecology research made fundamental in agricultural universities and research institutes and policies redirected in favour of agroecology promotion to enhance the transitioning. Additionally, the system should encourage farmers' contribution to develop their traditional knowledge through collaboration. However, these expected outcomes might not be guaranteed given the politico-economic structures that determine agri-food systems and the dominant conventional systems in Nigeria (see Bernstein 2016; McMichael 2016; Meynard 2018). The non-existent support for an agroecological system in Nigeria will have a detrimental effect on the development of agroecology and therefore, it becomes crucial to ascertain any source of agroecological information and knowledge that can be leveraged to enhance access to and sources in Nigeria in the short-term, especially at the local or farm level which may be transferred to the institutional level in the long-term. This is also important given that smallholder farmers are equipped with their own local, ecologically-based indigenous knowledge that is specific to their local environment in managing their agricultural activities (Mosissa et al. 2017), it is, therefore, best to engage them in driving the process of transitioning from the grassroots.

10.2.3 Sources of agroecological information and knowledge

The fact that farmers in this survey expressed willingness to engage in agroecology required the exploration of the sources of agricultural information and knowledge in the area. Nigeria's agricultural sector and the associated AKIS and AIS are largely controlled by the state governments but the majority of agricultural production directives are assigned directly from the federal government (Adesina 2014; Agwu et al. 2008). This was also echoed in the present study as the participants elucidated that the extension and research institutions are answerable to the government of the day in ensuring increased agriculture and food production. And as earlier stated, these institutions are more inclined with the conventional systems of agriculture which could suffocate any idea of agroecological transitioning aimed at them for enablement. The notion that farmers' access to information and knowledge sharing is the key to all aspect of agricultural development (Chibonga 2012), cannot be overemphasised. Thus, transitioning to agroecological production could be dependent on which type of knowledge is accessed, why it is shared, the usefulness and ease of use and which sources they are from. Their behaviour change could also be dependent on trust and other facilitating conditions. This study showed that the main sources of agricultural information and knowledge in the area were from both formal and informal sources. Where the formal source is the organised institutions such as extension, research, education, agricultural ministries, input companies etc., whereas the informal source is smallholder farmers' local networks such as friends, family, and neighbours. These findings align with some other studies carried out in Nigeria. For example, Omoregbee et al. (2013), noted that the major sources of agricultural information available to cassava farmers in Delta State Nigeria were the ministry of agriculture, friends, and neighbours. Similarly, Adetimehin et al. (2018) discovered that friends or relatives were the main sources of information used by rice farmers in Ondo State Nigeria. However, this current study observed that the informal sources and exchange of knowledge at the community level were the major source of locally adapted ecological knowledge that is widely accepted as agroecological knowledge in the area. The study further confirmed that the smallholders' first point of contact for the problem-solving initiative within their local context is their local networks. These findings support other previous studies on the role of farmer local networks in agricultural knowledge exchange in promoting sustainable farming practices (Cadger et al. 2016; Isaac 2012; Oerlemans and Assouline 2004). This local learning and/or collaboration in problem-solving is particularly important in the transition towards agroecological practices. The cohesive relationship amongst these smallholders facilitates the sharing of their traditional assets within their communities through village meetings, local markets, and cultural events. Some of such ecologically-based traditional knowledge include: 1) the use of charcoal and wood ash for soil health; 2) neem solutions for biological control of pests and diseases; 3) heaped fencing for erosion control; 4) cassava peal mulch for soil moisture conservation; 5) peppermint leaf solution for stillbirth control in ruminants; and 6) crop rotation, shifting cultivation, and mixed cropping. These practices though represent the continuous improvement of resources within the farms, diversified production and established interaction cycles that produce synergies (see Migliorini and Wezel 2017). This could suggest that a more critical awareness about the benefits of continued promotion of these practices and other relevant ones is required at the grassroots, as well as exploring other agroecological-based innovative approaches that will improve the effectiveness of these ecologically-based practices.

The conclusion that smallholder farmers' expertise in managing their farming activities using their own traditional or local knowledge considered as a valuable source for agroecological knowledge development, has always resonated in the agroecological development and transition thinking (Gliessman 2018; Wezel et al. 2014; Wezel et al. 2020). For the farmers in this survey, even though the influence of formal knowledge persists, they were still motivated to maintain and preserve the traditional knowledge and practices handed down to them by their forefathers. Accordingly, this study demonstrated that smallholders maintained these traditional practices to 1) continually develop adaptive strategies in managing their changing farming conditions; 2) avoid knowledge extinction; 3) conserve their few available local seeds and domesticated animal varieties; and 4) respect and promote communal farming values. These findings are in consonance with a case study in coastal Kenya, which reported that the smallholder farmers maintained their traditional practices to reduce the risk of climate change and preservation of traditional varieties (Swiderska et al. 2011). Likewise, a study in Delta State, Nigeria which examined the characteristics of smallholder farmers who continued to maintain their traditional farm practices, noted that they did so to save cost, manage risk, be environmentally friendly and because of quality of the produce (Ofuoku and Alert 2014). These views could suggest an undying trust the smallholder farmers have built over years on their indigenous ecological farming practices, as well as the perceived usefulness of such practices (see Adnan et al. 2017; Zeweld et al. 2017). Additionally, this showed that smallholder farmers are and remain the custodians of ecological knowledge and practices (Fitzpatrick 2015; IFAD 2013), and their cohesive nature in knowledge sharing can help them to form social movements in tackling some of the hindrances of agroecological development and making their voices heard about the benefits of their traditional assets. Hence in developing agroecological systems, there is a need to tap into their knowledge and collaboratively engage them in sharing such revered knowledge with other field-based actors to promote intimate knowledge of such traditional practices as well as combined research and innovation to promote agroecological enhanced food security. Though it is imperative to encourage smallholders to share their knowledge and collaboratively develop agroecology to foster transitioning, it is also important to explore other challenges that could hinder the process and innovative ways that can ameliorate some of such issues.

10.2.4 Challenges that can affect agroecological development and opportunities for improvement

Importantly, considering the factors responsible for hindering those smallholder farmers who are or might be willing to fully transition towards agroecological practice holds key lessons to agroecological development. Thrupp et al. (2015) identify that farmers' decisions about the practices they use are unavoidably affected by institutional and policy factors at the national and regional levels, by environmental factors that affect their specific local context, and most prominently, by market pressures and economic forces that are generally beyond their control. This present study confirmed that some perceived challenges such as the reduction in family farm size due to increasing household numbers, unfavourable weather conditions, poor soil quality, scarcity of local and biological farm resources, and weeds, diseases, pests, and insects infestation impact on smallholder farmers' engagement in agroecological practices. In addition to the lack of support and incentives for practising farmers, as well as poor research that promote agroecology and agroecological practices at the local level. These farmers' perception of the environment-related factors could be because they are yet to realise that agroecological practices are environmentally viable and economically sustainable if well implemented, managed, and maintained (Pretty et al. 2011). Financial motivation is also ascribed to be one of the key aspects of the decision-making process amongst farmers and thus offers a mechanism for transition (e.g., Alarcon et al. 2014; Greiner et al. 2009; Greiner 2015; Padel 2001). The surveyed farmers also attested that they required information on how to secure finance to boost their farming. This means that promoting agroecological transitioning should be coupled with creating opportunities for smallholders' access to financial support, within a conducive socio-political frame that can help farmers to minimise any potential risk in undertaking the transitioning.

The development of an agroecological market system is also critical to the promotion of agroecological practices, given the value-added characteristics of the farm products (Van der Ploeg 2018). In other African countries such as Tanzania, Tunisia, and Uganda where agroecological practices are gaining recognition, their success stories come from the support of the state, local non-governmental organisations, and international development agencies (Adebiyi 2014; Bakewell-Stone 2006). Other factors that contribute to the status of the practices in these three countries include export market linkages and growing domestic markets for agroecological produced products (Adebiyi

2014). However, in Nigeria, there is a lack of government support for agroecological development nor the marketing apparatus. In the aspect of organic agriculture, Mgbenka et al. (2015) insisted that it needs popularisation as they highlighted that the first if not the only organised market structure in Nigeria that supports organic products is located in Ibadan, Oyo state Nigeria. And worst still, the existing market is only for a few organically certified crop products for export and none for general agroecological grown crops and livestock products (Olaito 2014). The domestic markets except in Lagos and Abuja, have no premium value for organic farm products and unfortunately, there is no recognition yet for agroecological food systems. The large population and the economic advantage of these cities could open up an increased economic value for agroecological produced products. However, traditionally, middlemen buy farm products from the smallholder farmers at the farm gates and sell at higher prices to the food hubs, so farmers make fewer gains (Dipeolu et al. 2009). The lack of an established agroecological market can hamper the development of the practices generally, hence this might require a different approach to market access where the middlemen can be omitted as in the case of direct interactive engagement with consumers (i.e., short supply chain). As well as creating a market niche and more remunerating outlets for agroecological products through collaborative efforts of the smallholders locally and nationally (e.g., Arfini and Manciniet 2018; Brunori et al. 2009; Van der Ploeg et al. 2012). The new market structure can link smallholders and consumers in novel ways which may yield better off-farm prices (Van der Ploeg et al. 2012). However, given the situation in Nigeria, this may be difficult to actualise in a short term as building circular and solidarity economies requires a fundamental change in the agri-food system. And also, realising agroecology-based food systems will involve a sustainable approach in the way food is produced, distributed and consumed (see AFSA 2015; Altieri et al. 2017; Méndez et al. 2013).

Agricultural development in Nigeria is underpinned by a top-down delivery of agricultural information to the farmers, and this approach has been heavily criticised in the aspect of effectiveness and efficiency (Davis 2008; Izuogu and Chikerenma 2015). Although the top-down system such as the AVS and REFILS brought about smallholders' access to the extension agents and improved extension-research linkages, they are still faced with many challenges (Faborode and Ajayi 2015; Issa 2017). The most important is the recent AVS programme which is confronted with low funding resulting in irregular service delivery to the farmers as stated earlier in this study. More and better collaboration with the smallholders has repeatedly been identified as the key strategy to promote agroecology (Altieri 2018; Pimbert 2018). Therefore, adopting a top-down delivery system could also impact agroecological development should there be any support for agroecological innovation from the research institutes as this will continue to alienate smallholders' knowledge and their context-specific issues. Moreover, reaching remote communities can be difficult, time-consuming, and costly, limiting smallholders' engagement (Kagbu and Issa 2017). On the contrary, increasing access to and ownership of mobile phones such as feature and smartphones and advances in internet penetration in Nigeria (Ogbeide and Ele 2020; Statista 2020; Techpoint 2021), offer opportunities to improve the interactive exchange of knowledge amongst agricultural actors and providing more accessible ways and timely means of interaction. Studies have continued to prove that mobile phone-enabled facilities such as m-apps can breach the gap of the non-interactive feature of the top-down approach in agricultural information delivery systems (Laureys 2016; Maurel and Huyghe 2017; Rioba 2018). Various studies reported different types of m-apps used in agricultural development specifically in Africa (Baumüller 2015, 2016, 2017; Ifeoma and Mthitwa 2015; Waldron and Amusin 2017). This study also demonstrated that in Africa m-apps are playing a key role in enhancing smallholder farmers' access to and sourcing of both the formal knowledge and traditional ecological/agroecological knowledge from and within their local networks (i.e., informal sources). This finding is in consonance with Okafor and Malizu (2013) and Bolarinwa and Oyeyinka (2011) in their findings which stated that mobile phones are enabling farmers' access to agricultural information in Nigeria. This is also in tandem with other studies on farmers' use of mobile phones in other African countries which acknowledged that farmers commonly exchange informal knowledge with their friends and neighbours using mobile phones (Masinde et al. 2012). The findings also confirmed the studies of Kikulwe et al. (2014) and Sekabira and Qaim (2016) which reported that m-app financial services enabled convenient and direct transactions between farmers and buyers in higher-value markets resulting in their increased income. Similarly, Courtois and Subervie (2014) noted that farmers using Esoko received higher prices for their products. Furthermore, Kirui et al. (2013) documented that TradeNet which is an m-app financial service in Kenya enabled farmers to make an informed decision about the best harvest and selling times. Moreover, m-apps allow smallholder farmers to learn about soil conditions, weather information as well as train at their convenient time and place, and when specific information is needed. In addition to promoting social capital and enhancing the successful exchange of knowledge between agricultural actors (FAO 2018a; Ingram 2018). Masinde et al. (2012) also claimed that farmers benefited from up-to-date information about the weather forecast to choose the time right for planting, harvesting and storage. A similar confirmation was made by livestock farmers that use iCow, they had increased milk yield which also improved their income (iCow 2010). Besides, similar m-apps have provided platforms for farmers to interact, get informed about produce prices and input availability, record and track their produce from delivery to destination, and when to sell (Baumüller 2016; Henze and Ulrichs 2016). These findings confirmed the important role m-apps play in farmers' daily farming and trading activities that reflect their living standard.

As well as m-apps' ability to improve farmers' agricultural activities and livelihoods, there are also other challenges farmers face in using such services (see, Baumüller 2017; Evans 2018; Misaki et al. 2018; Nwaobiala and Ubor 2016; Ogunniyi and Ojebuyi 2016; Okafor and Malizu 2013). Most significantly, this study supports other studies in arguing that agricultural field actors in developing countries have adapted to the challenges such as the erratic supply of electricity which have been associated with the use of the mobile phone for agricultural development (Mago and Mago 2015; World Bank 2017; World Economic Forum 2018). In this current study, the participant echoed that they used various strategies such as ensuring they have reliable power bank adaptor and extra phone chargers and owning more than one phone at a time in managing such situation. Thus, the benefits of the use of m-apps for agricultural knowledge transfer and its ability to facilitate an interactive exchange of knowledge created the need and confirmed the opportunity for the framework that incorporates mobile phone for interactive knowledge exchange. This study, therefore, argued that that collaborative knowledge exchange among the relevant stakeholders can enhance mutual learning and knowledge sharing.

10.2.5 The potential for m-apps principally SmartAgroecology to facilitate the interactive exchange of agroecological knowledge and the perceived barriers to its wider use

Informed by the social capital theory, this section highlights the opportunities for the use of m-apps to enhance the interactive exchange of knowledge and the possible challenges that might threaten their wider use.

This study's findings suggest that using m-apps can promote the collaborative exchange of agroecological knowledge and farmer decision-making which would support agroecological transition. During the demonstration workshop, all participants found the SmartAgroecology m-app useful and were able to engage with it. The participants varied in their ages and competence with mobile phone technology, but all got to grips with the m-app. Considering Heeks and Molla (2009) ICT4D value chain concept (i.e., m-app for agroecology development in this study), this study demonstrated the readiness and availability for the use of this initiative. The outcome was encouraging; however, further work would be needed to develop this concept for the wider market in Nigeria. Given the small sample of participants in this study, the findings may not be representative of the wider population of agricultural actors in Nigeria, and therefore more research and demonstration are needed to understand the useability and/or uptake and impact of such initiatives (Heeks 2010; Kleine 2010).

Many researchers have emphasised the importance of collaboration and knowledge sharing in the transition to agroecology and this requires interaction amongst the relevant stakeholders (AFSA 2017; Altieri 2018 De Schutter 2010; Uphoff 2013). Levidow et al. (2014) emphasised the importance of cooperative engagement amongst researchers and non-researchers (e.g. farmers, consumer citizens, extension agents etc.) for co-creation and co-validation of knowledge about agroecology and Pimbert (2018) also noted that agroecological knowledge is strengthened by the collaborative efforts of smallholders. In fact, despite the possible unequal power relationships that may occur during the collaborative process, this present finding suggests that the interactive m-app can serve as a reliable alternative to knowledge co-creation space (meeting point) for the stakeholders. But to improve the power dynamics inherent in communal knowledge generation, Altieri (2015), de Molina (2013) and Levidow et al. (2014) called for a respectful collaboration amongst the stakeholders, the use of diverse skills and knowledge in intervening in the power dynamics, as well as recognition of farmers' indigenous knowledge. This study, therefore, suggests that such an initiative can enhance farmers' knowledge networks as well as participatory agroecological research and/or innovation. It can also support smallholders' direct access to consumers thereby boycotting the middlemen and improving profitability. Although, this may not be a one-size-fits-all intervention and perhaps should not be used in isolation from the face-to-face interaction, as well as not neglecting the social, economic, and environmental implications of m-app interventions (Friederici et al. 2020; Heeks 2010; Kleine 2013; Steyn and Van Greunen 2014; Winters and Toyama 2009). Accordingly, Emeana et al. (2020) and Heeks et al. (2021) suggested the need for detailed information, regulation and collaboration by relevant institutions, funders, and developers to address the downsides of digital technology initiatives like m-apps.

There are potential barriers to the wider use of m-apps such as SmartAgroecology, which are peculiar to the situation across Africa (Friederici et al. 2017; Smart et al. 2016). Even when m-apps have been developed and tested with the target users, they may still be abandoned by users or require improvements even after they have been launched (Laureys 2016). Pertinently, these current study findings are no different from other previous findings of the challenges of the use of m-apps especially in developing countries like Nigeria (e.g. Akpabio et al. 2007; Kang 2014; Malik et al. 2017; Otene et al. 2017; Rimi and Chudi 2017). This study indicates that over expectations placed on the planned initiative, the developers not understanding the target environment and disregarding the target users' skills level are most frequently associated with these problems. Additionally, lack of trust in the initiative and its content, use of language that is difficult to comprehend by the target users, and poor collaboration between the developers and target users, as well as the cost (e.g., it may cost more to download the service or use it with internet) affect the long-term use of such initiatives. The findings confirmed previous findings by Anjum (2015), David-West (2010), Donner (2009), Ifeoma and Mthitwa (2015), Narsalay et al. (2012), Schalkwyk et al. (2017), however importantly, the present findings elucidated that the prospective developers should always bear the interest of the target users in mind when designing the initiative so as not to contribute to their poverty and/or inequality. There are a number of key challenges in Nigeria. Internet penetration is still developing in Nigeria although with lots of positive prospects for development (see GSMA 2018c), and most importantly, many rural farmers may not own a feature or smart mobile phone and/or access reliable internet. Additionally, the electricity supply is reported to be so erratic as well as not all relevant actors in agriculture may have the necessary skills to operate technologies (e.g., Agwu and Uchechi 2019; Akpabio et al. 2007; Cynthia and Nwabugwu 2016; Tanko et al. 2013). As such, these could hinder their full participation and opportunity for learning and to contribute to agroecological knowledge sharing and transition. Hence, ensuring sustainability in and through the design of m-apps is important (Blevis 2007; Brynjarsdottir et al. 2012; Remy et al. 2018; Roedl et al. 2017), this current study, therefore, detailed the importance of analysing and understanding the target environment before implementation (e.g., availability of internet facilities, the capacity of the target users, type of digital policy etc.). Additionally, planning and designing for scale and long-term use, as well as ensuring privacy and security of user(s) sensitive data to avoid data theft or unauthorised access, can improve the lasting use of the initiative. Moreover, the benefit of collaboration amongst developers is that they can avoid replication of existing initiatives and reuse or improve the quality of already piloted one(s) and at the same time maintain their applicability and impact.

The use of m-apps to support agroecological transition is relatively new and there is no study to date that has explored the potential of an interactive service such as SmartAgroecology for agroecological knowledge exchange. The findings of this study suggest that a collaborative approach using mobile phone-enabled service can institute the opportunity for egalitarian, democratic control of how and what knowledge is produced as the process progresses. Nevertheless, this study also acknowledged that such a concept could be faced with bottlenecks as the decentralisation of knowledge control might be faced with outright rejection by the existing knowledge generators due to the proposed horizontal power arrangement, and political and/or economic interest of those already in higher authority. But this could be ameliorated through respectful collaboration (see Altieri 2015; Levidow et al. 2014). This study also acknowledged the importance of face-to-face contact for interaction, however pertinently, though some of these suggestions may seem aspirational, the study strongly supported the notion that a more interactive knowledge exchange process can be facilitated using mobile phone platforms or services. Additionally, a practical approach that engages in the training and collaboration about agroecology and the formation of a local network may help to achieve the desired change.

10.3 Contribution to knowledge, recommendations and suggestions for further research

This present study contributes to the discussion on agroecological development and strategies that can enhance the transitioning. It highlights the benefits and positive impacts of agroecological practices on smallholder farmers' farm and their livelihoods, as well as the challenges to transition and further explores the opportunities for improvement. Most importantly, the study establishes the scholarship of the use of m-apps for the interactive exchange of agroecological knowledge and how that can be used to achieve the transition. Particularly, the study outlines the following main conclusions; support, policy and infrastructural perspective that are based on the study outcomes and suggests strategies that might contribute to the wider practices of agroecology to enhance smallholder livelihoods. The recommendations and proposed future research work are in no particular order.

10.3.1 Support perspective

The analysis of the state of agroecological practices indicates that despite a general lack of government support, agroecological practices are gaining recognition in the African clime, though they are still in infancy in Nigeria. The farmers surveyed showed a general willingness to adopt or transition to agroecological approaches as they expressed concerns about the negative impacts of conventional methods. And there is also an indication that some still maintain some of their traditional practices and share such practices with their counterparts locally, while still depending more on conventional systems. This situation requires fundamental changes in the way agroecology and agroecological practices are promoted to create more grassroots awareness of the benefits and viability of agroecological practices. Hence, the study suggests that the current situation can be improved through:

- The support for evidence-based agroecological-managed farm case studies and collaborative generation and documentation of agroecological research.
- The promotion and use of participatory action research approaches such as ethnographic enquiry or farmer-led research for agroecology-related studies.
- The efficient utilisation of opportunities such as local farmers' field workshops or farmers' field schools that provide collaborative engagement of the smallholder farmers at the grassroots.
- Multilateral unification of the existing agroecological movements in Africa (e.g. Participatory Ecological Land-use Management (PELUM) and African Biodiversity Network (ABN), AFSA etc.) to establish contacts and form alliance with the gatekeepers of other local communities where agroecology is still not widely practised.
- There should be an inter-country exchange of ideas where various already established agroecology-based NGOs communicate the techniques and benefits of agroecological approaches to the smallholders through peer-to-peer farmer groups and extend such initiatives to areas like southeast Nigeria to encourage adoption and transition.

While earlier studies on the co-creation of agroecological knowledge and farmer behavioural theories (de Molina 2013; Levidow et al. 2014; Meijer et al. 2015; Moellers et al. 2018; Mutyasira et al. 2018), and this present study, confirmed the possible influence of power dynamics and factors that can affect the transition, there is no clarity on how these recommendations can be actualised. Hence, there is a need for further research on how to significantly help smallholder farmers to improve their existing agroecological practices and transition to other widely accepted agroecological approaches. A continuous collaboration involving organisations at the local, national and international level such as NAERLS, NAON, FAO, AFSA, PELUM, farmer cooperatives etc. may be important to understand the different needs of all types of farmer groups (e.g. men, women, elderly, youths, fisherfolks, pastoralists and labourers). The use of Gliessman's transition framework proved useful in understanding the step-by-step approaches smallholders can adopt at the farm level to initiate transitioning (Gliessman 2016). Thus, this approach can be explored especially for these farmers who expressed willingness to adopt agroecology, although other factors that might influence behavioural change such as perceived ease of use, perceived usefulness, social influence and the facilitating conditions need to be considered. Interventions to their individual needs which may include, access to markets, nutrition, water etc. and other services could be useful. The services might range from providing information on quality nutrition, making all agroecological activities/information available and ensuring accessibility to addressing cultural barriers against marginalised groups such as women, illiterate farmers etc. The future study should examine wider and less complicated interactive models that can accommodate individuals at different levels and are socially appropriate and acceptable.

10.3.2 Policy perspective

The analysis of the impact of extension agents' activities on agroecological development at the farm level indicates that the agricultural knowledge, information, and innovation systems are determined by the current agricultural promotion policy in Nigeria. The various policies are aligned with the support for conventional agricultural systems with little or no support for agroecological practices. This, therefore, requires a policy reform at the national level that will incorporate agroecology and agroecological knowledge in the agricultural extension and educational systems, as well as at the local level that will support farm level transitions. But such reforms could involve both long-term tactical plan and short-term policy action and thus, it may be useful to consider:

- An exchange of knowledge between farmers, extension agents, policymakers etc. to understand the benefits of agroecology and how they can contribute to sustainable food security.
- Setting up a better long-term strategic plan for the integration of agroecology into the existing sustainable agricultural development policies such as the 1999 Environmental Protection Plan, extension system and academic institutions.
- Explore constructive ways such as face-to-face meeting, mobile interactive discussions, or online forums with relevant stakeholders (e.g. farmers, extension, policymakers, NGOs, research institutions, civil society organisations etc.) to commit all parties to transition to agroecology.
- Identify how actors in the whole food chain (e.g. farmer level, cooperatives, food processors, suppliers etc.) can be committed to taking action to contribute to protecting biodiversity, support for environmental and public health to reflect the IAASTD agreement.
- *Ad hoc* training on agroecological techniques could be provided for the extension personnel at the zonal level and the template replicated at the national level to kick-start agroecological extension. This could be achieved through partnership with other agroecology-based NGOs or establishments in other countries as in the case of organic agriculture skills development in FUNAAB Abeokuta, Nigeria.
- An agricultural extension policy that will ensure that the extension and advisory services incorporate farmers' needs assessment activities, to guarantee mutual knowledge generation.

Considering the hegemonic characteristics inherent in the corporate agricultural sector (Clapp 2014; Holt-Giménez and Shattuck 2011; McMichael 2009; Sage 2013), and the polity and/or economic and political interest that may influence or avert any form of policy change or reform. There is a need for further study to understand how agricultural policy development in the Nigerian context can be better positioned to balance polity, economy, social and environmental aspects of agriculture using an agroecological system approach that can support smallholder farmers. This could require a policy reform from that of neoliberal focus to a more liberal approach that gives farmers autonomy as in the case of La Via Campesina campaign. Additionally, there is a need to investigate further, the strategies that can facilitate agroecological capacity building for all relevant stakeholders. This could be achieved through collaborative workshops to improve informed agroecological know-how amongst them. Though generally, this study does not alienate from the fact that '*he who pays the piper dictates the tune*' (Gopalan 2018) in the case of who funds these strategies and their best interest.

10.3.3 Infrastructural perspective

The analysis of the sources of agroecological knowledge, the challenges that can hinder the development, and the potential for m-apps to enhance the interactive exchange of knowledge show greater opportunities for agroecological development. If the social capital is leveraged capably, there is also a prospect for agroecological knowledge and experience to be spread or developed through ecologically-based traditional practices within smallholders' local networks. The knowledge of such traditional practices is shared amongst the smallholders to preserve their cultural heritage and values, as well as form stronger views in problem-solving which may promote agroecology at the farm level. Though the analysis of extension delivery systems (e.g., AVS) showed improved smallholders' access to extension services, such a top-down approach may not be the best for agroecology as an agroecological system is farmer-led and uses bottom-up strategies in empowering people to become their own change agents. Sharing of context-specific ecological knowledge through participatory processes such as farmer field schools could have a fundamental effect on agroecological development. Moreover, the local networking structure can be explored to create synergies across food systems locally and this could enhance fair and sustainable market structure at the grassroots (FAO 2018; IPES-Food 2018, 2020). Participatory guarantee systems could also be useful in ensuring quality assurance systems and might be an effective approach to develop local markets and premium for agroecological grown products, enhance income for smallholders, healthy food consumption and fair price for consumers. Although achieving these ideas will require responsible, efficient, and effective governance structures at various levels (Wezel et al. 2020), therefore, the following recommendations should be considered:

- Provide incentives for the farmers that already maintain their existing traditional practices and encourage peer-to-peer learning on the already existing and other agroecological practices using strategies such as spoke and hub approaches or train the trainers.
- Explore the co-creation of knowledge between smallholders and other formal knowledge agents or field-based actors through collaborative research that can

enable the generation of agroecological-based knowledge adapted to farmers' specific context and real needs.

- National non-governmental agencies (e.g., Friends of the earth) should collaborate with farmers to contextualise techniques that value and preserve local heritage as well as advocate for respect for social values.
- Explore opportunities for promoting circular and solidarity economies that connects farmers and consumers for agroecological grown produce and instituting quality for such products and equitable markets.
- Adopt grassroots supported participatory guarantee systems that will focus on quality assurance of agroecologically grown products locally as an alternative to third-party certification.

Given the importance of mobile phone-enabled interaction, detailed investigations must be carried out to integrate the human aspirations of learning, and to understand how mobile phone interactive services can be embedded to expand the online space for agroecological training, digital agroecological marketing and knowledge exchange from the grassroots. Advances in the digitalisation of the agroecological knowledge system will serve as an enormous asset to boost constructive collaboration and co-creation of agroecological knowledge. Therefore, further research should explore the incorporation of m-apps which could enhance farmer education and participation, especially within the marginalised group as in the case of CONECT-e platform.

While the SmartAgroecology m-app had great potential to promote an interactive exchange of agroecological knowledge amongst actors, there were also issues identified that can hinder the wider use. But leveraging the advantages and potentials of m-apps, the study concludes that such services can enhance adoption and transitions in Nigeria. However, the initiative is a stand-alone tool or initiative that could reach its potential if:

- Incorporated into an effective and efficient system with supportive policies and suitable governance structures (e.g. NAERLS could utilise the initiative to engage in an interactive exchange of knowledge with farmers, even in the remotest areas). But, NAERLS may need to collaborate with internet service providers such as MTN, Glo, etc. to enhance and provide internet services at an affordable rate.
- The initiative can be used to foster the engagement of smallholders locally.

Following this understanding, it is, therefore, necessary to direct further research on how to improve on the initiative to digitise the exchange of agroecological knowledge to advance agroecological development. It is also important to explore the organisational factors that may constrain the implementation of the proposed interactive framework for agroecological development. In addition to exploring ways of securing funding and support for its actualisation, further practical research is required to explore how such interactive initiative can be integrated into the local market system to encourage a short supply chain and facilitate smallholders' sole decision in product pricing. Future research should explore the training of all relevant stakeholders especially farmer groups on digital skills and, find ways of helping them to adapt to the ever-increasing technological innovations. While farmers must be digitally active to ensure the actualisation of the proposed framework, it is fundamental for the potential initiators to aim for sustainability in and through the design of the target initiatives (Remy et al. 2018; Vignare 2013). As well as consider the economic, social, and environmental implications of the integration of digital facilities in rural agricultural development (e.g., Heeks 2010; Kleine 2013). Finally, although the use of interactive platforms brings people together and could be important in promoting social capital as in today's world experience, face-to-face contact is also important in its own right in facilitating knowledge exchange (e.g., Burbi and Hartless Rose 2016; Leema et al. 2018). Hence, this study supports further research that explores the integration of both strategies to enhance the interactive exchange of knowledge and innovation of agroecology within the AKIS and AIS systems. And at the same time, this study does not ignore the challenges that are peculiar to smallholders' livelihoods situation and the current state of digital coverage throughout Nigeria, as well as the challenges associated with technological impacts in Africa.

10.4 The general limitations of the overall study

As with any research study, there are unavoidable issues related to the validity, replicability, reliability, and representativeness of the findings. To understand the study limitations, the appraisal of the overall methodological foundations is essential. As indicated above, this study adopted two distinct methodological frameworks (i.e. participatory action research and design science research), of which each has different assumptions with similar components as highlighted below, as a means of accomplishing the aims and objectives, as well as the research questions that emerged.

- Participatory action research – interpretivism

- Design science research – pragmatism

Their components include:

- Qualitative approaches used in data collection (semi-structured interviews, focus groups, participant observations, and design, development, and demonstration workshops)
- Qualitative data analysis (thematic analysis, inductive coding, and interpretation)

This exploratory approach enabled the study to retain its focus on design for change purposes, as outlined in the initial aims. The significance of this process is that the findings are based on knowledge inquiry, without the researcher's assumptions that may hamper the full richness of the findings. Nonetheless, the qualitative nature of the study raises issues about subjectivity and reproducibility. Most of the data were subjectively coded and interpreted, and as such this may have been impacted by the researcher's positionality and the replicability of the methods in other contexts. Care was taken to consider these aspects when designing the approach. The limitations of this approach have been critiqued by other scholars (e.g. Myers 2019). This study could have adopted an in-depth ethnographic methodology that allows an extended time period of enquiry about the cultural life, relationship and settings of the participants, and which would have allowed the researcher to gain a deeper understanding of the participants' day-to-day activities. The researcher did spend considerable time as an intern student with the NAERLS which allowed her to shadow the extension agents in their daily extension activities, more time would have enabled a greater immersion and reflection of the overall study process with all the participants. The study may have also benefited from including quantitative approaches to data collection which could have resulted in more extensive data, but the researcher's belief and interest in the lived experiences of the individuals informed the decision to use qualitative approaches.

The purposive selection of the participants and location is another important determinant to the type of data generated and the findings. The southeast region of Nigeria is comprised of five states: Abia, Anambra, Ebonyi, Enugu and Imo. The south-eastern region was initially selected because the five states met the main study criteria in terms of their agricultural activities, mobile phone ownership, internet availability and use. From these, Imo and Abia states were then selected because of participants' accessibility, logistics and the researcher's familiarity with the environment. Other regions of Nigeria (e.g. south, southwest, northwest, northeast, and northcentral) or even a comparison between other districts can and could have been used, but given the limitations of time and funding, these settings and participants were selected. This approach may limit the generalisation and application of the findings to other regions of Nigeria. Different findings may have certainly emerged in other settings, however, the agricultural extension system in Nigeria has a unified system of practice, which therefore may not be too different from the situation at the study locations. Moreover, the proposed framework could be subject to critique because it was based on a small sample out of the entire agricultural stakeholders' population in Nigeria, but, the uniqueness of the AKIS in the country makes the framework a national concept. The opinion of other lecturers (e.g. lecturers in environmental science and agricultural extension) could have also revealed other strategies for the proposed framework. Nevertheless, given the uniqueness of the institutional structure of agricultural education in the wider Nigeria context, their individual experience on the agricultural information available to the students may not have been different.

The limitations of the scoping review method applied in chapters 3 and 8 could have an impact on the findings. Although database searches were thorough, publications were only obtained from 44 out of the 54 countries in Africa. Studies with information not written in the English language were excluded which may have resulted in the exclusion of some important local studies. Moreover, due to the time taken for this study, agroecology and the scholarship of transition have evolved, as well as the scholarship of ICT4D studies.

It is also noteworthy to point out that there is a need, to include more variables in assessing the participants' perception about the potential impact of SmartAgroecology which could provide more detailed information about the participants' perception of its potential ability to facilitate the agroecological transition through the interactive knowledge exchange or the adoption of the initiative. Additionally, the study measured the perception just once, which might have overlooked the possibility of individual's perceptions changing over time as they gain experience which can influence their later decisions. Thus, the implication requires a further validity of findings of similar projects to ensure replicability in other parts of the country.

10.5 Self-reflection

The time spent during this study period has somehow satisfied my curiosity about the lived farming experiences of the smallholder farmers and gave me an understanding of how their relationship with the extension agents as well as their local networks shaped their farming decisions. Most importantly, my interest in sustainable agricultural practices such as agroecology inspired my creativity in exploring strategies that can enhance the interactive knowledge of agroecological practices. Though not without the steep hills of learning the different theories and concepts and my ability to understand their intersections and how they relate to my study. My intention was that the outcomes of this study would be useful in promoting an agroecological system for a sustainable environment, safe food for consumption and livelihood improvement for the growing population in Nigeria. In conjunction with this present study, is the FAO and ECOWAS Commission (2018) which highlighted the need for diversification of agricultural production that can enhance the environmental conditions and balanced nutrition for the increasing population of Nigeria that is already experiencing food and environmental crises (FAO and ECOWAS Commission 2018). Given my position as an agricultural extension agent by profession, I ensured that my positionality did not influence the participants' opinions as I adopted an inductive approach throughout the study process both in data collection and reporting. Evaluating my interaction with the study participants, I have a strong belief that collaborative learning and exchange of knowledge, as well as practical experimentation of ideas, creates real-world impact. Having understood the state of agroecology in the study area and confirmed approaches that can enhance farmers' transition towards the practices, I hereby recommend that more research is still required to advance this '*new*' and at the same time '*old*' concept in Nigeria. I referred to agroecological practices as '*new*' in Nigeria because 1) the idea of agroecology is still developing and yet to be formally recognised at the local/farmer and national/government levels, and 2) some of the approaches have been in use informally or 'by default' by the smallholder farmers for millennia.

10.6 Conclusions

The start of this study saw the scarcity of literature on agroecology and transition studies, but as the research progressed the scholarship has continued to evolve. The dearth of literature led to the extended scope across Africa to understand the state of agroecology and agroecological practices, while maintaining the specific focus on Nigeria and particularly the southeast region as the area of study. Nigeria is an agrarian society with an estimated 80% of smallholder farmers in charge of food production and her agriculture employs nearly 40% of the labour force. Despite evidence of various policy reforms and promotion of conventional systems to boost food security and ameliorate the various agricultural extension delivery challenges, the country still depends on importation of food and the research-extension-farmers linkage system remains weak as the dominant top-down approach seemed inadequate. In addition to smallholders' agriculture and farm families still faced with economic, social, and environmental challenges (Akinsuyi 2011; Aikhionbare 2015; Olorunfemi et al. 2020). A number of alternative agricultural techniques have been proposed by different schools of thought, however, agroecology is gaining more support globally as a viable system that can improve food insecurity challenges (Altieri 2017; FAO 2018; HLPE 2020). Despite that Nigeria is signatory to supporting agroecological systems (IAASTD 2009), there is still little information about agroecology in Nigeria both in theory and practice. Moreover, to improve the extension and advisory service delivery systems in Nigeria, some researchers have called for a more participatory knowledge exchange in agricultural sector (Emeana et al. 2020; Okojie 2020). The use of ICTs such as mobile phones and their facilities can enhance interactive exchange of knowledge between farmers and other relevant agricultural actors (Chipeta et al. 2016; Klerkx and Gildemacher 2012). Therefore, in exploring how agroecological practices can be encouraged and transition achieved as well as leveraging the use of mobile phone-enabled applications (m-apps) to promote interactive exchange of agroecological knowledge, formed the aims and objectives of this study.

In addressing the aims and objectives, the study adopted different theories and approaches as presented in Figure 4.6. The Gliessman's transition framework (Levels 1, 2 & 3) represents the different steps in which farmers' transitioning towards agroecological practices in the case of Nigeria's agricultural system context can be achieved. This framework was highly appropriate for this study as it showed a step-by-step approach for encouraging farmers to transition. Then in understanding the factors that could influence farmers' behaviours and decision-making towards agroecological practices, the theory of planned behaviour [TPB] was applied. The TPB provided insight into some overarching components of other theories that are very crucial for this study in identifying the intrinsic and extrinsic factors that are inherent in analysing farmer knowledge and behaviour change, as well as their use of any initiative such as the m-app. These are social capital theory, the unified theory of acceptance and use of technology, perceived ease of use and perceived usefulness. Additionally, the incorporation of m-apps and the evaluation of their potential to promote exchange of agroecological knowledge were informed by ICT4D theories which include ICT4D capability and sustainability in and through design approaches. These theoretical underpinnings helped to critically understand the extant literature and study participants' individual differentiation during research design, data collection and analysis. As detailed in Table 10.1 above, each aim, objective and sub-questions were all explored and accounted for.

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Appendices

Appendix 1: Policy option to improve agroecology

Policy options to improve agroecology

Build local and national capacity in agroecological research, extension and education

- *Establish a national framework for the implementation of agroecological production*; invest in agroecological research, extension and education.
- *Encourage collaboration* among farmers, indigenous peoples, extensionists, educators and researchers in problem-identification, experimentation and innovation.
- *Revise institutional priorities*, professional incentives and budget allocations to support these goals.

Support small-scale farmers and their organizations

- *Strengthen women's, farmers', indigenous and community-based organizations;* invest in rural areas.
- *Ensure farmers have secure access* to productive resources, information, credit, certification and marketing infrastructure.
- *Provide technical assistance* in agroecological production and agro-processing, and in adjusting to and mitigating climate change and other system stresses.

Establish supportive economic policies, financial incentives and market opportunities

- *Use full-cost accounting measures* to evaluate and compare the social, environmental and economic costs of different agricultural production systems.
- *Provide financial incentives* (credit lines, crop insurance, income tax exemptions, payment for ecosystem services) for resource-conserving practices, and for reducing reliance on chemical, fossil fuel and water-intensive production methods.
- *Encourage geographic, fair and sustainable production labels, affordable third-party certification, and increased market opportunities* for farmers adopting agroecological practices.
- *Reduce volatility in commodity and food prices* by establishing grain reserves, price bands and other supply management mechanisms. These measures enable farmers to invest in longer-term resource-conserving strategies and support national food security goals

Strengthen institutional supports

- *Revitalize local and regional food systems*: Establish democratic food policy councils; encourage urban and peri-urban agriculture projects; regionalize food procurement.

- *Establish fair regional and global trade arrangements* that enable farmers to meet food and livelihood security goals and diversify production.
- *Revise laws of ownership and access*: Implement effective land reform; revise intellectual property rights; devise equitable resource use policies; distribute credit to enable small-scale farmers to compete more effectively.
- *Establish social and environmental standards* for production, food quality and procurement, with liability mechanisms to address health or environmental harms arising when standards are not applied.
- *Guide and regulate private sector*: Reward private investment in safe, sustainable products, technologies, in situ reserves and markets; initiate competitive bidding for public funding based on capacity to meet equitable, sustainable development goals; implement anti-trust and competition regulations.
- *Enhance institutional integrity*: Enforce codes of conduct to preserve public institutions' capacity to perform public-good research.

Source: Excerpt from IAASTD 2009

Appendix 2: Principles of agroecology

Source: CIDSE 2018

Appendix 3: Some designs of diversified farming systems and their main agroecological effects

Crop rotations: Temporal diversity in the form of cereal-legume sequences. Nutrients are conserved and provided from one season to the next, and the life cycles of insect pests, diseases, and weeds are interrupted.

Polycultures: Cropping systems in which two or more crop species are planted within certain spatial proximity, resulting in biological complementarities that improve nutrient use efficiency and pest regulation, thus enhancing crop yield stability.

Agroforestry systems: Trees grown together with annual crops, in addition to modifying the microclimate, maintain and improve soil fertility as some trees contribute to nitrogen fixation and nutrient uptake from deep soil horizons while their litter helps replenish soil nutrients, maintain organic matter, and support complex soil food webs.

Cover crops and mulching: The use of pure or mixed stands of grass-legumes, e.g., under fruit trees, can reduce erosion and provide nutrients to the soil and enhance biological control of pests. Flattening cover crop mixtures on the soil surface in conservation farming is a strategy to reduce soil erosion and lower fluctuations in soil moisture and temperature, improve soil quality and enhance weed suppression, resulting in better crop performance.

Green manures are fast-growing plants sown to cover bare soil. Their foliage smothers weeds and their roots prevent soil erosion. When dug into the ground while still green, they return valuable nutrients to the soil and improve soil structure.

Crop-livestock mixtures: High biomass output and optimal nutrient recycling can be achieved through crop-animal integration. Animal production that integrates fodder shrubs planted at high densities, intercropped with improved, highly-productive pastures and timber trees all combined in a system that can be directly grazed by livestock, enhances total productivity without need of external inputs.

Source: The third world network 2015

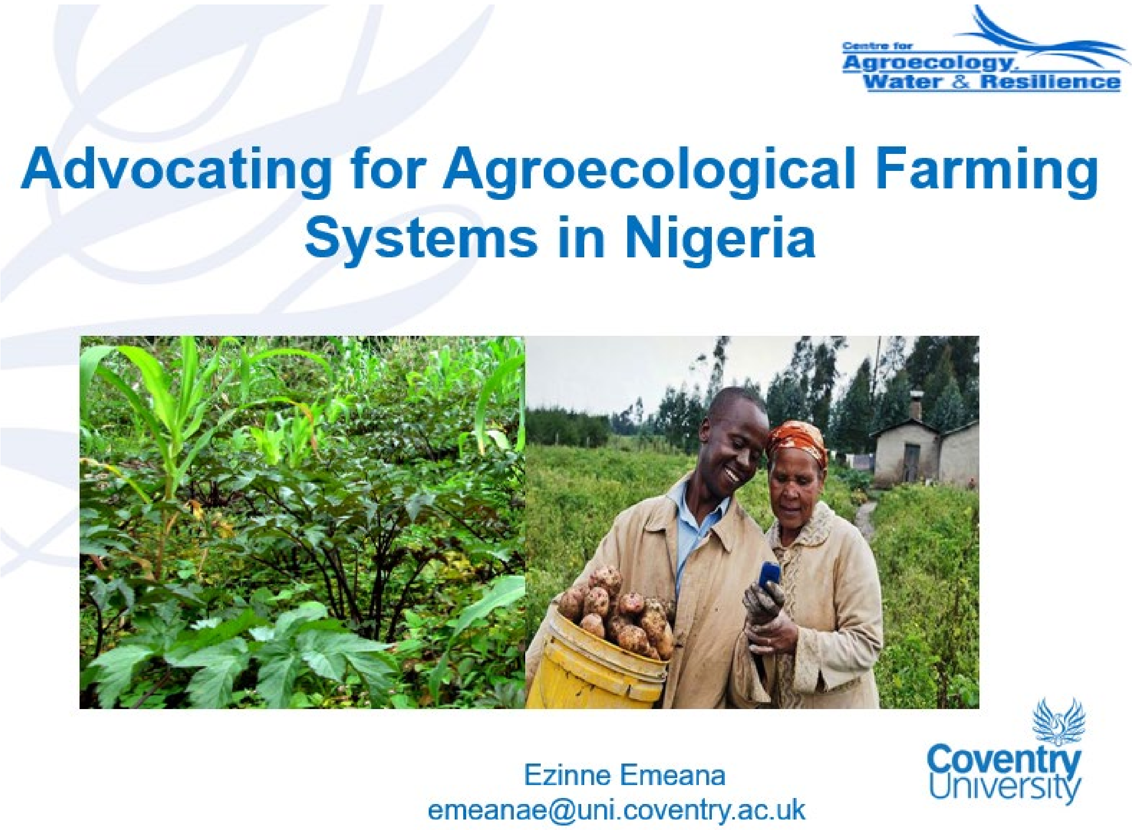
Appendix 4: The current state of agroecology in Africa: a review

Abstract

Africa is facing a food crisis, whilst the green revolution has increased cereal production, this had been at considerable cost to humans and the environment. Agroecology and its practices are viable in improving food security sustainably and in ameliorating these challenges. This study uses scoping review methods to explore the current state of agroecology in Africa. It sought to explore the understanding and practices of agroecology and the challenges hindering transition. Findings revealed that agroecology is improving the livelihoods of smallholder farmers by positively contributing to the achievement of the sustainable development goals of the United Nations. Such that the practice is helping them to enhance their farm yield, nutrition and income, as well as restoring biodiversity. Because the approaches are affordable, profitable and productive influences their transitioning and adoption. However, unfavourable policies, poor research support and a dearth of the required information on the approaches impede the pace of transition. The study, therefore, concludes that despite the challenges, agroecology is gaining a foothold in Africa and recommends collaborative efforts in the transition process, policy implementations and dissemination of information on agroecology.

Keywords: agroecology, agroecological approaches, drivers for transitioning, challenges, Africa

Appendix 5: A presentation at the NAERLS conference



Appendix 6: Interview schedule (outcome in Chapter 6)

<u>Interview schedule</u>

My name is Ezinne Emeana, I am conducting a study on the use of a mobile phone-enabled application that can facilitate interactive exchange of knowledge on agroecological practices and principles to improve the adoption agroecological farming system in Nigeria.

I am glad to listen to your views about this, therefore, feel free to comment on any issue discussed. This interview will be recorded; however, confidentiality will be highly maintained.

Date: …………

Questions for the smallholder farmers

- Is farming your main job and are there other people involved in your household?
- How long have you been doing agriculture and what are your responsibilities?
- Do you own the land and how will you describe your farmland area?
- Are there different cultivation patterns in different farming seasons?
- How do you describe your agricultural practices?
- What type of crops do you cultivate?
- Do you own livestock and what are they?
- How do you manage your crops and livestock?
- Do you always have access to information you require to achieve your desired farm practices and what are they?
- What is your best way and means of communication with everyone within your agricultural chain?
- Tell me about the AVS scheme?
- Evaluating the medium of communication what are the best ones considering your circumstances?
- What are the challenges you encounter throughout the farming season?
- Looking at the challenges you encounter in the farms are there other practices you use to minimise or overcome such challenges?
- Explain what you understand by agroecology and agroecological practices?

- Can you describe the supports you receive for implementing agroecological practices?

Questions for the extension personnel

- Is agricultural extension your main job?
- How long have you worked in the service?
- What are your responsibilities?
- Are there challenges you encounter within your job jurisdiction?
- How do you communicate with your clients and how frequent?
- What are the best ways and medium of communication?
- What is your opinion about the farming practices presently promoted by the agricultural policy?
- What is the major agricultural information available to your clients?
- What is your opinion about the farmers' traditional methods?
- What kind of improvement do you expect to see in the existing agricultural and extension practices?
- What are your opinions about agroecology and agroecological approaches?
- Can you describe the ways you think the government can help to promote agroecological practices?

Appendix 7: Interview schedule (outcome in Chapter 7)

<u>Interview schedule</u>

My name is Ezinne Emeana, I am conducting a study on the use of a mobile phone-enabled application that can facilitate interactive exchange of knowledge on agroecological practices and principles to improve the adoption agroecological farming system in Nigeria.

I am glad to listen to your views about this, therefore, feel free to comment on any issue discussed. This interview will be recorded; however, confidentiality will be highly maintained.

Date: …………

Questions for the farmers

- Can you describe the types of crops you grow and who decides which one to grow?
- Who are involved in cultivating your farmland? How do you source labour?
- How do you grow your crops in farmlands?
- How do you access farmlands? How are decisions made about the allocation of land? Who decides how the agricultural outputs are sold?
- How do you access market? Are there marketing outlets?
- What are the ways of accessing and sourcing for agricultural information?
- How do you source for agricultural inputs or resources?
- Can you describe the type of agricultural information are available to you?
- Can you explain your cultivation pattern and farmland area?
- Why do you source for agricultural information?
- Can you describe the ways you deal with agricultural challenges?
- Apart from the agricultural information you receive from extension agents, are there other useful available information?
- What source of agricultural knowledge do you have in the community?
- How can you describe your own traditional methods?
- Since how long do you have this type of traditional knowledges and how do you get them?
- How long have you been practicing your traditional knowledge?

- Can you explain the benefits of your local methods?
- Can you explain why you share and use such traditional methods?
- What do you think that can be done to encourage you to develop more on your own traditional methods?
- What can be done differently judging the recent extension activities and the support you receive?
- What are your opinions about agroecology and agroecological approaches?

Questions for the extension personnel

- Apart from extension service job, do have any other job?
- How do you provide services to your clients?
- How do you describe your activities with your clients?
- What are the ways of reaching your clients and how often?
- Can you describe the type of agricultural information available to your clients?
- Can you describe who is responsible for the information generation and how the information gets to your clients?
- Given the successes of AVS, how are you using the system to improve your access to farmers?
- What kind of improvement do you think can be made to the agricultural extension system to enhance your service?
- Given that agroecology is developing, are there other initiatives that can be used to promote the practice?

Questions for the lecturers/researchers

- How long have you been in your job role?
- Can you describe your main activities and role for agricultural development?
- Judging the present agricultural activities, what are your opinion for improvement for education, extension, and research?
- How is the research-extension-farmer information linkage like?
- What are your thoughts about agroecology and agroecological approaches?

Appendix 8: Focus group/workshop guide (outcome in Chapter 9)

Discussion Schedule

My name is Ezinne Emeana, I am conducting a study on the use of a mobile phone-enabled application that can facilitate interactive exchange of knowledge on agroecological practices and principles to improve the adoption agroecological farming system in Nigeria.

I am glad to listen to your views about this, therefore, feel free to comment on and evaluate any issue discussed. These discussions will be recorded; however, confidentiality will be highly maintained.

Date: …………

Questions for the application developers

- How are the best mobile phone application features that can host interactive platform for many participants?
- What are the factors for consideration before, during and after app development and launching?

Questions for the farmers

- Think of the various challenges you experience in accessing inputs, seedlings, and information, what characteristics of agroecological practices can ameliorate these?
- Given the understanding of agroecology and the benefits of your ecologically based traditional knowledge, how do you describe the ways to improve the knowledge and ensure that others access such knowledge?
- In terms of facilitating regular access to information and/or knowledge, think of the benefits you derive from the use of mobile phone, can you detail how interactive exchange of knowledge can be achieved through it? What are the resources needed to meet this need?
- How can you describe your ability to use interactive mobile applications, given your use of mobile phones?
- What factors determine every farmer being able to use such app?

- Can you explain how much you spend weekly for phone accessories?
- What type of activities do you normally spend money to use on your phone?

Questions for the extension agents

- Think of your activities to meet the demand of your clients, what are the best ways to share information with them?
- What are your opinions about the techniques the farmers need to improve crop yield?
- What are your opinions about the benefits of agroecological practices?
- Given that mobile phone facilitates interactive exchange of knowledge, in what ways do you think it can benefit all actors in agriculture?
- How is your ability to use mobile phones like?
- Can you describe the activities you spend time and money to use on your phone?

Questions for both groups (farmers and extension agents)

- What is your general experience about the app?
- Can you describe how the features of the app that will benefit every user will look like?
- What do you think of the app in facilitating interactive exchange of knowledge among actors?
- What is your opinion about the wider use of the app by others?
- Are there strategies you think that could be applied to improve the app?
- What can you say about the app facilitating agroecological knowledge?

Appendix 9: USAID mobile application capability checklist

Some materials have been removed from this thesis due to Third Party Copyright. Pages where material has been removed are clearly marked in the electronic version. The unabridged version of the thesis can be viewed at the Lanchester Library, Coventry University

Source (Bell and Payne 2011)

Appendix 10: ICT Option Assessment Tool

Some materials have been removed from this thesis due to Third Party Copyright. Pages where material has been removed are clearly marked in the electronic version. The unabridged version of the thesis can be viewed at the Lanchester Library, Coventry University

Source (Bell and Payne 2011)

Appendix 11: Decision-making and planning framework

Some materials have been removed from this thesis due to Third Party Copyright. Pages where material has been removed are clearly marked in the electronic version. The unabridged version of the thesis can be viewed at the Lanchester Library, Coventry University

Source (Bell and Payne 2011)

Appendix 12: ICT Infrastructure Questionnaire

Some materials have been removed from this thesis due to Third Party Copyright. Pages where material has been removed are clearly marked in the electronic version. The unabridged version of the thesis can be viewed at the Lanchester Library, Coventry University

Source: (Bell and Payne 2011)

Appendix 13: Ethical approval for the pilot fieldwork activities

Certificate of Ethical Approval

Applicant:

Ezinne Emeana

Project Title:

OPPORTUNITIES FOR MOBILE PHONE APPLICATIONS TO IMPROVE THE ADOPTION OF AGRO-ECOLOGICAL SYSTEM OF FARMING IN NIGERIA

This is to certify that the above named applicant has completed the Coventry University Ethical Approval process and their project has been confirmed and approved as Medium Risk

Date of approval:

22 March 2016

Project Reference Number:

P40337

Appendix 14: Ethical approval for the six months of fieldwork activities

Certificate of Ethical Approval

Applicant:

Ezinne Emeana

Project Title:

Can Mobile Phone Applications Improve the Adoption of Agroecological Farming Systems in Nigeria?

This is to certify that the above named applicant has completed the Coventry University Ethical Approval process and their project has been confirmed and approved as Medium Risk

Date of approval:

04 February 2017

Project Reference Number:

P47072

Appendix 15: **Ethical approval for the 5 months of fieldwork activities**

Certificate of Ethical Approval

Applicant:

Ezinne Emeana

Project Title:

Can Mobile Phone Applications Improve the Adoption of Agroecological Farming Systems in Nigeria?

This is to certify that the above named applicant has completed the Coventry University Ethical Approval process and their project has been confirmed and approved as Medium Risk

Date of approval:

01 December 2017

Project Reference Number:

P61825

Appendix 16: Satisfactory approval of the latest fieldwork set out procedures

Content removed from the electronic version of this thesis on data protection grounds

Appendix 17: A sample of informed consent form

Informed Consent Form

Title of Project: CAN MOBILE PHONE APPLICATIONS IMPROVE THE ADOPTION OF AGROECOLOGICAL FARMING SYSTEMS IN NIGERIA?

Name of Researcher: Miss Emeana Ezinne Merianchris

Please Tick

1. I confirm that I have read and understood the participant information sheet for the above study and have had the opportunity to ask questions. ☐

2. I understand that my participation is voluntary and that I am free to withdraw at any time without giving reasons, without my legal right being affected. ☐

3. I understand that colleagues within the sector who access the PhD thesis or other publications derived from the research may be able to identify me and my involvement in the research study. ☐

4. I understand that all the information I provide will be treated confidentially and that I also have the right to change my mind about participating in the study for a short period after the study has concluded. Final date for withdrawal is 30th of April, 2018. ☐

5. I agree for communications (conversations, meetings, events, workshops) in which I take part in the study to be documented either by notes, photos, Dictaphone or video. I also agree for quotes from these to be used so long as they are anonymised and previously approved by me. ☐

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Name of Participant	Date	Signature
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Witnessed by (if appropriate)
Date
Signature

Appendix 18: A sample of participant information leaflet

Participant Information Leaflet

This document aims to inform you about the research project that is conducted by Emeana Ezinne Merianchris in fulfilment of her PhD in Agroecology and Food Security, at Coventry University, United Kingdom. The study title is “CAN MOBILE PHONE APPLICATIONS IMPROVE THE ADOPTION OF AGRO-ECOLOGICAL FARMING SYSTEMS IN NIGERIA?”

If you agree to participate in the study, then you will have to complete an informed consent form which will be provided for you. The consent form indicates that you (the participant) are consenting to everything described in this leaflet, thus both the participant information leaflet and consent form depend on each other.

The purpose of the project

The study aims to improve the adoption of agroecology farming systems, as well as evaluate the effectiveness of mobile phone applications for agroecology dissemination. The PhD proposal was developed out of Ezinne’s curiosity to find out if the increased use of mobile phones and their applications can help increase the adoption of agroecology which has been confirmed to be less practiced due to poor information dissemination services to the farmers.

Why you have been chosen

The reason why you have been asked to participate in this study is because you are part of the principal drivers of farming in the study area. The researcher believes that you are competent in providing accurate and relevant answers which this project aims to achieve.

Why you have to participate

Participation is voluntary and you are free to withdraw at any time without notice. Your decision to participate or not will not affect you in any way. Furthermore, if at any time point in the communications with the researcher, you do not wish your views to be documented let the researcher know at the earliest possible. That is on or before 30th of April 2018.

What the plan is for this project

The researcher in collaboration with the mobile phone application developer will develop an application based on your farming information needs, opinions and evaluations. This work requires that the researcher documents the discussions, interviews and any other relevant communication with you (the participant). The documentation can be in the form of note taking, recording through video camera or Dictaphone.

The researcher will be assisting in the application development by interviewing you (the participant), asking series of questions previously approved by her Director of Studies (Liz Trenchard) and handling qualitative data. The data will be used for the PhD research.

What you have to do

Read this participant information leaflet carefully and ask any question you may have. Please, also sign the informed consent form and attend meetings, interviews and events related to this work.

What are the risks associated with this study?

The only risk at this stage is data protection. However, the information you provided will remain confidential and anonymous. All materials (text, audio and video) will be stored in OneDrive which is the file hosting service provided by Coventry University. OneDrive is subject to monitoring by Microsoft and the files are protected by accessing Coventry University student portal with an exclusive username and password.

What are the benefits in taking part?

Participation may enable you to better understand the importance and benefits of farming agroecologically. The research aims to find the opportunities and challenges of the National agricultural Extension Research and Liaison Services in the delivery of sustainable farming systems (agroecology) information. The research will find best practice that will improve information delivery and will also aim to inform future policy concerning delivery and adoption of agroecology in Nigeria.

What are the withdrawal options?

Content removed from the electronic version of this thesis on data protection grounds

When does the consent form expire and what happens next?

The consent form expires on the 30th of April 2018 and this authorises the researcher to document any communications/discussions with you for the purpose of the research.

How is the data going to be used?

The information will be used as evidence-based inquiry in PhD research. Data will be published in the dissertation and potentially academic publications and reports.

What if things go wrong? Who do I complain to?

Content removed from the electronic version of this thesis on data protection grounds

Appendix 19: Evaluating the role of public agricultural extension and advisory service in promoting agroecology transition in southeast Nigeria

Abstract

Agroecological farming approaches sustain food production with zero or reduced dependence on agrochemicals. The study investigated the impact of the public agricultural extension activities in enhancing the transition to agroecological approaches in the southeast Nigeria. Data were collected from 30 farmers and 20 extension agents using in-depth interviews. The extension agents were purposively selected, while the smallholder farmers were selected using a purposeful random sampling technique. The results show that extension and advisory activities are influenced by existing and current agricultural policies. Extension agents currently focus almost exclusively on intensive agricultural practices because of the agricultural transformation agenda which surprisingly ignores the principles of agroecology. Factors such as policy, social, environmental, research and extension management were observed to impede the organic farming transition towards agroecological practices. It is concluded that there is a need for implementation of agriculture policies that support farmers' ecological knowledge, agroecological research and innovation, as well as agroecological information exchange. A participatory approach in policy formulation and information sharing that incorporates farmers' ecologically-based traditional knowledge with the capacity to establish and strengthen a collaborative agricultural information structure is recommended to improve agroecological transition.

Keywords: agroecological transition, agroecological development, extension and advisory services, smallholder farmers, Nigeria.

Appendix 20: Table 6.3 – Summarised responses, the number of farmers and extension personnel that mentioned each theme

Table 3: Summarised responses, the number of farmers and extension personnel that mentioned each theme

Response	Farmers who mentioned this response (n=30)	Extension personnel who mentioned this response (n=20)
Agro-ecology approaches improves soil fertility and nutrient cycling	5	
Willingness to practice organic farming	30	
Agricultural policies promote yield maximisation and increased food quantity	26	20
Government interest in food quantity	28	19
Research interest in genetic modification of organism	15	18
Lack of practical organic farming extension skills and services	6	14
Limited trust for organic farming benefits		14
Lack of institutional structure for organic farming extension		15
Inadequate training for organic farming		15
Extension personnel disregard farmers' traditional knowledge	22	11
Increasing household number of farm families impact on land and food availability	27	
Drastic weather conditions such as heavy rains affect the pre and post-harvest management of local crop varieties	25	14
Lack of expertise in the preparation, use and management of organic inputs	23	
Reduced interest of the youths in farming	20	
Limited access to organic farm resources	26	8

Data from the in-depth interviews analysed using Miles et al. (2014) strategy.

Appendix 21: Developing a framework to enhance agroecological practice and knowledge exchange in the southeast Nigeria

Abstract

The growing recognition of the positive impacts of agroecological approaches on smallholder farmers' livelihoods and the environment has resulted in the experimentation of various collaborative strategies that can enhance the transition. The transition towards agroecology requires improved access to and enhanced flow of agroecological knowledge amongst the relevant actors. To achieve the desired goal requires the understanding of the existing agricultural knowledge and innovation system in the given setting. Hence, this study explores what, why and how agricultural information is shared to ascertain any available and accessible agroecological knowledge (e.g. ecologically-based traditional practices) in the area. It, therefore, uses in-depth interviews involving 12 farmers, eight field extension personnel and ten agricultural university lecturers, all purposively selected, in identifying the agricultural knowledge flow, structures and factors that contribute to the efficiency. The findings revealed formal and informal knowledge systems. Formal knowledge is transferred in a top-down system through extension agents to farmers. While the informal knowledge which is consistent with agroecological approaches is exchanged amongst farmers within their communities. The formal flow of knowledge omits the farmers' collaborative contribution to knowledge generation. This study observed that the informal exchange of knowledge was the only mainstay for agroecological knowledge and learning. It was also observed that despite the importance of face-to-face meetings, mobile phones were the most preferred means of access to and sourcing of knowledge. Therefore, the study concluded by proposing an interactive mobile phone platform for enhanced agroecological knowledge exchange, with the intent of creating a bilateral sharing of agroecological knowledge to improve the transition to agroecology in the study area.

Keywords: farmers indigenous and agroecological knowledge, explicit and implicit knowledge sources, AKIS, interactive knowledge exchange, Nigeria

Appendix 22: The Revolution of Mobile Phone-enabled Services for Agricultural Development (m-Agri Services) in Africa: The Challenges for Sustainability

Abstract

This study presents an exploratory literature review of the evolution of mobile phone-enabled agricultural information services (m-Agri services) and their impacts on smallholder farmers' livelihoods in Africa. Although improvement has been made in the development of m-Agri services, there remains a wide information gap in the reasons why many fail to scale up or are abandoned. Findings show that m-Agri services are facilitating smallholder farmers' access to financial services and sourcing of agricultural information about input use, practices and market prices. Moreover, the study revealed services for which the implementers ignored the literacy, skills, culture and demands of the target users and ones which the users have wavering trust on, as a result, are highly likely to fail or be abandoned. This study recommends that to enhance the sustainability of m-Agri services, the implementers need to design the services with the users involved, analyse and understand the target environment, and design for scale and long-term purpose. While privacy and security of users need to be ensured, the reuse or improvement of existing initiatives should be explored, and projects need to be data-driven and maintain open-source. Thus, the study concludes that policymakers can support the long-term benefit of m-Agri services by ensuring favourable policies for both users and implementers.

Keywords: M-Agri services, Cell phones, Smallholder farmers' livelihood, Sustainability challenges, Strategies for improvement, Policy implications, Africa.

Appendix 23: The potential of a mobile phone-enabled application ‘SmartAgroecology’ to enhance agroecological knowledge exchange in southeast Nigeria

Abstract

Farmers’ transition to agroecology is an ambitious challenge requiring a concerted effort. Information Communication Technology (ICT) plays a significant role in improving smallholder farmers’ livelihoods by linking them to markets, access to weather forecasts, agricultural techniques and other essential services. The application of ICT such as mobile phones in agroecology could address the challenges identified which currently hinder agroecological transition. Nigeria is amongst the sub-Saharan countries where agroecology is yet to gain a foothold. Mobile phone companies have invested extensively in Nigeria taking advantage of the population (which was estimated at 200 million in 2019), resulting in improved access to mobile and internet facilities which could facilitate agroecology through interactive knowledge sharing. In a one-year pilot, a mobile phone-enabled platform known as SmartAgroecology was developed with 30 farmers and 20 extension personnel purposively selected for the study. Using a participatory action design research framework with focus group discussions, the participants’ perception of agroecology and the information delivery through the platform was ascertained. Additionally, the limitations of the application’s wider use were evaluated. Although there were some socio-economic barriers to the application’s wider use, the study concludes that such an initiative has the potential to improve agroecological knowledge exchange and transition towards the practice. The study, therefore, recommends unified efforts by all stakeholders in promoting initiatives that promote agroecology, whilst emphasising efficiency and sustainability of such initiatives.

Keywords: Mobile phone-enabled application, SmartAgroecology, Agroecological knowledge and transitioning, Nigeria

Appendix 24: A training manual for extension agents