Master's Thesis – master Innovation Science

The Inclusiveness of Digital Innovations in the South African Agriculture System

Closing the Inequality Gap through Innovation

Image 1: Siyakhana Garden, Small Farm in Suburban Johannesburg, South Africa (Source: Author)

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Summary

Inequalities in South Africa have been increasing since the end of Apartheid and are especially present in the agricultural sector between smallholder farmers (SHF) and commercial farmers. Novel digital technologies, also known as e-agriculture innovations, are emerging in South Africa's agriculture sector. As it is not yet clear, how inequalities between SHFs and commercial farmers are affected by these novel e-agriculture technologies, their impact needs to be analyzed. *Inclusive* e-agriculture innovations appear to target challenges of SHFs and with that support their development and aim at the reduction of present inequalities. To further promote inclusive e-agriculture technologies, factors that hinder and factors that support their development and distribution have to be identified. This was done by conceptualizing inclusive innovation system (IIS) functions based on technology innovation systems functions combined with insights from inclusive innovation.

To execute the research, 28 semi-structured interviews with relevant system actors in the South African e-agriculture sector were conducted. In a first research step, most pressing challenges for SHFs in the South African e-agriculture sector were analyzed. These have been identified to be the exclusion of SHFs from the formal market due to strict market standards, which are almost impossible for SHFs to fulfill. Moreover, certain SHFs characteristics, such as their unorganized nature, hamper collaborations with SHFs and their integration into the market. Within the second research step, the development and distribution of e-agriculture innovations was analyzed by applying the IIS functions approach. This indicated that knowledge regarding the needs of SHFs is often lacking, present policies are weakly enforced, access to funding is limited and uncertainties of farmers regarding the usefulness of the technologies hamper adoption. At the same time, a strong willingness of all system actors towards the inclusion of SHFs and the development of inclusive e-agriculture has been observed. In a third step, potentially inclusive innovations have been analyzed regarding their impact on SHFs as well as their responsiveness towards their challenges. In this regard four mobile phone applications, three satellite data enabled technologies and one IoT device have been identified to target these challenges. E-agriculture technologies mainly pursued two approaches to integrate SHFs. Firstly, technologies assist the integration of SHFs by modifying current system requirements. Secondly, technologies support SHFs in their adoption to the present system requirements were observed. Therefore, inclusive e-agriculture technologies have been identified to be able to support SHFs and should be further promoted by resolving identified hindering factors.

“We need the food system to change. And we need to empower black farmers. Everyone wants it. Generally, everyone is unanimous that we need to transform the country. And I would say that is the biggest driver. And that means we can all ideologically, without any trouble, just connect to this ideology and move on.”

- *Prof. Dr. Naudé Malan*

List of Abbreviations

AI	Artificial Intelligence
BBBEE	Broad-Based Black Economic Empowerment
BFAP	Bureau for Food and Agricultural Policy
CSR	Corporate Social Responsibility
CSV	Creating Shared Value
DAFF	Department of Agriculture, Forestry and Fishery
DTPS	Department of Telecommunications and Postal Services
FAO	Food and Agriculture Organization
G.A.P.	Good Agricultural Practices
ICT	Internet and Communication Technology
ICT4D	Internet and Communication Technologies for Development
IoT	Internet of Things
IIS	Inclusive Innovation System
IS	Innovation System
NDP	National Development Plan
NGO	Nongovernmental Organization
NPC	National Planning Commission
RRI	Responsible Research and Innovation
SHF	Smallholder Farmer
TIS	Technology Innovation System

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1. Introduction

The economically successful BRICS countries face the challenge of rising inequalities between high- and low-income groups (Radulescu, Panait & Voica, 2014; Ivins, 2013). These inequalities may hinder growth (Aghion, Caroli, & Garcia-Penalosa, 1999) and can lead to political instabilities (Alesina & Perotti 1996). That makes it difficult for BRICS countries to achieve long term sustainable development (Gandolfo, 2015; Suljovic, 2018). A recent study of the World Bank outlines that South Africa "is one of the most unequal countries in the world, and (...) inequality has increased since the end of apartheid in 1994" (Sulla, Victor, Zikhali & Precious, 2018, p. XV). Therefore, the reduction of inequalities is a key challenge for South Africa to achieve long term sustainable development.

High inequalities can especially be observed in the South African agriculture sector (Aliber & Hart, 2009). Pienaar & Traub (2015) state that in South Africa approximately 87% of farming land is in the hand of 3500 mainly white large-scale farmers. These farmers produce 95% of South Africa's agricultural output. The remaining land is operated by roughly four million generally black smallholder farmers (SHFs) (Aliber & Hart, 2009). According to the World Bank, a "smallholder farm is widely defined as a family-owned enterprise that produces crops or livestock on 2 hectares or less" (International Finance Corporation, 2018, p. 6). Throughout literature and other organizations, definitions on what distinguishes SHFs amongst each other and from commercial farmers, differ greatly (Cousins, 2010)[1]. As there is no consensus in literature, in this thesis SHFs are considered as farmers with limited sizes of land and low commercially oriented production outcome. Many inequalities are initially rooted in the expropriation of black people during Apartheid (Lahiff & Cousins, 2005). After Apartheid, the South African government reacted by pursuing land redistribution programs from commercial farmers to SHFs. However, primarily due to the "neglect of post-transfer support" (Lahiff & Cousins, 2005, p. 129), land redistribution in South Africa has contributed little to improving SHF's livelihoods (Lahiff & Cousins, 2005). "Redistributing land and rights in land cannot, by itself, achieve the objectives of alleviating poverty, promoting equality and contributing to economic growth." (Lahiff & Cousins, 2005, p. 129). Challenges of SHFs in South Africa go beyond concerns about land distribution. As explained by various researchers, the greatest challenges for SHFs are limited access to financing and insurance, limited access to the market and productivity-related problems (yield gaps) due to limited resources (Von Loper et al., 2016; Tittonell & Giller, 2013; Qiang, Kuek, Dymond & Esselaar, 2012). These complex challenges lead to increasing inequalities between SHFs and commercial farmers .

The agricultural sector itself is currently facing substantial changes in its setup through the emergence of novel digital technologies such as the application of Internet of Things (IoT) sensors and artificial intelligence (AI) algorithms (Mwendera, 2018). Such digital technologies for agricultural purposes are also coined as *e-agriculture* innovations by the Food and Agriculture Organization (FAO, 2017). One example for e-agriculture is the application of IoT sensors to measure irrigation or fertilization levels to precisely adjusted inputs such as water or pesticides to the demands of the plants, resulting in increasing yields (Dahlman, Mealy & Wermelinger, 2016). While there is a general agreement that these e-agriculture innovations will affect the agriculture sector (Mwendera, 2018; Sung, 2018; Teranzono, 2018), it is not yet clear how they influence inequalities between SHFs and commercial farmers.

On the one hand, e-agriculture technologies may have the potential to contribute to tackling some of the mentioned challenges. Qiang et al. (2012) for example explain how mobile applications can provide SHFs with better access to markets, financing or information regarding best practices in farming in

[1] A more detailed discussion on the different perspectives regarding attributes that distinguish SHFs from commercial farmers can be found in Cousins (2010). Here different definitions of SHFs throughout literature and policy documents are discussed. Further different classifications of SHFs are discussed. Here SHFs can range from subsistence farmers that produce only for their own interest to commercially oriented SHFs.

order to increase their yields. The concept of applying digital technologies for solving developmental problems is also known as internet and communication technologies for development (ICT4D) and has gained the attention of various researchers (Heeks, 2008; Thapa & Sæbø, 2014). On the other hand, e-agriculture innovations, such as all other innovations, can also lead to increasing inequalities (Cozzens et al., 2009). Digital technologies for example often replace unskilled labor or labor-intensive jobs (Loebbecke & Picot, 2015), which are often found in the agriculture sector. Santiago (2014) explains that "while innovation could help addressing the poverty challenges, innovations that emerge from formal (...) structures and organizations rarely address the needs of the poor" (Santiago, 2014, p. 1). Therefore, the impact of these e-agriculture innovations on inequalities between SHFs and commercial farmers has to be analyzed.

The concept of *inclusive innovation* can help to analyze the impact of innovation on inequalities (Heeks, Foster & Nugroho, 2014). To explain inclusive innovation, Heeks et al. (2014) contrast the term to *mainstream innovation*. Mainstream innovation solely aims at increasing economic output and mostly affects higher income groups. This type of innovation is usually inaccessible to lower income groups and is therefore considered to promote the increase in wealth gaps (Paunov, 2013). Inclusive innovation, on the other hand, actively focuses on the needs of marginalized groups to specifically create benefits for them (Heeks, Amalia, Kintu, & Shah, 2013). Usually such innovations developed by and for marginalized groups improve their livelihoods and have the potential to reduce economic inequalities (Heeks et al. 2014). Heeks et al. (2014) place inclusive innovation at the intersection of development studies and innovation studies. Therefore, the concept of inclusive innovation allows to analyze how innovations influence inequalities between mainstream and marginalized groups.

To analyze the inclusiveness of an innovation, Heeks et al. (2013) suggest to define which groups are targeted by the innovation and in which way they should be included. Inclusive innovation can target and involve a variety of marginalized actors. This thesis primarily investigates the reduction of inequalities between SHFs and commercial farmers and how inequalities can be reduced through inclusive innovation. Heeks et al. (2013) suggest a ladder of inclusive innovation to precisely determine in which way marginalized groups are included in and impacted by the innovation. However, besides this in-depth analysis, it is possible to directly identify which technologies are generally accessible for SHFs and/or have the intention to positively influence SHFs. These can be differentiated from technologies which are neither accessible to SHFs nor have the intention to positively influence their livelihoods. By targeting the challenges of SHFs, inclusive e-agriculture innovations have the potential to reduce inequalities between SHFs and commercial farmers. This makes it interesting to understand which factors influence the emergence of these inclusive e-agriculture innovations. Once factors responsible for hindering or supporting their emergence are identified, measures can be taken to further promote the development and distribution of inclusive e-agriculture innovations.

In the field of mainstream innovation, innovation scientists often apply an innovation systems (IS) perspective to analyze the emergence of innovations within a system. This perspective allows to understand the complexity of interrelations between various system components such as actors and institutions and how they each contribute to the development and distribution of innovation (Edquist, 2005). As an extension to the IS perspective, literature regarding system functions has emerged, which serves as a tool to analyze the functioning of an IS by observing activities performed by system actors (Hekkert, Suurs, Negro, Kuhlmann & Smits, 2007). This allows to identify how well the suggested functions are fulfilled and whether they support or hinder the development and distribution of innovations within the system (Johnson, 2001; Hekkert et al., 2007).

The IS approach and its functions mostly focus on the development and distribution of innovation from an economic perspective without including challenges of inequality (Kraemer-Mbula & Wamae, 2010). To understand how inclusive e-agriculture innovations emerge, the IS perspective needs to be enhanced with insights from inclusive innovation literature. The combination of these two perspectives has also been suggested by many prominent researchers in the field of inclusive innovation (comp. Cozzens & Sutz, 2012; Foster & Heeks, 2013; Chataway, Hanlin, & Kaplinsky, 2014; Santiago, 2014). A first contribution was made by Foster & Heeks (2013) who modified traditional IS components to specificities of inclusion, creating an inclusive innovation system (IIS). Besides first attempts to conceptualize IIS components, very little empirical evidence for the application of an IIS framework is available (Grobbelaar, Tijssen & Dijksterhuis, 2017). To determine supporting and hindering factors for the successful development and diffusion of inclusive innovation, the system functions approach needs to be conceptualized based on the specifics of inclusive innovation.

After being able to determine factors for the successful development and diffusion of inclusive innovations, their actual impact on inequalities between SHFs and commercial farmers can be analyzed in detail. Only when innovations transcend from merely having intentions to actually support SHFs in overcoming specific challenges, they may contribute to reducing inequalities. This leads to the following research question:

Which factors in the South African inclusive innovation system (IIS) hinder or support the development and diffusion of inclusive e-agriculture innovations and how do they affect inequalities between SHFs and commercial farmers?

To answer this research question, three subsequent analytical steps are conducted. Firstly, challenges faced by SHFs that lead to inequalities between SHFs and commercial farmers are analyzed. This is done by observing system actors, institutions and infrastructure of the South African agriculture system. This first step outlines the most prevalent challenges faced by SHFs. In a second step, factors that hinder or support the development of potentially beneficial digital technologies in agriculture are analyzed. Understanding these factors allows to take measures to further promote the emergence of inclusive e-agriculture innovations in South Africa. In a last step, the impact of these digital technologies on inequalities between SHFs and commercial farmers is analyzed. This enables to determine, whether e-agriculture innovations are able to contribute to diminishing inequalities between SHFs and commercial farmers.

These findings are important, as other measures such as land reform alone failed to substantially reduce inequalities in South African agriculture. From a practical perspective, this thesis provides an overview of inclusive e-agriculture technologies developed and distributed in South Africa. Additionally, their effect on the livelihoods of SHFs and inequalities is analyzed. This allows to understand which technologies may be useful in reducing inequalities between SHFs and commercial farmers. When further encouraging the emergence of these 'useful' e-agriculture innovations, SHFs can be supported in their development. In order to promote these beneficial technologies, specific factors that hinder or support their development and distribution are outlined. These factors can then be targeted through policy development or the engagement of other system actors, resulting in a more efficient development and distribution of inclusive e-agriculture.

Moreover, this thesis contributes to the emerging field of inclusive innovation by applying the IIS approach to the South African context. According to Grobbelaar et al. (2017) little empirical evidence is available in the field of IIS. The available studies mainly apply the IIS concept to low and lower-middle income countries (Altenburg, Lundvall, Joseph, Chaminade, & Vang, 2009; Foster & Heeks, 2013; Kraemer-Mbula & Wamae, 2010). This study, however, applies the framework to an upper middle-income country such as South Africa, in which marginalized groups may face a different set of challenges. Therefore, this study enhances inclusive innovation literature by applying the IIS framework to the context of upper middle-income countries.

IIS functions are conceptualized in this thesis, contributing to the existing IIS framework. These functions are conceptualized based on mainstream innovation oriented technology innovation system (TIS) functions and enhanced by literature from inclusive innovation. This new set of IIS functions allows understanding factors that specifically support or hinder the development of inclusive innovations which address economic inequalities. These proposed functions can serve as a baseline for further studies regarding the development and distribution of inclusive innovations.

Additionally, there are already many studies regarding the application of digital technologies in agriculture within the research field ICT4D. However, these studies mainly focus on developmental aspects, whereas little attention has been brought to the actual emergence of these technologies within an innovation system itself. The analysis of digital technologies from a systems perspective is important for understanding how these technologies emerge and how they can be further promoted. Therefore, this study enhances ICT4D literature by analyzing digital technologies in agriculture from an IIS perspective.

2. Theory

The complex nature of the relation between inequalities and innovation (Cozzens et al., 2009), can be analyzed through the combination of the IS perspective and the inclusive innovation perspective. This allows to understand how the development and diffusion of novel technologies influence and are influenced by the challenges of marginalized groups. While an IS perspective provides insights into how the system influences the development and distribution of a novel technology, the inclusive innovation perspective analyzes the impact of an innovation on the marginalized group. Therefore, to understand how technologies that can contribute to reducing economic inequalities between SHFs and commercial farmers are developed and distributed, a combination of both perspectives is needed.

Section 2.1. discusses the concept of e-agriculture in South Africa, focusing on how these innovations may influence inequalities between SHFs and commercial farmers in a positive or negative way. Secondly, in section 2.2. IS theory is introduced as a tool for observing the development and diffusion of technologies. Section 2.3. discusses the concept of inclusive innovation, which provides insights into how innovation can positively impact the livelihoods of marginalized groups. Lastly, in section 2.4. IS theory and inclusive innovation theory are combined to conceptualize the IIS framework in order to understand how inclusive innovation is developed and distributed.

2.1. Digitalization in South Africa's Agriculture

The world-wide trend of digitalization is arriving in the South African agricultural sector. Media representatives already speak about the upcoming digital revolution in the agricultural sector (Mwendera, 2018; Dixie, 2018; Sung, 2018) and promise that the sector, as known today, will be disrupted by emerging digital technologies (Teranzono, 2018). In general, digitalization refers to the conversion of analog information[2] into digital information[3,4] (Moreno, 2013). Digital technologies are devices which are able to create, store, retrieve and transmit information faster and without interferences (Moreno, 2013). One example of digital technologies is the invention of the computer, which can also be regarded as the start of the digitalization era (Moreno, 2013). Therefore, digital technologies can optimize industrial processes by making use of increasingly available information.

Due to the potential impact of digital technologies on various industries, many companies, from startups to multinational companies, are developing digital technologies for the application in agriculture (McGrath, 2018). One example is the multinational company Microsoft, which is heavily involved in the digitalization of various industries. Since 2015, Microsoft is actively researching and developing digital technologies for the agricultural sector in their so called FarmBeats program (Microsoft, 2019). Within the agricultural sector the FAO coins the application of these digital technologies as e-agriculture (FAO, 2018). E-agriculture ranges from simple apps developed for mobile phones, over 'smart' IoT devices, the application of big data or AI through the usage of drone and satellite imageries to the integration of blockchain technologies in the agricultural sector (Sung, 2018; Teranzono, 2018; Mwendera, 2018; Dixie, 2018). A summary of the wide range of e-agriculture applications, as defined by the FAO, can be found in figure 1.

[2]Analog information is characterized as being continuous. This type of information has endless values and is not fixed between the two states 0 and 1 (Lathi, 1998).
[3]Digital information is characterized by being numeric and binary. This means, that digital information only differentiates between the two values 1 and 0 and expresses either yes/no, on/off. (Moreno, 2013)
[4]Digitalization of information refers to the transformation of analog information to digital information
Analog information can be transformed into digital information by assigning discrete values to the continuous value. The more discrete numbers are assigned to a continuous value, the higher is the quality of the digital signal (Zuch, 1979).

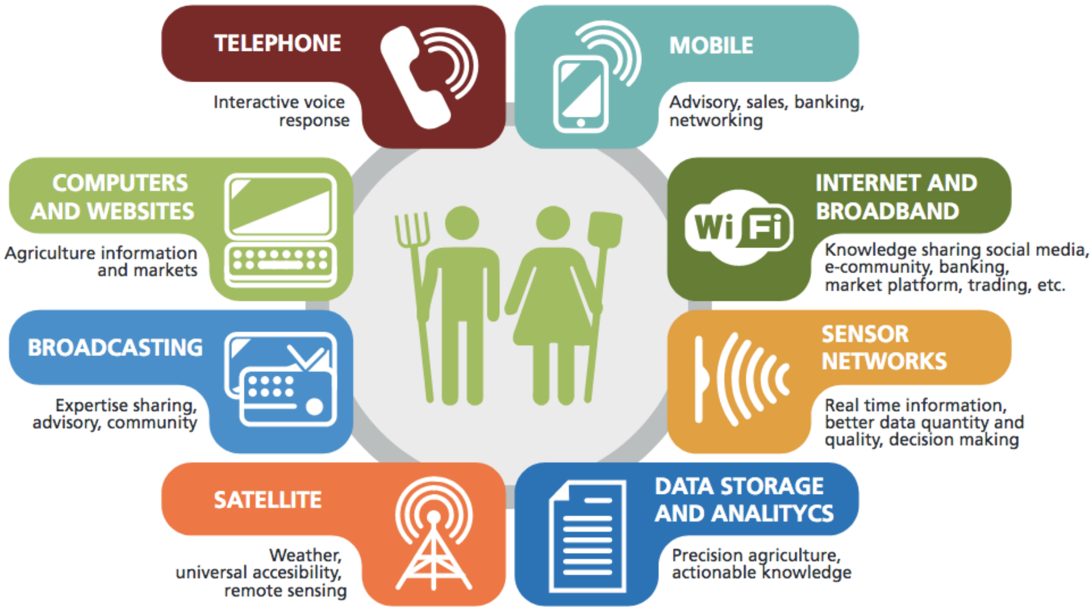


Figure 1 - Range of e-agriculture applications (Source: FAO, 2017)

One concrete example of the application and benefits of e-agriculture is the so-called precision agriculture. Maumbe & Okello (2013) explain that precision agriculture allows to reduce costs and environmental risks, allows more accurate managing of inputs, improves environmental administration, and results in increasing agricultural yields. Precision agriculture can, for example, be enabled by the application of IoT sensors, which gather information about fertilization and irrigation levels. This information can then be used by AI algorithms which calculate the precise needs of fertilizers and irrigation based on information such as crop and soil types (Radicle Group, 2019). Such technology-based precision agriculture also benefits novel crop developments, as they are highly sensitive regarding the correct amounts of inputs (Tittonell & Giller, 2013). Other examples are mobile phone applications, which can improve access to information, markets, advisory and finance (Qiang et al., 2012) or the use of drones which can observe farming land and detect potential pests at early stages (Mwendera, 2018).

Besides the potential of e-agriculture to change current practices and disrupt the overall agricultural sector, it is not yet clear how these digital technologies affect inequalities between SHFs and commercial farmers. As already discussed, inequalities are especially high in the South African agriculture sector. Aliber & Hart (2009) analyzed that in South Africa, 3500 commercially oriented large-scale farmers produced 95% of the overall agricultural outcome, leaving only 5% to the other 4 million SHFs. Analyzing how e-agriculture innovations change the overall setup of the agricultural sector helps to understand their impact on inequalities between SHFs and commercial farmers.

On the one hand, digitalization can increase inequalities between high-income and low-income groups (Hindman, 2000). Increasing inequality based on the presence of digital technologies is coined as the *digital divide*. This is often due to varying adoption rates of digital technologies between groups of different age, education and income (Hindman, 2000). Additionally, often unskilled labor and labor-intensive jobs are substituted by digital technologies (Loebbecke & Picot, 2015). This favors commercial farmers that mostly farm on a large scale with a minimum of personnel over SHFs that mostly farm in a labor-intensive way. Therefore, the introduction of e-agriculture can lead to an increase in inequalities between SHFs and commercial farmers.

On the other hand, there is extensive literature and research on how internet and communication technologies (ICT) may support the development of marginalized groups and reduce inequalities

(Thapa & Sæbø, 2014). This field of research is known as ICT4D and is often considered to especially have a positive effect on inequalities within the field of agriculture (Heeks, 2008; Qiang et al., 2012; Pienaar & Traub, 2015). Qiang et al. (2012) for example show that mobile phone applications can especially support smallholder farmers by providing better access to information (e.g. best practices in farming), enable access to financing and insurance as well as increasing market access, which are seen as the main drivers for inequalities in agriculture. An overview of potential benefits, as identified by Qiang et al (2012), can be found in appendix 1. Dlodlo & Kalezhi (2015) explain that e-agriculture such as IoT devices are becoming more and more accessible and affordable to low income groups. This allows SHFs to also participate in precision agriculture, reducing yield gaps between SHFs and larger commercial farmers (Dlodlo & Kalezhi, 2015).

These examples show that the development and distribution of e-agriculture can positively or negatively affect inequalities between SHFs and commercial farmers. Therefore, it is important to understand which types of e-agriculture emerge in South Africa and how they impact current inequalities between SHFS and commercial farmers.

2.2. Innovation Systems

Researchers agree that technological innovation does not emerge through a linear process of innovation, but that it occurs in a system through the interaction of different actors that exchange knowledge resulting in interactive learning (Lundvall, 1992; Freeman, 1995). Modelling a system around the technology of interest allows for a better understanding of the complex interrelations of system components and functions which “influence the development, diffusion, and use of innovations” (Edquist, 1997, p. 14). To understand how e-agriculture is developed and diffused a systems perspective is needed.

According to Edquist (2005), an IS consists of three main elements. These are system boundaries, system components and system functions. Firstly, clear system boundaries are needed to analyze the innovation system and understand what is in and outside of the system (Bergek, Jacobsson, Carlsson, Lindmark, & Rickne, 2008). Such boundaries can be based on spatial-, sectoral- or activity-based factors (Edquist, 2005). In this thesis, the boundaries are set by the South African agricultural sector, including e-agriculture related industry. This narrowed scope allows to analyze the included system factors more in-depth.

The second element of an IS are its components based on the specified system boundaries. Every IS consists of structural components, which can be understood as basic building blocks of the system (Suurs, Hekkert, Kieboom & Smits, 2010). Analyzing the interrelations between different components may “help to identify missing actors or institutions, or assess the quality and capabilities of specific system components” (Grobelaar et al. 2017, p.3). IS literature suggests different sets of components for such an analysis. Edquist (2005) defines *actors* and *institutions* as the two main components. Other studies add components such as *relations*, *innovations* or *infrastructure* to these (Suurs et al., 2010, Hekkert Negro, Heimeriks & Harmsen, 2011, Foster & Heeks, 2013). These additional components are often already included in the two main components. Edquist (2005) for example explains that institutions influence the relation between the actors. Additionally, infrastructural components often play an important role in countries that are still in transition (Kraemer-Mbula & Wamae, 2010) and are therefore included as a third type of component.

Lastly, the third element of an IS are the so-called system functions. These functions can be understood as necessary activities for the successful development and distribution of novel technologies (Hekkert et al., 2007; Bergek et al., 2008). System functions for example observe the development or distribution of novel knowledge, determine if expectations regarding the capability of the novel technology are shared or if sufficient resources for its development are available (Hekkert et al., 2007). In total there are seven system functions, which are all interrelated and contribute to the ‘functioning’ of the system. Such a functional analysis allows to understand how well certain activities are carried out and which actors are involved. This helps to determine which aspects either support or hinder the development and the diffusion of the innovation (Johnson, 2001). Insights form a function analysis can be used to provide advice on how to facilitate the further development of the technology of interest (Hekkert et al. 2007). Therefore, a system functions perspective is needed to understand how e-agriculture is developed and distributed within South Africa.

This conventional systems perspective only focuses on mainstream innovations aiming for economic growth and fails to address concerns and challenges of marginalized groups. This may lead to technologies being developed which mainly benefit specific groups and excludes others resulting in increasing inequalities (Foster & Heeks, 2013). To create a system in which inequalities may be reduced, inclusive innovations have to be promoted and facilitated. Thus, the IS perspective needs to be combined with inclusive innovation theory to reorient the focus of conventional IS theory from mainstream innovation to inclusive innovation. This combination allows to understand mechanisms which can lead to development and distribution of inclusive innovation.

The combination of the IS perspective with inclusive innovation theory has been suggested by many prominent researchers in the field of inclusive innovation (Cozzens & Sutz, 2012; Foster & Heeks, 2013; Chataway et al., 2014; Santiago, 2014). Most of these contributions explain the need for an inclusive innovation system, without clearly stating which IS elements need to be adapted and in which way. Only Foster & Heeks (2013) conceptualized first elements of an IIS by outlining how system components need to be adapted to strongly focus on the development of inclusive innovation within an IIS. The full adaption of an IIS, including boundaries, components and functions, has not yet sufficiently been elaborated.

2.3. Inclusive Innovation

Technological developments, for example in the agricultural sector, can either increase or decrease inequalities (Cozzens et al., 2009). Profit-driven innovation mainly benefits the inventors themselves and their potential customers (Paunov, 2013). Innovations that are inaccessible for SHFs while increasing the welfare of large-scale commercial farmers will increase inequalities (Paunov, 2013). Heeks et al. (2014) coins innovation "associated with increasing inequality" (Heeks et al. 2014, p. 3) as *mainstream innovation*. Mainstream innovations mostly focus on economic developments instead of social challenges faced by marginalized groups. Therefore, growth achieved by innovation which is only accessible for high- and middle-income groups increases the wealth gap to low-income groups (Planes-Satorra & Paunov, 2017). *Inclusive innovation*, contrarily, aims at including marginalized groups into the value chain by responding to social challenges of these groups (Heeks et al. 2014). Therefore, this type of innovation should improve the livelihoods of marginalized groups.

For innovations to have a positive impact on marginalized groups they must be available to the targeted group and actively address the needs and challenges these groups face. Only when the innovation actually targets the identified challenges, the livelihoods of the marginalized groups can be improved (Heeks et al. 2013). In case technologies do not directly emerge from within the marginalized groups themselves, one way to identify and meet the needs of the marginalized groups is to integrate them into the process of the technology development. When integrating marginalized groups into the process, it will be possible to understand the most pressing social challenges they face and develop technologies that respond to them (Heeks et al. 2014). Therefore, inclusive innovation combines a technology driven perspective with perspectives regarding social challenges of marginalized groups (Thapa & Sæbø, 2014).

To explain how inclusive certain innovations are Heeks et al. (2013) introduced the ladder of inclusive innovation. This ladder contains six different levels of inclusive innovation, of which each level contains the level before and adds an additional degree of inclusion, which helps to evaluate the potential impact of an innovation on the marginalized group itself. While the first few steps on the ladder mainly consider the marginalized group as a consumer of the innovation, the later steps evaluate the integration of the marginalized groups within the development of the innovation, or even consider structural changes of the innovation system (Heeks et al. 2013). Figure 2 visualizes the six levels of the ladder of inclusive innovation:

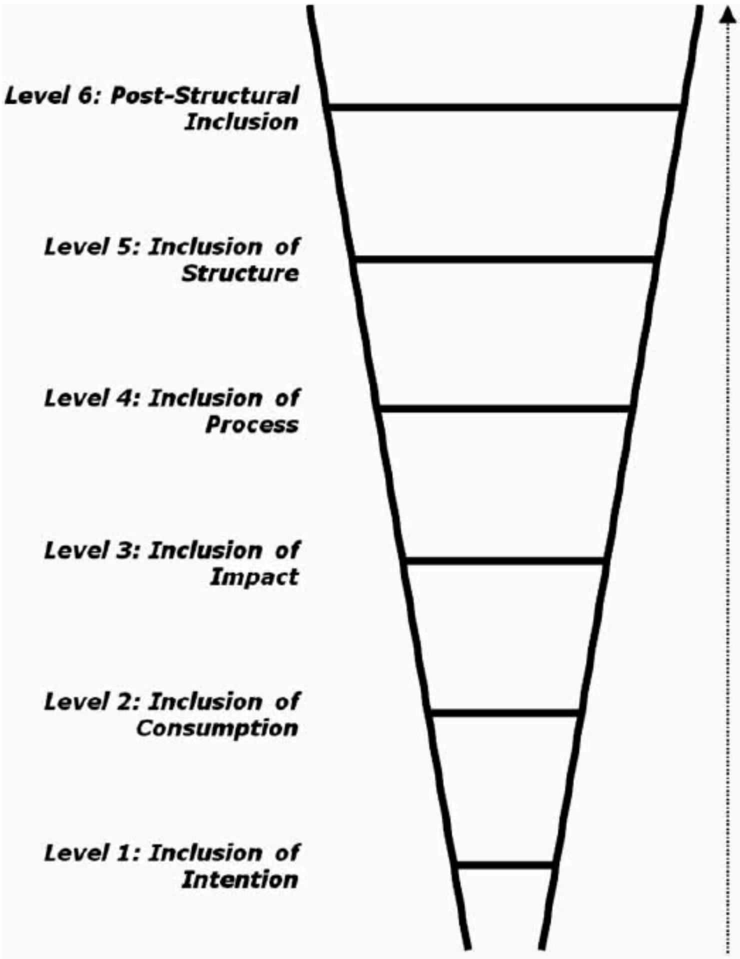


Figure 2 - Ladder of Inclusive Innovation from Heeks et al. (2014)

- **Level 1/Intention:** the intention of the innovation is to improve the situation of the marginalized group.
- **Level 2/Consumption:** the innovation is a concrete good or service, which can be adopted by the marginalized group
- **Level 3/Impact:** the innovation is not only adopted, but has a positive impact on the marginalized group. To reduce inequalities, not only the *absolute* impact needs to be positive, but the *relative* impact in comparison to higher-income groups has to be higher.
- **Level 4/Process:** the marginalized group is included in the development of the innovation. This involvement can happen on different levels starting from (1) being informed, (2) being consulted, (3) collaborating, (4) being empowered or (5) controlling.
- **Level 5/Structure:** the innovation is created within an inclusive system structure. This means that the overall system including institutions and organizations are inclusive themselves and the system itself has changed to being inclusive.
- **Level 6/Post-Structure**: the innovation has been developed based on inclusive knowledge-frames. This relates to the discourse of how inclusion is seen within society and its key actors.

Besides measuring the degree to which an innovation is inclusive, Heeks et al. (2013) suggest to clearly define the marginalized group which is targeted by the innovation. Inclusive innovation can target a wide range of marginalized groups such as “women, youth, the disabled and ethnic minorities” (Heeks et al. 2013, p.6). Heeks et al. (2013, p. 6) explain that most inclusive innovation studies focus on the challenges of “the poor” as the marginalized group of interest. Throughout the process of developing and distributing e-agriculture, various system actors are involved in and influenced by the innovation. For example, marginalized groups could be empowered by being employed for the development of the innovation, by being targeted as a consumer of the innovation or even by being positively affected due to changes in the overall supply chain related to the innovation. However, the main goal of this thesis is to identify how inequalities between SHFs and commercial farmers can be reduced through innovation. While e-agriculture innovations can be inclusive or exclusive for various groups that qualify as ‘the poor’, the main focus lays on SHFs. Narrowing down the group of beneficiaries allows to provide a more detailed view on particularly how SHFs are included or excluded from the innovation.

The selection of SHFs as the target of inclusive innovation is based on different factors. Firstly, the agricultural sector is one of the most important sectors in South Africa. Agriculture, forestry and fishery contributed 2.4% to South Africa’s gross domestic product in 2017. 15.6% of South African households are involved in the production of agricultural produce (Department of Agriculture, Forestry and Fishery [DAFF], 2012). This makes agriculture one of the biggest sectors of employment (National Planning Commission [NPC], 2013). According to the DAFF (2009) the agricultural sector has been the only sector which did not decline during the recession in South Africa. This shows the great importance of the agricultural sector in South Africa for employment and economic success.

Secondly, vast inequalities between poor and rich South Africans are present in the agricultural sector. Especially black communities in South Africa face enormous disadvantages. Governmental studies show that a small group of 40.000 predominantly white commercial farmers are responsible for 95% of the official agricultural output (DAFF, 2012). The rest of the production can be assigned to approximately four million smallholder farmers which are mainly black (Aliber & Hart, 2009). These numbers show the strong inequalities between black SHFs and white commercial farmers. Therefore, focusing on the reduction of inequalities between SHFs and commercial farmers has the potential to reduce poverty and improve rural development (Pienaar & Traub, 2015).

2.4. Inclusive Innovation Systems

As stated before, the IS framework can be used to analyze system factors which influence the development and diffusion of novel technologies. This perspective, however, mainly focuses on technology related factors, without considering the various impact on marginalized groups such as SHFs. Inclusive innovation theory, on the contrary, especially focuses on the impact of novel technologies on marginalized groups, but lacks a systemic perspective regarding the development of these technologies. Thus, to analyze the development of inclusive e-agriculture in the South African agricultural sector, a combined approach is required. By enhancing the IS approach with insights from inclusive innovation, systemic factors that hinder or support the development of e-agriculture with a positive impact on SHFs can be identified.

Combining insights from these two perspectives allows to conceptualize the IIS. To do so, the system elements components and functions have to be adapted regarding inclusive innovation. First of all, to adapt IS components to inclusive innovation, previously introduced IIS components by Foster & Heeks (2013) were used as a base to further include inclusive innovation literature. Subsequently, IIS functions were developed. This was done by comparing conventional system functions as introduced by Hekkert et al. (2007) and Bergek et al. (2008) with insights from the most prominent contributions in inclusive innovation literature. These comparisons allowed to broaden and change the scope of the conventional system functions to content-related insights in inclusive innovation literature.

2.4.1. Inclusive System Components

To conceptualize IIS components, conventional IS components have to be adapted to the core ideas of inclusive innovation literature. By comparing key components of IS literature with theoretical insights from inclusive innovation literature, Foster & Heeks (2013) suggested a first set of IIS components. As discussed before, different studies focus on different IS components. While Foster & Heeks (2013) focuses on the components *innovation, actors, learning, relations and institutions*, this thesis focuses on the components *actors, infrastructure and institutions.* Therefore, some of the IIS components by Foster & Heeks (2013) serve as a first guidance for the adaption of IS components in this thesis. Additionally, further insights from other relevant inclusive innovation literature are considered when discussing IIS components.

Generally, the conventional components remain the same while merely the content of the components shift (Foster & Heeks, 2013). Therefore, in the following the three identified system components actor institution and infrastructure are discussed and compared to insights from inclusive innovation.

Actors

First of all, an innovation system consists of various system actors, which *"*are either directly or indirectly engaged in the process of innovation*"* (Chataway et al., 2014, p. 8). According to Edquist (2001), these actors are private companies, knowledge institutions, venture capital organizations and governmental organizations. In a conventional IS, the main focus is the development and distribution of mainstream innovation through formal organizations. These mainly target higher income markets or consumers (Foster & Heeks, 2013). When focusing on the emergence of inclusive innovation, the targeted group includes or mainly focuses on marginalized, low-income consumers, which are often reached through non-traditional informal markets (Foster & Heeks, 2013).

Chataway et al. (2014) put the emphasis on three key sets of actors, which are strongly related to the development of inclusive innovation. The first set of actors are local and global private companies, which throughout the past decades became more and more engaged in the development of inclusive innovation, targeting low-income markets. These increasing engagements may be induced by pursuing corporate social responsibility (CSR) strategies (McWilliams & Siegel, 2001), or seeking additional profits through the means of creating social impact (Porter & Kramer, 2019). The second group are government actors, which become more and more aware of the need to support inclusive innovation to empower low-income groups. These actors engage increasingly in the support of inclusive innovation projects initiated by others such as private organizations (Chataway et al. 2014). These two types of actors are already of importance within the conventional IS. Within an IIS, however, their responsibilities change to focus more strongly on challenges faced by marginalized groups. Lastly, Chataway et al. (2014) see non-profit markets as a primary driver of inclusive innovation. These non-profit markets are enabled by the engagement of nongovernmental organizations (NGOs) and other foundations, which are the third type of actor. These actors collaborate with governments or local private sectors and can provide initial funding or increasing legitimacy for inclusive innovation projects (Paunov, 2013).

Because of the focus of this thesis on the development of inclusive innovation towards the empowerment of SHFs, the SHF becomes a central actor in the system as well. Based on the setup of the agricultural sector, intermediates, who act as middlemen or distributers between SHF and retailers may play an important role in the distribution of technology to reach the informal SHF market and distribute knowledge regarding the innovation (Foster & Heeks, 2013; Kraemer-Mbula & Wamae, 2010). Therefore, within the IIS, most conventional actors remain important with slightly different roles to fulfill, while additional actors such as NGOs and intermediaries become important.

Infrastructure

Within IS literature different types of infrastructure are discussed in different studies. Lundvall (2007) for example discusses knowledge infrastructure, technology infrastructure and public infrastructure as three important types of infrastructure. Hekkert et al. (2011) mention physical infrastructure, technological infrastructure and political and economic infrastructure. As most components such as knowledge exchange or the emergence of technologies are discussed in other fields, infrastructure in this thesis relates to the physical infrastructure. This includes for example roads and transport, buildings or other physical installations such as the availability of mobile networks.

While in most developed countries basic infrastructure such as electricity, internet or even roads is widely accessible, the lack of such adequate infrastructure often poses obstacles for economic growth and poverty reduction in sub-Saharan African countries (Calderón & Servén, 2010). This lack of infrastructure can also be observed in the rural areas of South Africa, in which most farmers, also SHF, are situated (NPC, 2013). Especially innovations in the field of e-agriculture, are often dependent on internet access, or even access to basic farming infrastructure such as irrigation systems. Therefore, infrastructure-related problems are important factors to be analyzed within the South African agricultural IIS (Planes-Satorra & Paunov, 2017).

Institutions

There are two types of institutions in a system. Hard institutions refer to formal structures such as laws and rules, while soft institutions include habits or routines, which influence the behavior of actors in the system (Woolthuis, Lankhuizen & Gilsing, 2005; Edquist, 2001). Foster & Heeks (2013) explain that in the 'conventional' IS, usually formal and static institutions play an important role and are analyzed by observing laws and policies. Contrary, when focusing on inclusive innovation towards low-income groups, Foster & Heeks (2013) identified that within informal sectors, formal institutions are often lacking or are disregarded.

Additionally, focusing on SHF in South Africa, context related aspects, such as influences of Apartheid and the expropriation of black farmers during these times are exceedingly important and must also be taken into consideration. As seen by governmental policies such as the Broad-Based Black Economic Empowerment (BBBEE), introduced by the Department of Trade and Industry (2019), discrimination remains critical in South Africa and may influence the integration of SHF in the process of developing and distributing inclusive innovation. Therefore, aside from analyzing formal institutions as suggested in the conventional IS, informal institutions, such as habits, rules and views of system actors become important for the analysis of the e-agriculture IIS of South Africa.

2.4.2. Inclusive System Functions

Similar to the system components, the conventional system functions have to be adapted based on core ideas of inclusive innovation literature. To conceptualize IIS functions, a first set of system functions were derived from IS literature. Most prominent contributions to the system functions approach are the proposed functions by Hekkert et al. (2007) and Bergek et al. (2008). Both contributions suggest similar sets of functions, which aim to analyze the development and distribution of specific technologies.

To conceptualize the IIS functions, these conventional system functions have been enhanced with insights from inclusive innovation literature. To do so, a similar approach compared to the conceptualization of IIS components conducted by Foster and Heeks (2013) was pursued. Thus, the content of the 'conventional' system functions, as suggested by Hekkert et al. (2007), was compared to ideologies from inclusive innovation literature and accordingly adapted. The inclusive innovation literature was selected based on them being fundamental, agenda setting or prominent contributions in the field of inclusive innovation. The following literature was consulted: Chataway et al. (2014), Cozzens & Sutz, (2012), Cullen, Tucker, Snyder, Lema, & Duncan (2014), Foster & Heeks, (2013), Heeks et al., (2013), Heeks et al., (2014), Paunov, (2013), Planes-Satorra & Paunov, (2017), and Qiang et al. (2012). Next, the original IS functions and how they were adapted based on inclusive innovation literature are discussed.

Function 1: Inclusive Innovation Activities

Hekkert et al. (2007) introduce the first function within an IS as 'entrepreneurial activities', which can be seen as "*entrepreneurs´ risky experiments"* (Hekkert et al., 2007, p. 422). These activities are necessary for the emergence of innovation and important for the creation of new knowledge. They can then disrupt current markets and help to deal with uncertainties.

When focusing on the development of inclusive e-agriculture, the main premise is to make the innovation accessible to marginalized groups, in this case SHFs. Foster & Heeks (2013) explain, that inclusive innovations are not necessarily disruptive but rather incremental innovations. The idea is to adapt technologies already used by mainstream groups to the needs of marginalized groups. Therefore, the first function of the IIS does not solely focus on novel and disruptive technologies, but rather on technology that can be adapted by marginalized groups. This shift from disruptive innovation to incremental innovation results in a shift in who these entrepreneurs are. While in the TIS, these entrepreneurs are often new entrants or incumbents searching for new business opportunities (Hekkert et al. 2007), in the IIS, innovation is often developed in informal markets by intermediaries or users (Foster & Heeks, 2013).

The innovation activities within an IIS also have to be inclusive. According to Heeks et al. (2013) innovation activities should at least have an intention to positively impact the marginalized group in order to be considered inclusive (Level 1 inclusion). It can also be analyzed, whether the innovation is accessible by SHFs (level 2) or whether it has a positive impact on their livelihoods (level 3). For innovation activities to be inclusive SHFs themselves may be included in the development process (level 4). In the best case, the innovation activity is embedded in an inclusive system (level 5) or changes the overall innovation system towards being inclusive in itself (level 6). Therefore, within an IIS, innovation activities should target or include the marginalized group to a certain extent, in order to result in the development and diffusion of inclusive innovation.

Function 2: Knowledge development

The innovation process is based on the creation of new knowledge, including mechanisms of learning (Hekkert et al., 2007). This idea is applicable to all types of innovation, no matter if they aim for increasing returns or the inclusion of marginalized groups. Therefore, to develop novel e-agriculture solutions, technological knowledge needs to be developed (Hekkert et al., 2007).

Within an IIS, however, the creation of new knowledge regarding the technology cannot capture its potential impact on marginalized groups. For the resulting innovation to positively impact marginalized groups, knowledge regarding their challenges is needed (Paunov, 2013; Heeks et al., 2014). For example, this can be achieved by including marginalized groups in the knowledge development process itself (Heeks et al., 2014). Moreover, by creating knowledge for marginalized groups, they can be positively impacted (Foster & Heeks, 2013). This relates to information on how to use novel technologies or how to overcome specific challenges. Therefore, by creating new knowledge in interaction with SHFs, knowledge regarding their actual needs can direct the innovation process.

Function 3: Knowledge diffusion through networks

Knowledge also needs to be exchanged between different system actors. Through the interaction between the different system actors, their expectations can be aligned (Hekkert et al., 2007). Especially expectations of governmental actors, which are responsible for the development of policies regarding the innovation, and expectations of private companies, which plan their research and development activities should be aligned (Hekkert et al., 2007). Throughout this process also knowledge can emerge. This is known as learning by interacting and learning by using (Hekkert et al. 2007).

To integrate marginalized groups in this learning process, Qiang et al. (2012) and Cullen et al. (2014) suggest platforms for knowledge exchange between formal and informal actors. This knowledge exchange could be one directional by only learning about the challenges of marginalized groups, or by providing information for marginalized groups regarding the usefulness and use of innovation (Paunov, 2013). Knowledge platforms which even allow for a bi-directional exchange between the different actors including the marginalized groups can be considered as an inclusive system structure (level 5) (Heeks et al., 2013). Therefore, it is important to include SHFs in these knowledge exchange plattforms.

Function 4: Guidance of Search

Hekkert et al. (2007) introduce the function guidance of search, in order to align and bundle investments towards one direction of innovation. Different system actors such as the government, or industry actors can contribute to fulfilling this function.

This function seems to be crucial within an IIS, as a clear vision towards inclusive innovation needs to be shared amongst all actors in the system (Heeks et al., 2014). Once this shared vision is established, a collective action towards the improvement of the livelihoods of the marginalized groups can be taken (Cozzens & Sutz, 2012; Heeks et al. 2014). Especially the alignment of governmental policies towards inclusive innovation are crucial for the empowerment of marginalized groups (Planes-Satorra & Paunov, 2017).

Function 5: Market Formation

In the conventional IS, novel technology competes with technologies already embedded in the market, and therefore often starts in niche markets, to later become the dominant technology itself (Hekkert et al., 2007). Such competitive market structures, pose an additional challenge for inclusive innovations. Marginalized groups such as the poor, cannot heavily invest in novel technologies. This challenge makes it especially interesting to analyze the market formation as a function of the IIS. A market can be understood as the supply and demand of goods or services. There must be a demand for the technology amongst the marginalized groups, and a supply of technology from other system actors. Here intermediaries can play an important role as brokers providing knowledge about the usefulness and use of the innovation to the SHF (Foster & Heeks, 2013; Paunov, 2013). Usually intermediaries have strong connections to SHFs as they act as distributors selling SHFs produce to commercial actors. Therefore, intermediaries already have connections to SHFs and act on a trust base, which allows them to introduce technologies and induce SHF demand.

Next to that, it is important to understand if there are factors in the IIS enabling the development and distribution of technologies, which may be economically challenging. Such factors may be governmental subsidies or NGOs financing the development of inclusive technologies (Chataway et al., 2014). Additionally, large private companies may invest in the development of technologies targeting SHFs based on CSR engagements, or by anticipating future returns of emerging markets (Chataway et al., 2014). Local companies may engage in the development of inclusive innovation due to concerns regarding local challenges (Chataway et al., 2014). Therefore, it is crucial to observe the market mechanisms through which inclusive innovations transcend to SHFs.

Function 6: Resource Mobilization

Resources such as financial and human resources are important for the development of novel technologies, for example the creation of knowledge (Hekkert et al., 2007). Such resources are also prerequisite for the development of inclusive innovations (as described in function 5). Inclusive innovation often emerges within the marginalized groups themselves (Foster & Heeks, 2013).

Therefore, these resources need to be also accessible to all groups of the system and not only to formal commercial actors.

Function 7: Creation of Legitimacy/ Counteract Resistance of Change

Function 7, analyzes how well the innovation is accepted or disregarded within the system. One influential factor are lobbying activities of commercial actors for or against the innovation. Some actors may aim for changes in policies to lower barriers of entry for the innovation into the system. Contrary, other actors may request higher standards, which pose an additional burden for new technologies and stop their diffusion. Additionally, different interest groups either support or oppose the integration of the innovation. These groups may therefore take actions such as demonstrating for or against its development and diffusion (Hekkert et al., 2007).

Within the IIS, organizations such as NGOs, governmental actors or multinationals can provide legitimacy for other organizations to engage in the development of inclusive innovations. Private actors often lack sufficient trust to engage with informal markets in which many innovations emerge that favor marginalized groups (Chataway et al., 2014). Therefore, it is exceedingly important to have big and trustworthy organizations engaging in the innovation process of inclusive innovations.

3. Methodology

3.1. Research design

The overall research question aims to identify system factors, which support or hinder the development of inclusive innovations in the e-agriculture sector to reduce inequalities between SHFs and commercial farmers. To answer this research question, three main research steps were executed. Firstly, based on the IIS components factors that contribute to increasing inequalities between SHFs and commercial farmers within the agricultural IIS are analyzed. Secondly, based on the conceptualized IIS functions, factors that support or hinder the development of mainstream and inclusive e-agriculture in South Africa were outlined and compared. Lastly, the identified inclusive innovations from the second step were evaluated regarding their level of inclusion on Heeks et al.'s (2013) ladder of inclusive innovation and analyzed based on their respondence to the challenges identified in the first step.

The IIS analysis was performed on the level of the e-agriculture sector in South Africa, meaning there are two boundaries. South Africa served as an interesting case as it ranks as the country with the highest income inequalities in the world based on the Gini index, calculated by the World Bank (World Bank, 2018). Therefore, the South African government, more specifically the National Planning Commission (NPC, 2013), launched a National Development Plan in 2013, which aims to eliminate poverty and reduce inequalities by 2030. Besides this active engagement towards inclusive activities, inequalities remain high in South Africa (Sulla & Zikhali, 2018). Within South Africa, the agricultural sector serves as an interesting case. On the one hand, inequalities in the form of large income gaps between SHFs and commercial farmers are especially high (Pienaar & Traub, 2015). On the other hand, the development of e-agriculture, meaning the application of novel digital technologies in agriculture, promises to disrupt the current agricultural sector worldwide (Teranzono, 2018; Mwendera, 2018). Within this field, different studies outline potential positive and negative effects that e-agriculture can have on inequalities (Dlodlo & Kalezhi, 2015; Maumbe & Okello, 2013). Therefore, the development and distribution of e-agriculture innovation, which influences inequalities between SHFs and commercial farmers in South Africa, was analyzed.

Factors supporting or hindering the development and distribution of inclusive e-agriculture innovations were identified by applying analytical frameworks. First of all, IIS components were derived from the work of Foster & Heeks (2013), who introduced a first set of IIS components, which in this thesis were further complemented by additional inclusive innovation literature. IIS functions were fully conceptualized by comparing conventional IS functions from Hekkert et al. (2007) and Bergek et al. (2008) with inclusive innovation literature. This analytical framework guided the research process by indicating potentially important factors. Hence, the research design is of deductive nature.

For high data validity, data triangulation was performed. Semi-structured interviews with relevant system actors were conducted. Information was further enhanced by qualitative documents such as research articles, governmental policy documents and newspaper articles. Lastly, an expert interview with a professor of innovation studies and inclusive innovation was conducted to validate main ideas of the analysis.

3.2. Data Collection

Semi-structured interviews and qualitative documents were used as the main sources of data. In this thesis a combination of a purposive sampling (Bryman, 2012, p. 418) and snowball sampling (Bryman, 2012, p. 424) was applied. To identify relevant system actors in the South African e-agriculture sector and to obtain a first set of relevant documents such as newspaper articles, a systematic search, based on the combination of selected search terms, was executed. These search terms were grouped by agricultural and digital technology terms and respectively combined with the term "South Africa", as indicated in figure 3. This resulted in 83 possible combinations of search terms. For each combination the first ten pages on Google were analyzed to identify system actors and documents related to the field of interest. Actors were identified by either being directed to their website or by following up on publications about these actors. After the first 44 possible combinations, data saturation was achieved as several rounds did not result in the identification of further actors. This extensive search resulted in a preliminary list of 79 system actors, in the categories business, NGOs, governmental actors, retailers and research institutes. Additionally, 36 relevant newspaper articles were identified. The documents were enhanced by policy documents from governmental websites. Within the websites of the national government, the DAFF and the department of telecommunications & postal services, 10 relevant policy strategies related to inclusive development, agriculture and ICT were identified. The names of the documents can be found in appendix 2.

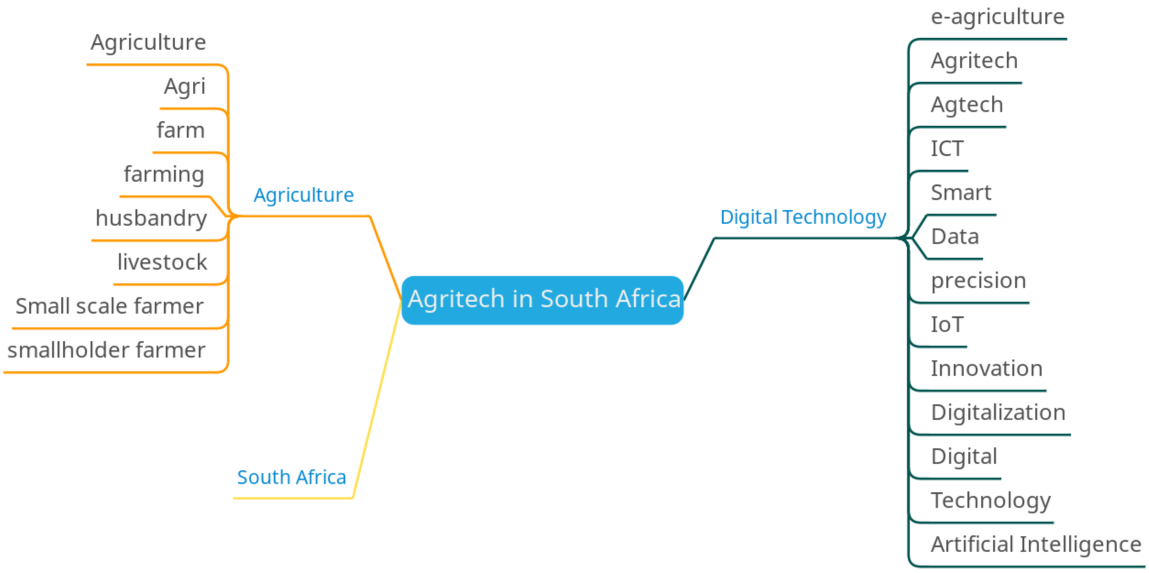


Figure 3 - Search Terms for Relevant E-agriculture Actors (Source: Author)

For better data quality, accessibility and understanding of the overall situation, the interviews were conducted in South Africa in person. Due to vast distances in South Africa and time constraints, only a limited number of places could be visited. As the majority of the identified actors was based in the areas (1) Pretoria, (2) Johannesburg and (3) Cape Town, only actors based in these regions were contacted and incorporated in interviews. Therefore, in a first approach 53 actors were contacted, resulting in 18 interviews which were arranged before the field trip. Based on snowball sampling, ten additional interviews were conducted on the ground. This resulted in a total of 28 interviews which are listed in appendix 4.

As the overall e-agriculture system contains a much larger number of agricultural and technological actors, not all could be contacted. However, interviewees reinsured that the most relevant actors in the system were covered. The interviews were predominantly performed face to face and all in English. Interviews were conducted with the most knowledgeable person regarding the impact of e-agriculture innovation of the organization to obtain the deepest insights. However, this person was not always available for an interview, leading to differences in the insights obtained from each interview. The most knowledgeable persons also differed in the positions they hold, depending on the setup of the company. While in Startups, often the CEO had the most insights, in large organizations project leaders are more knowledgeable regarding the topic. This made a comparison of the insights gained more challenging. Lastly, the limited access to SHFs poses another limitation leading to challenges to fully understand their perspective regarding the adoption or non-adoption as well as their usage of technologies.

The semi-structured qualitative interviews allowed to gain as much insight as possible from the interviewed actors. The interviews were structured by first explaining the overall context of the study to give the interview partner an introduction into the topic. Further, the interview was adapted, based on the background and interest of the interview partner. Afterwards, open questions, based on the conceptualized frameworks, were asked. Questions were only used to redirect the interview partner towards the topic when he or she was deviating. This allowed to obtain credible unbiased responses from the interviewee and additionally provided insights into the personal views of these actors. The interview guidelines of the semi-structured interviews can be found in appendix 3. Each interview had a duration of 15 minutes up to 1 ½ hours, with an average duration of 44 minutes. Appendix 4 provides an overview of the interviewed system actors.

The interviews were conducted with 12 different types of actors. The biggest group were technology developing companies with 9 interviews. These companies were at heart of the research as they were the most relevant for analyzing the development and distribution of digital technologies. The rest of the organizations provided additional system insights. An overview of types of organizations interviewed is provided in table 1. Within the 9 technology companies, 3 focused mainly on the commercial sector and 6 focused on the SHF-sector.

Table 1 - Types of Organizations (Source: Author)

Type of Organization	Number of Interviewed Actors
Technology Company	9
Research and Educational Institutes	4
Retailer	4
Governmental Actor	3
Other Organizations	3
NGOs	2 (One also engaged in Technology Development)
Media	1
Farmer	1
Financial Organization	1
Extension Officer	1
Total	**29**

3.3. Operationalization

To analyze the data, a coding framework based on the conceptualized IIS was created. This first theoretically conceptualized framework consisted of seven categories, representing the IIS functions, including several subcategories. Additionally, an eighth category was used to capture impact related factors of the technology and a ninth category in line with the IIS components was created to gather context specific aspects. The subcategories were refined and adapted throughout the coding process. This was done, in case new concepts within one category appeared, which had not been covered in the initial framework. One example is the second category representing knowledge development. Its subcategories originally only covered the fields 2.1 technical knowledge, 2.2 knowledge creation about the needs of SHFs, 2.3 knowledge creation for SHFs and 2.4 knowledge creation in interaction with SHFs. A fifth subcategory was thereafter established which captured knowledge creation of SHFs in general, such as location and type of produce. This category only appeared throughout the coding process. The final coding framework including a set of coding rules and examples can be found in appendix 5.

3.4. Data Analysis

The data gathered through the semi-structured interviews was recorded and afterwards transcribed. The interview transcripts can be obtained upon request and approval. The transcribed documents were then used for axial coding, which allowed for analytical induction as an approach to analyze the gathered data. Here the initial system functions served as a baseline to understand the gathered data. All interviews were coded twice, to increase data validity. The first iteration was done with Nvivo, in which additional sub-categories were created. The second iteration was done in Excel spreadsheets with the final coding framework. These two different programs were used to improve data comparison, as Nvivo allowed for a better in-depth analysis of one subcategory, while the matrix structure of Excel coding allowed for better comparison between different interviews.

3.5. Research Quality

Most important in qualitative research is measurement validity. Through data triangulation a higher external measurement validity was aimed for. To do so, different sources, such as qualitative semi-structured interviews, qualitative documents and an expert interview were used. To increase internal validity, the interviews were transcribed and coded according to clearly defined coding rules. Additionally, face-to-face interviews allowed to recognize context specific aspects and increased data validity. Lastly, the expert, a professor from the Netherlands and South Africa specialized in innovation systems and inclusive innovation, was interviewed to validate the research setup before the data analysis and after the interviews were conducted.

This study is a qualitative study, with the focus on the specifics of the IIS in the e-agriculture sector of South Africa. As several factors are country specific, and depend on local factors, findings from these studies are usually difficult to directly apply to other countries or sectors. However, the outcome of this research suggests important system factors that may influence the development of inclusive e-agriculture solutions and therefore may be used as a starting point in related research and tested with further empirical evidence.

4. Results

The result section is set up as following: In chapter 4.1. factors that contribute to increasing inequalities between SHFs and commercial farmers are analyzed based on the IIS components. This enables an understanding of the challenges SHFs face and how they could be overcome. Afterwards, in chapter 4.2., the development and distribution of e-agriculture technologies in South Africa are analyzed based on the IIS functions approach. Special focus lays on factors that hinder or support the development and distribution of e-agriculture technologies concerning SHFs. In chapter 4.3. it is then analyzed how the identified technologies aim to support the development and inclusion of SHFs. Figure 4 portrays the structure of the results section.

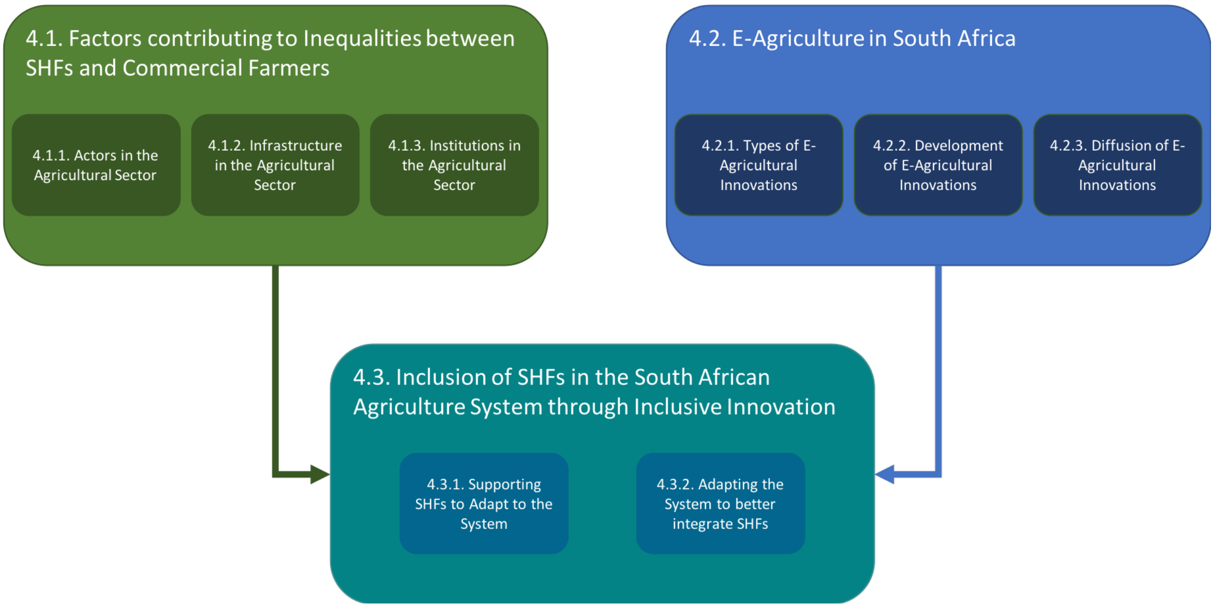


Figure 4 - Structure of Results (Source: Author)

4.1. Factors contributing to Inequalities between SHFs and Commercial Farmers

As stated in previous chapters, the agricultural sector has proven to be highly important for employment and economic stability in South Africa. Additionally, high levels of inequalities between SHFs and commercial farmers are present in this sector. One example, as observed by different types of system actors is the increasing land concentration with fewer farmers (Interview 10, 13 & 24). This trend is observed worldwide and is mainly due to (1) a diminishing and (2) an aging farmer population. In the view of large retailers, only large farmers can compete with the high demands of quantity, quality and low prices (Interview 24). Economies of scale allow farmers with large farming land to produce in a profitable manner, driving smaller farmers out of business (Interview 13, 19 & 24). Governmental representatives also believe that less and less young people are interested in the agricultural industry (Interview 19). This contributes to the decreasing farmer population, leaving fewer farmers with more land. The increasing land concentration with fewer agricultural actors reinforces inequalities between large and small farmers.

This is only one of many factors leading to inequalities within the South African agricultural sector. In the following, specific factors contributing to inequalities between SHFs and commercial farmers are further analyzed by observing IIS components of the agricultural system. As it is impossible to provide an exhaustive overview of factors resulting in the inclusion or exclusion of SHFs, only factors observed through the application of the IIS components and therefore somehow related to inclusive innovation are discussed. Firstly, relevant system actors and their relation towards the inclusion or exclusion of SHFs are outlined. Secondly, infrastructure and infrastructural challenges are described. Finally, institutions towards inclusion of SHFs are presented. These are mainly policy frameworks and initiatives of private organizations, representing their view towards the inclusion of SHFs.

4.1.1. Actors in the Agricultural Sector in South Africa

First of all, farmers are differentiated between large commercial farmers and SHFs. Throughout the sector different criteria to classify a farmer as a commercial or SHF were identified. Some actors considered size (interview 15 & 18), lack of experience (interview 7 & 24), market access (interview 5), or the overall turnover (interview 17) as criteria for SHFs. Besides these identified disparities between SHFs and commercial farmers, vast differences can be seen in their organization. Agri Western Cape, a representative organization of farmers, elaborated that the commercial sector is highly organized (Interview 22). According to the DAFF and Agri Western Cape, the commercial sector is organized based on the different commodities which are represented by their own unions (Interview 11 & 22). Additionally, organizations such as Agri SA, or its provincial organizations e.g. Agri Western Cape, bundle interests of the different unions and aim to positively influence policy making regarding the agricultural sector (Interview 22). Contrary to these, the smallholder sector is mostly unorganized with only very few representative organizations (interview 18 & 22). This shows that the commercial sector benefits strongly from its organization and is better represented than the SHF-sector when policy decisions are made.

This organizational setup of the agricultural sector in South Africa strongly influences the relation between retailers and farmers. Weak unorganized SHFs compete against strong and organized commercial farmers. A tech startup explained that big retailers often prefer to deal with only a few commercial farmers instead of many SHFs (Interview 18). A big retailer also admitted that SHFs are perceived as being too risky to deal with (Interview 24). This is mainly due to SHFs often not fulfilling the required market standards. These standards are for example global Good Agricultural Practices (GlobalG.A.P., 2019), or locally derived standards which focus on food product safety, environmental impact and the health, safety and welfare of workers. Therefore, retailers prefer to maintain their collaborations with well-known commercial partners that fulfill these market standards (Interview 24). Moreover, in other African countries SHFs are crucial for the overall food supply chain ensuring food security, which results in a dependence of retailers on SHFs. In South Africa, on the contrary, the big commercial market is able to cover most demands (Interview 18). This makes it harder to integrate SHFs in the commercial market as it is widely self-sufficient.

To integrate SHFs into the food system and to support them in their organization, intermediaries act as brokers between SHFs and retailers. As stated by a tech startup these intermediaries know the industry and environment and therefore are needed to connect SHFs to the market (Interview 18). However, at the same time they often aim at maximum profit and try to get as much produce as possible for the lowest price possible (Interview 18). This results in intermediaries often being able to connect some SHFs to the market, not necessarily providing many benefits for SHFs.

Besides the organizational setup certain characteristics of SHFs make it challenging to include them into the formal agricultural system. Different private organizations such as retailers and tech startups claim that SHFs lack certain knowledge and skills to compete with established farmers (Interview 24). For example, some farmers are perceived to not have sufficient farming experience and knowledge about the market. This includes information about where to obtain fertilizer, seeds or other inputs to a fair price (Interview 5). Secondly, based on the experience of a big retailer, most SHFs possess basic farming knowledge, but lack business skills to engage in the market and often fail to understand the importance of reinvesting into the business (Interview 24). Additionally, as stated by one SHF and technology company, the size of SHFs limits their competitiveness as economies of scale almost make it impossible to compete with commercial farmers (Interview 15 & 18). Commercial farmers can produce in large quantities, allowing them to cover fix costs such as storage and transport (Interview 24). Another tech startup summarized these challenges as a general lack of market access faced by

SHFs, which hinders them to purchase and sell agricultural commodities (Interview 5). These different challenges and characteristics are all mutually dependent, as the turnover of SHFs for example remains limited due to the lack of market access, experience and farming land.

The government aims at targeting these challenges by supporting SHFs through extension officers (Interview 17). At the same time the government is aware of the limited number of extension officers, therefore not being able to provide sufficient support: "*incidentally, a study was done in 2007. That study told us that the Western Cape needed to have 119 extension staff, almost 120. We are still at 65*" (Interview 17). A private organization and two NGOs stated that governmental organizations often lack information regarding the location of the SHF, the type or amount of produce (Interview 8), and the concrete needs of SHFs (Interview 4 & 18). Due to the lack of knowledge about SHFs, it becomes a challenge to set up required support structures to assist SHFs in their development (Interview 7 & 24).

> *"There isn't currently a database of smallholder farmers, we don't know where they are, we don't know how many they are, and what their (...) challenges are on the ground."* (Interview 4)

Another challenge for SHFs are the requirements from banks for obtaining loans. To be able to compete with commercial farmers, SHFs need to invest in their business by buying land, procuring fertilizers and seeds or investing in novel technologies. As stated by the Land Bank, loans for these purposes are mainly provided on the premise of having collateral (Interview 13). However, as already indicated SHFs often only possess small sizes of land (Interview 15 & 18) or even only farm on borrowed land (Interview 13). Even though the Land Bank plans to provide loans to SHFs based on supply contracts with retailers, most SHFs remain excluded from obtaining loans from banks (Interview 13).

The lack of support for SHFs from governments and banks is often compensated by NGOs. As stated by an NGO, own extension staff has been sent to support SHFs, provide information and support services (Interview 7). One of these extension officers explained that they had performed a baseline study to locate SHFs and understand their needs, as the local government lacked this type of information (Interview 8). Additionally, such NGOs provide financial means to SHFs for the investment in their farms (Interview 7), or support private initiatives with funding for other support programs (Interview 28). Hence, NGOs play a crucial role in the development of SHFs.

As stated by the Western Cape agriculture technology and research department there is a lot of research directed towards novel agricultural solutions in collaboration with various universities (Interview 17). However, not all of this knowledge is useful for SHFs. Nevertheless, it was observed that several research organizations such as the Southern African Food Lab or the Bureau for Food and Agricultural Policy (BFAP) strongly engaged in the development of novel agricultural solutions directed to the needs of SHFs (Interview 4 & 25). This shows a general high level of engagement towards the development of novel agriculture solutions, and research towards the integration of SHFs.

Most of these factors influence technology companies, which aim at the development of e-agriculture innovations for SHFs. One tech startup mentioned the unorganized character of SHFs as a challenge to collaborate with them (Interview 5). Another tech company outlined the lack of governmental funding to develop technology for SHFs as a challenge (Interview 3). Additionally, as explained by a technology consultancy company, SHFs often do not have the money to invest in novel technologies (Interview 1), which makes it hard for tech startups to reach returns on investments (Interview 18). Resultant, the development of inclusive digital technologies is often challenging for profit-oriented companies.

Concluding, this section showed that on the one hand, certain characteristics of SHFs pose a challenge towards their integration into existing supply chains (Interview 5), which results in SHFs driving themselves out of the commercial market. On the other hand, due to the licenses, regulations and demands from big retailers or banks, the agricultural system itself is set up in a way which excludes SHFs from participating in the market and favors organized commercial farmers (Interview 18):

"*And emerging farmers are unorganized. You literally need to be their babysitter (...) And at some point we wanted to give up, because we felt like this is too much admin. Because we could easily just work with guys that are already big, that just need a better structure to selling their produce.*" (Interview 5)

"*We, at that stage, did not do business in South Africa with smallholder farmers because we knew, that that segment of the market is not very well organized. Because supermarkets, the formal markets, global G.A.P, all of those exports are addressed or focused and geared towards commercial farms in South Africa.*" (Interview 18)

4.1.2. Infrastructure in Rural Areas

Besides the challenges posed by actor relations to integrate SHFs into the system, South Africa's infrastructure poses additional challenges. As explained by one technology company, most farmers (both commercial and SHF) are often situated in rural areas where internet connections are poor or non-existent (Interview 3). Additionally, load shedding, which is an intentional electrical shutdown, leads to inconsistent energy supply (Interview 3). Therefore, digital technologies need to be developed in an autonomous way that neither depends on consistent energy supply nor internet connection.

Vast distances between farms, markets and off-takers, result in logistical problems of transport and storage. As stated by technology companies, aggregation or collection points are often located in inconvenient locations due to mismanagement or miscommunications between decision makers (Interview 3 & 18). While commercial farmers can distribute the resulting high logistics costs between large production quantities, SHFs may not be able to target the commercial market with lower quantities. A large retailer emphasized that the small production quantities of SHFs may not even cover the total transportation costs (Interview 24).

In the case of SHFs, technology companies recognized that often basic farming technologies such as irrigation and cooled storage are sparse (Interview 2 & 3). An NGO identified that not all SHFs possess smartphones, but rather feature phones, which do not provide them with access to the internet (interview 7 & 8). However, often children of SHFs are in possession of smartphones which allows SHFs access to the internet (Interview 8).

These aspects outline that infrastructure characteristics in rural areas of South Africa pose additional challenges, which have especially strong effects on SHFs. Therefore, infrastructure support programs are needed to lower first barriers towards the integration of SHFs increasing their competitiveness.

4.1.3. Institutions towards the Inclusion of SHFs in the South African Agriculture sector

Lastly, formal and informal institutions influence the inclusion or exclusion of SHFs in the agricultural sector and therefore are analyzed in detail. To understand formal institutions, governmental laws and regulations are outlined. Afterwards, informal institutions such as the position of actors towards the inclusion of SHFs are described.

The South African government is highly dedicated to decrease inequality. This is articulated through two superordinate plans, the National Development Plan (NDP) 2030, and the New Growth Path. These plans were set up after the government realized that even 18 years after Apartheid, the level of inequality is increasing (NPC, 2013). Therefore, it is the government's foremost goal to eliminate poverty and reduce inequalities by promoting an inclusive economy: "*The New Growth Path and the National Development Plan recognize that inclusive economic growth in South Africa is critical to addressing inequality*" (DTP, 2016, p. 10). Explicitly the South African government set itself the goal to reduce national levels of inequality based on the Gini index from 0.69 to 0.6 by 2030 (NPC, 2013). To pursue this ambitious long-term vision of the NDP, medium term strategic frameworks (MTSF) that identify more concrete measures have subsequently been drafted. Additionally, the program BBBEE program solely aims to empower previously disadvantaged, mainly black groups. This demonstrates that the South African government's target is to strategically decrease inequalities.

The South African government especially aims to address inequalities in the agriculture sector, by taking measures that improve the livelihoods of smallholder farmers (NPC, 2013). For example, by continuously developing the agricultural sector, 1 million new jobs are expected to be created by 2030 (NPC, 2013). Additionally, basic services such as health care and education are aimed to be improved, irrigation agriculture expanded and new financing and investment models established on the base of technology. Next to that, there are concrete land reform plans to redistribute 20% of commercial agriculture land back to black farmers. To further empower SHFs, extension officers aim at deepening collaborations between farmers, providing additional training and skill development, and aim at integrating SHFs into the food value chain (NPC, 2013).

Aside from governmental plans individual ministries articulate plans to tackle inequality. Exemplarily, the DAFF is dedicated to this task. Core ideas of the NDP and New Growth Path are combined in the Integrated Growth and Development Plan in order to adapt these government-wide plans to agriculture (DAFF, 2012). Furthermore, in line with the Integrated Growth and Development Plan the Agricultural Policy Action Plan aims to provide more concrete measures on how to improve and develop the agricultural sector, especially by emphasizing on the development of SHFs and the integration of innovative technologies (DAFF, 2014). Additionally, many other programs such as the African Agriculture Development Plan, the Agricultural Broad-Based Black Economic Empowerment, the Comprehensive Agricultural Support Programme or the Agricultural Policy Plan, all focus on the reduction of inequalities and the inclusive development of smallholder farmers (DAFF, 2012). All these programs demonstrate the South African government's strong focus on the inclusion of SHFs into the agricultural market.

Besides efforts within the agricultural sector, the department of telecommunications and postal services (DTPS, 2016) published a national integrated ICT policy white paper. This document is strongly aligned with the NDP and aims at creating a shared vision towards development and innovation in the ICT sector. The document itself suggests that ICT innovation can be used to address the nine most striking challenges as identified in the NDP. Further, great investments for the development of ICT innovations and digitalization of the whole economy are demanded, however no concrete expenditures are mentioned. Besides this broad vision, the DTPS also developed a more concrete e-strategy, which also aims at economic and social inclusion in ICT (DTPS, 2017). In this document, the DTPS emphasizes to promote ICT innovation, not only within the ICT sector itself but in other key sectors of the economy in which ICT enabled solutions may be applied. Here the agricultural sector is suggested as a key industry to be part of South Africa's digital industrial revolution (DTPS, 2017). One concrete example for planned ICT interventions is the "use of ICTs in the agriculture value chain with specific emphasis on enabling emerging and small holder rural farmers (also known as Smart Farming)" (DTPS, 2017,p. 14). These strategy documents offer insights into governmental goals to advance digitalization in agriculture while creating social and economic inclusion.

The idea of including SHFs more strongly and supporting their development is not only present in formal governmental plans, but is also widely shared amongst many system actors. Two smaller local retailers stated that their goal is to support local SHFs by sourcing as much produce from them as possible (Interview 6 &14). Another large retailer and a technology company stated that commercial farmers endeavor to support neighboring SHFs (Interview 3 & 24). A big retailer explained that often successful commercial farmers transfer knowledge and best practices experiences to SHFs, or allow SHFs to contribute their produce to already established supply chains between commercial farmers and retailers (Interview 24). Various research projects aim at linking stakeholders of the food system to find solutions for SHFs (Interview 16 & 25). One example is the project iZindaba Zokudla, which supports the exchange between different system actors and SHFs to create opportunities for SHFs

(Interview 16). Professor Naudé Malan from University of Johannesburg is the leader of this food systems project and identified that all types of system actors aim to integrate and empower SHFs:

> *"They all need a food systems change. We all want it. And I think that is actually the driver. Everyone wants it. We need the system to change. And we need to empower black farmers. Those are massive political drivers. And everyone wants it. I mean in South Africa, (...) we moan about the government, but generally, everyone is unanimous that we need to transform the country. And I would say that is the biggest driver."* (Interview 16)

These formal and informal institutions show a general agreement amongst most actors to strongly focus on the inclusion of SHFs into the agricultural system and show that e-agriculture may play an important role in doing so.

4.1.4. Evaluation of Structural Components on the Inclusion and Exclusion of SHFs

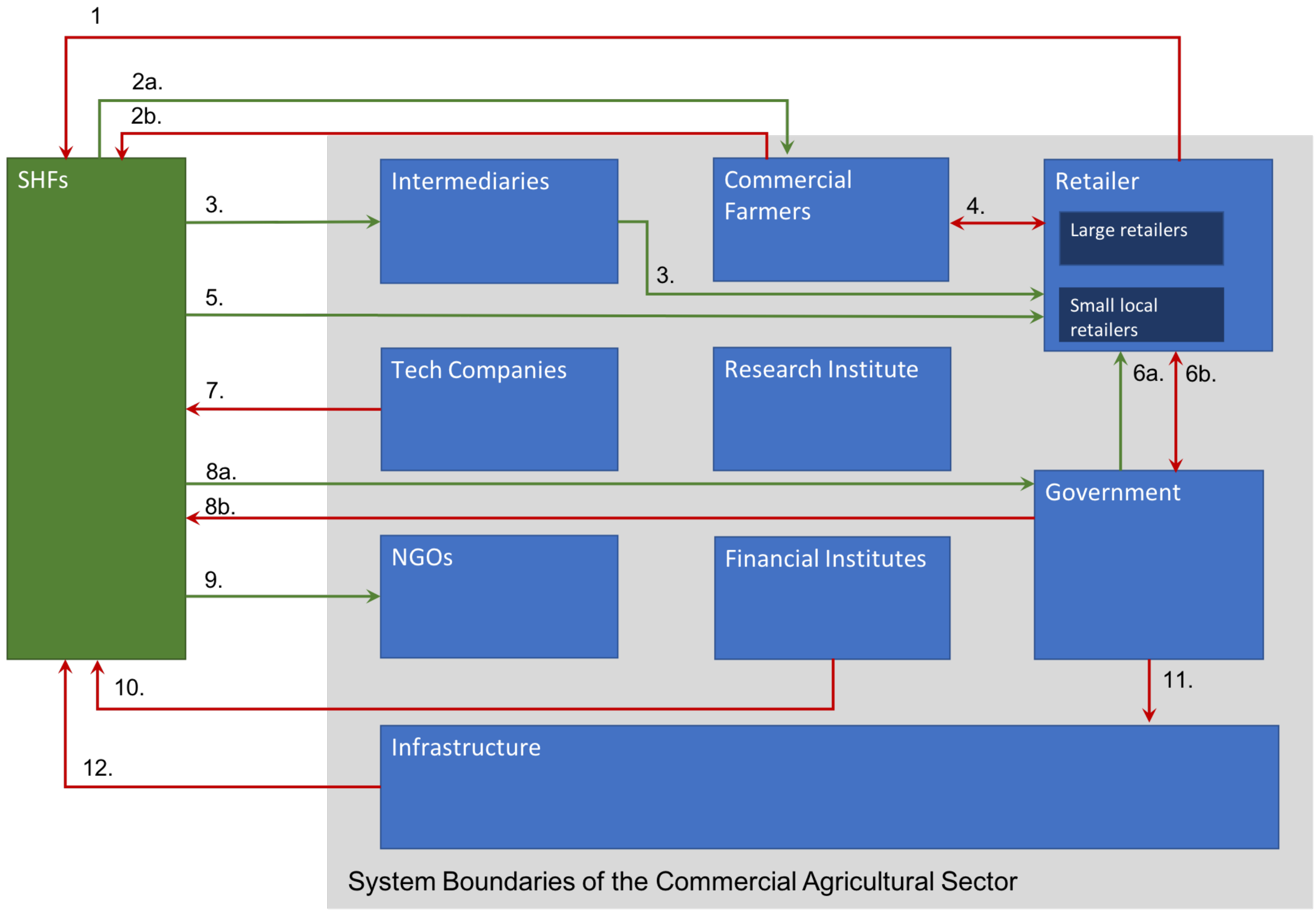
This chapter analyzes different factors influencing the inclusion and exclusion of SHFs from the overall agricultural system. On the one hand, many factors *excluding* SHFs from the system have been identified. First of all, characteristics of SHFs have been observed, which hamper their inclusion in the agricultural system. Most prevalent characteristics are their unorganized nature, the lack of collateral and the lack of business-related knowledge. Secondly, the requirements of certain system actors often result in further exclusion of SHFs from the system. Exemplarily are the requirements of banks or retailers, which are often utterly impossible to be fulfilled by SHFs. Thirdly, infrastructural challenges such as long distances, the lack of farming equipment and the missing presence of technology pose further obstacles for SHFs. Accordingly, many factors contribute to the exclusion of SHFs from the agricultural system.

On the other hand, formal and informal institutions for the *inclusion* of SHFs into the system have been identified. Formal institutions such as policy documents and regulations compel retailers to source from SHFs or engage in supporting SHFs. Other policy documents focus on the promotion of e-agriculture innovations to reduce social and economic inequalities and integrate SHFs in the system. Informal institutions such as individual positions of system actors show that the goal to include and support SHFs is shared amongst different actors. Local retailers or commercial farmers often endeavor to support SHFs as goodwill ambassadors supporting the overall community. This shows that a general agreement is shared between governmental plans and private initiatives towards supporting the development of SHFs and integrating them into the system.

However, the opinions of different system actors regarding the effectivity of governmental laws and regulations vary. One example is the BBBEE scorecard, a tool which assesses how strongly a company engages in and supports the development of the black society. Some experts in the food supply chain perceive this program as an effective tool to compel retailers to support and integrate SHFs into their supply chain (Interview 2 & 16). Others, such as a retailer and a technology company, suggest that most businesses see SHFs as too risky to deal with and rather go conform with other system requirements such as food safety, quality and availability and stick to established suppliers (Interview 18 & 24).

Additionally, a media representative and a consultant claim that some initiatives are often poorly executed and may even worsen inequalities (Interview 2 & 11). One example is land redistribution. The government redistributed land back to black farmers but failed to provide support for SHF with trainings, initial inputs or finance (Interview 11). A company stated that this resulted in the perception that SHFs are "*set (...) up to fail, and [have] absolutely no chance to succeed"* (Interview 23). Another company stated that often control mechanisms are lacking, which can lead to a misappropriation of financial support for agricultural development by the receiver (Interview 3). These examples show that even though governmental initiatives towards the reduction of inequalities are present their poor execution reduces or even reverses their impact.

These aspects highlight various reasons for the high number of inequalities between SHFs and commercial farmers and explain the exclusion of SHFs from the overall agricultural system. It can be concluded that both governmental and private actors aim to include SHFs and reduce inequalities. Nonetheless, such initiatives need to be executed carefully to achieve the desired outcomes. The exclusion of SHFs from the agricultural system is visualized in figure 5. Arrows between components indicate their relations, while the color of the arrow indicates their impact towards integration of the SHF into the system. Red arrows indicate activities between components which either directly or indirectly exclude or push SHFs out of the system. Green arrows indicate activities which promote the integration of SHFs into the system.



Explanation:

1. Difficult to connect SHFS to commercial market due to unorganized character and high market requirements

2a. Commercial farmers support SHF-development through knowledge transfer
2b. Highly organized commercial farmers outcompete SHFs

3. Intermediaries connect SHFs to market

4. Established supply chains between retailers and commercial farmers make it hard for SHFs to participate in supply chain

5. Goodwill from local retailers to source from SHFs

6a. Polices to compel retailers to buy from SHFs
6b. Weak policy enforcement

7. Difficult to collaborate with SHFs

8a. Policies to support inclusion of SHFs
8b. Low number of extension officers

9. NGO support programs for SHFs

10. No bank loans for SHFs without collateral

11. Poor Infrastructure development

12. Vast distances between farmers and markets and poor internet access in rural areas

Figure 5 - Componential Setup of the Agricultural IIS in South Africa excluding SHFs (Source: Author)

4.2. E-Agriculture Innovations in the South African Agriculture Sector

Digital technologies play an important role in the agricultural sector. They promise to disrupt original agricultural operations leading to increasing production outcomes with decreasing inputs (Mwendera, 2018). In the following chapter, different types of digital technologies, their development and distribution in the South African agriculture system are analyzed. Here the IIS functions approach is used to understand which factors support or hinder the development and distribution of e-agriculture innovations. First conventional innovation system aspects that influence the development of both mainstream and inclusive innovation, are discussed. This is followed by a focus on mainly inclusive innovation.

4.2.1. Types of E-Agriculture Innovations in the South African Agriculture System

In line with the first function of the IIS, activities are analyzed which lead to new business opportunities or enable new markets. In total 39 different organizations were identified as engaging in the development or application of e-agriculture innovation to create new business opportunities in the South African agricultural sector. For this study, nine interviews were conducted with organizations developing e-agriculture technologies. Amongst these were five startups, two medium sized companies, one large company and one NGO. This shows the diversity of organizations engaging in the development of digital technologies in the agricultural sector.

Mainly three different types of e-agriculture innovations were identified in the interviews. These are apps, ‘smart’ IoT devices and image recognition through drones or satellites. Agriculture related apps focus on various purposes such as enhancing market access, finance and insurance access, access to extension services, access to market information and the collection of data about SHFs. One example is the farmer2market app which was developed by the NGO Solidaridad in collaboration with other organizations. This app serves as an exchange platform for various actors in the agricultural sector to support SHFs by improving their market access and suggesting best practices. In the field of IoT devices, mainly sensors measuring moisture or soil composition and devices for remote steering of irrigation systems were observed. Lastly, drones or satellite data were primarily used to gather data regarding changes of agricultural land over time, early pest detection or advanced weather data modeling. IoT devices and drones have been regarded to mainly increase farming outputs or increase the efficiency of employed resources.

The first IIS function, ‘inclusive innovation activities’, not only focuses on general innovation activities, but it aims at understanding exactly which technologies benefit SHFs. Specifically, it was found that predominantly apps with low investment costs have been developed for SHFs. More advanced high-tech solutions such as IoT devices and drones have mostly been deployed in the affluent commercial sector. This may be the result of high cost (Interview 23) or due to the fact that the infrastructure targeted by the technology is lacking for small-scale farms (Interview 3). Only image recognition technology through satellite data has been identified to be developed for both, SHFs and commercial farmers. Satellite data can be obtained relatively cheaply through the South African National Space Agency. Within the commercial applications one startup explained that satellite data is used to enhance drone images and observe changes over time (Interview 26). In the case of SHFs, two companies related to data and finance explained that satellite images are often used to observe farm sizes and growth rates of SHFs over the years enabling risk assessments of SHFs (Interview 9 & 27). This shows that basically low costs agricultural apps are developed for SHFs while high-tech solutions primarily focus on the commercial sector and often remain inaccessible for SHFs.

4.2.2. Development of E-Agriculture Innovations in the South African Agriculture System

The second function of the IIS focuses on the importance of sufficient new knowledge in the field of e-agriculture. Kintoki (2017) conducted a systematic literature review regarding the research of e-agriculture in South Africa. A total of 114 papers in the period between 2000-2016 were identified. These papers were categorized into 13 different groups. The two most researched fields were

“Geographic Information Systems” with 23.6% and “Satellite Enhancing Agriculture” with 22.8%. The two least studied fields were “E-government Direct Services” and “Mobile in Agriculture” with 1.8% each. These fields can be compared to the three types of digital technologies identified. The two most studied fields (Geographic Information Systems and Satellite Enhancing Agriculture) in South Africa can be placed in the category of image recognition technologies through drones and satellites. These technologies are mainly applied in the commercial sector. Contrary, “E-Government Direct Services” and “Mobile in Agriculture” can be placed in the category of agricultural apps which are usually employed for supporting SHFs. This points out that already during knowledge development more knowledge for commercially oriented technologies is created in comparison to SHF-oriented technologies. Nonetheless, Kintoki (2017) also finds that 10,5% of the studies specifically research possibilities on how ICT technologies can empower local agricultural communities.

Additionally, within the field of knowledge development in an IIS the knowledge development about marginalized groups and for marginalized groups is important. The lack of knowledge regarding the needs of SHFs is evident. This lack of knowledge is targeted by research organizations such as the Southern African Food Lab or the BFAP, which try to gather and analyze the challenges SHFs face (Interview 4 & 25). By providing this knowledge to various system actors these organizations are also able to steer the decision-making process in the agricultural system. Research organizations such as BFAP or governmental departments such as the Western Cape Development and Support Program also develop and provide knowledge for SHFs in order to support their businesses (Interview 4 & 17).

According to the third IIS function this new knowledge must be diffused between different system actors through interactive networks. Different channels and actors have been identified as important for the diffusion of the latest knowledge in the agricultural sector. Agri Western Cape, a representative farmers organization, uses newsletters to reach out to their communities to share knowledge (Interview 22). The technology and research branch of the agriculture department of the Western Cape government uses magazines and agricultural fairs to spread latest findings in the agricultural sector (Interview 19). Plaas Media, an agricultural newspaper agency, uses magazines, newspaper articles and radio stations to get through to farmers and communicate technology-related discoveries in agriculture (Interview 11). Clearly, various channels are used by different system actors to efficiently reach out to a wide range of agricultural actors and inform them about the most recent technological advancements.

Knowledge also needs to be diffused to SHFs to be inclusive . As observed by Plaas Media, certain print media such as magazines remain inaccessible for SHFs due to cost aspects (Interview 11). Instead, SHFs often prefer free sources such as social media to obtain their knowledge. The presence of established agricultural media outlets on social media platforms is not fully developed and remains marginal. This results in SHFs being excluded from certain knowledge. As stated by the national and provincial departments of agriculture, extension officers play an important role to provide SHFs with knowledge such as best practices and novel technology solutions (Interview 17 & 20). However, as already indicated, the number of extension officers remains lower than needed to cover all SHFs. Hence, in spite of the numerous channels used to share new knowledge regarding agricultural technologies with SHFs, further improvements for the diffusion of knowledge are needed.

Collaboration and knowledge sharing between diverse actors constitute a further form of knowledge diffusion. The department of agriculture of the Western Cape government explained that their own researchers collaborate with local universities and farmers to respond to relevant problems (Interview 19). Research organizations such as the Southern African Food Lab and the Food Systems Research at University of Johannesburg emphasize the importance of multi-stakeholder engagements in the development and distribution of knowledge and show examples in their own projects (Interview 16 & 25). The interviews with technology companies revealed that almost all technologies have been developed in collaboration, or at least in consultation, with both commercial and smallholder farmers

(Interview 3, 5, 21 & 26). Therefore, most technological developments have been advanced in close collaboration between various actors, taking different perspectives and needs into account.

The importance and impact of collaboration between technology companies and farmers during the development of technological solutions and their influence on that development is contested. Certain collaboration has been identified to serve only as feedback loops instead of including framers in the early stages of the technology development (Interview 7). An agricultural consultant stated, that this type of collaboration is the most useful, as farmers are no experts on what is available on the market: "*Sometimes the customer doesn't know what he wants [...]what they wanted was a faster horse. But they didn't know that there's a motor vehicle, which they could also get. So sometimes when you're dealing with the emerging farmer, you have to introduce them to something"* (Interview 2). Others, such as the research organization BFAP believe that this often leads to overengineered solutions which are imposed on farmers without actually solving the farmer's needs: *"Simple technologies for simple problems will add a lot of value. And what we see is, it's almost like giving somebody a Lamborghini. And actually, all they wanted was a bicycle, because a Lamborghini can't drive on the dirt road"* (Interview 4). These examples show the importance of identifying an adequate level of collaboration in order to provide farmers with the best solutions possible without imposing highly technical and unsuitable solutions on them.

The fourth function, guidance of search, suggests that a clear and shared idea about the development of technology is needed to bundle resources. Amongst private organizations different ideas or uncertainty regarding the future of digital technologies in the agricultural sector and their impact on SHFs, can be sensed. One technology company stated that IoT devices might support SHFs in the future (Interview 3), while others were less convinced of the usefulness of such technologies for SHFs in the future (Interview 4). Additionally, as indicated by the government itself, besides the formulated governmental visions, concrete action plans or the execution of plans regarding e-agriculture remains insufficient (Interview 20). Rather, the idea was to support farmers and technology companies once they request support. Moreover, vast differences between the engagement of provincial governmental departments were outlined by governmental actors and actors from a representative organization (Interview 17, 20 & 22). Contrary to many other provinces, the Western Cape province demonstrated concrete plans and programs to direct and support the development of e-agriculture. This reveals the different positions of governmental actors in guiding the direction of search in the emerging sector of digital technologies in agriculture in South Africa.

Lastly, as introduced by function 6, startups and companies require sufficient funding for the development of digital technologies in the agricultural sector. Here, system factors are observed which hinder the development of technologies specifically targeting SHFs, while favoring the development of commercially oriented technologies. In general, no technology company was identified which received financial support from the South African government in order to further develop any type e-agriculture innovation (Interview 3, 5, 9, 18, 21, 23, 26 & 27). Therefore, companies and startups need to finance the development of digital technologies in different ways.

Technology companies which develop commercially oriented technologies can usually fund themselves based on past incomes while anticipating future returns on investment through the sales of the new technology. Contrary, companies which aim to develop technology mainly addressing the SHF-market cannot anticipate returns of investment, as usually the targeted group does not have the financial means to invest in novel technologies (Interview 1). Additionally, as stated by the Land Bank and the agricultural department of the Western Cape government, as well as a technology data company, these SHF cannot obtain loans to invest in these technologies, as they need to be bankable including track records or providing sufficient collateral (Interview 13, 17 & 27). Therefore, technology which focuses on SHFs often fails to acquire funding from conventional sources.

Nonetheless, startups focusing on technologies for SHFs explained other ways to acquire funding. These are, for example, competitions initiated by large corporations or banks which provide awards to the best sustainable or social startups (Interview 5, 9 & 21). Additionally, as indicated by two startups, some banks provide loans on the premise of first proof of concepts (Interview 5 & 21). In these cases, NGOs often provide donor money for the development of a first beta version to attract further funding (Interview 18). Thus, funding remains a big challenge for the development of inclusive technologies without the presence of support organizations.

4.2.3. Diffusion and Adoption of E-Agriculture Innovations in the South African Agriculture System

The fifth IIS function focuses on the diffusion of novel technologies through the formation of markets. Technologies targeting commercial farmers are usually profit oriented and compete in the existing market. Inclusive technologies, contrarily, are often assumed to be depended on governmental subsidies, donor money from NGOs, or CSR engagements of private organizations (Chataway et al., 2014). However, only a few initiatives were found which are solely based on CSR activities, for example a smaller project of a large retailer organization (Interview 24). SHF-targeting technologies were instead found to aim for formal markets and generating profit to become self-sustaining (Interview 5, 9, 18 & 21). This shows that not only technologies developed for commercial farmers aim for profit-oriented markets, but also SHF-oriented companies aim for technology diffusion through profit-oriented markets.

The engagement of SHF-oriented technologies in a commercial market can be linked to two interrelated drivers. First of all, most companies aim for a long-lasting positive impact on SHFs. Different actors agreed that his can only be reached by self-sustaining organizations which are not dependent on the consistent support of donors (Interview 1, 5, 12 & 16). Secondly, it was observed that these projects are often connected to the main business of the company, as the SHF market is seen as one of the upcoming future markets (Interview 27). That indicates that increasingly companies aim to support SHFs to make profit. This trend is also described by Porter & Kramer (2019) as creating shared value (CSV) in which businesses aim to have a social impact, while aiming for profit. CSV differs from CSR, as the social impact is not seen as an act of philanthropy, but rather as “a new way to achieve economic success” (Porter & Kramer, 2019, p. 324). The social engagement of these companies can therefore also be analyzed as a response to an overall demand from society to reduce inequalities (Interview 16 & 22), in order to increase profits.

According to function 7, novel technologies often face resistance, which poses challenges on the adoption of the novel technologies. Adoption was found to be the biggest challenge faced by all types of e-agriculture innovation. Such adoption challenges of technologies in the agricultural sector, especially in developing countries are widely known and addressed in various studies, most notably by Feder, Just & Zilberman (1985). In this research, various adoption challenges were identified of which most can be related to uncertainties regarding digital technologies in agriculture.

Different technology startups described mainly two types of uncertainties among all farmers. First, many farmers are uncertain regarding the usefulness of the technology (Interview 7 & 26). This is related to the novelty, lack of experiences with e-agriculture innovations and their value for the agricultural business. Thus, farmers often prefer to hold on to established agricultural practices based on experiences from older farmer generations (Interview 11). Secondly, many farmers face the challenge of not understanding e-agriculture technologies due to the complex nature of certain technologies, such as the application of drones or IoT devices (Interview 11, 21 & 26). These factors lead to a reluctant position of farmers to invest in digital technologies.

To overcome these adoption challenges, Jochinke, Noonon, Wachsmann & Norton (2007) suggest a higher level of engagement and collaboration between farmers, manufactures and researchers. This allows farmers to better understand the technology before investing in it. Therefore, technology companies often try to provide sufficient information and training to the adopters (Interview 21 & 26). Moreover, technology developers aim to keep user interfaces as simple as possible to lower the barrier of understanding the technology (Interview 3, 5, 7 & 26). NGOs often support the development of first beta versions to demonstrate the usefulness of the technology based on first use-cases (Interview 7 & 28). This indicates that companies strongly engage in supporting adoption rates of e-agriculture innovation.

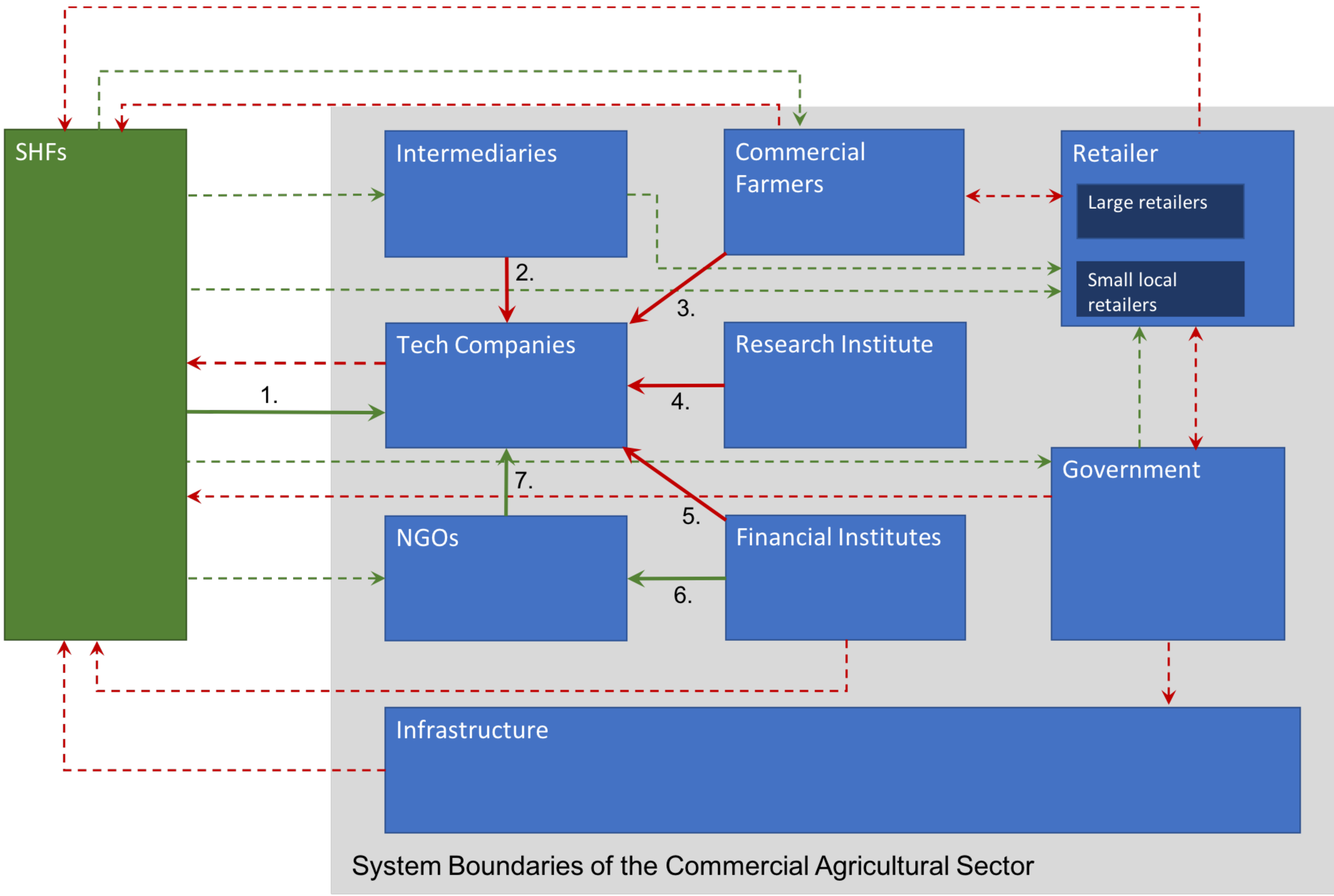
Several challenges regarding the non-adoption of technologies especially in the SHF sector were identified. First of all, as suggested by the research institute BFAP, SHFs often struggle with the basic business and therefore are less likely to invest in uncertain technologies (Interview 4). Secondly, as stated by a governmental department and the land bank, the lack of access to credit and access to information are common adoption challenges of SHFs in South Africa (Interview 13 & 19). Thirdly, as discussed by another technology company, intermediaries often feel threatened to be substituted by technologies, and therefore decide to not adopt certain technologies (Interview 18). Lastly, the identified lack of governmental guidance towards digital technologies in agriculture results in another challenge. As stated by Feder et al. (1985, p. 288) the “nonexistence of government policies in most adoption models is bothersome. Price support schemes, food taxes and subsidies, and input and output quotas are an important part of the reality of many developing countries and affect technological choices and diffusion process”. These challenges show that especially SHFs face many challenges regarding the adoption of technologies, which could be targeted by policy makers.

4.2.4. Evaluation of Digital Technologies in the South African Agriculture System

Throughout this analysis digital technologies have been identified which can be developed for both, commercial farmers and SHFs. The technologies developed for SHFs are mainly apps which are technologically less complex and cheaper in comparison to other digital technologies. These apps support SHFs in terms of market access and information, finance and insurance access and access to extension services. As a positive factor, it has been identified that many technology companies pursue the personal goal of supporting SHFs and reducing inequalities. Usually these companies combine this ideal goal of a positive social impact with profit-oriented goals which makes them more sustainable and self-sufficient.

On the other hand, several hindering factors for the development of digital technologies were identified. First of all, considerably low engagement of the government to guide the development of inclusive digital technologies is evident. A number of system actors call for stronger engagement by the government by providing support and guidance for the development of e-agriculture innovations in the agricultural sector in order to support SHFs (Interview 4, 8, 11 & 18). This is in line with literature in the field of ICT4D which suggests that one of the biggest challenges and barriers is insufficient support of ICT4D by governmental policies (Munyua, Adera & Jensen, 2009). Therefore, a stronger engagement of the government is necessary.

Additional challenges are related to funding, knowledge development and technology adoption. Funding has been proven to be a challenge for SHF-oriented technologies hampering the development of these technologies. In these cases, NGOs often support the funding of SHF-oriented technology projects, or sponsor first demo versions to demonstrate the usefulness of the projects. Knowledge production repeatedly favored the development of commercially oriented technologies. Lastly, technology adoption has been identified to be a challenge for all types of technologies. Especially SHFs often do not see the added value of digital technologies. These additional factors are visualized in figure 6, enhancing figure 5 by the identified function related challenges.



Explanation:
1. Development of SHF oriented e-agriculture technologies which can help integrating SHFs into the system

2. Intermediaries are often resistant in adapting novel technology solutions

3. Technology development often favors development of commercial e-agriculture solutions due to bigger financial power of commercial farmers

4. Research institutes mainly produce knowledge for commercially oriented e-agriculture

5. Low support for SHF oriented technology development, due to lower levels of return on investment

6. NGO funding for developing first prototypes often helps to attract further funding from financial institutes

7. Funding for developing first prototypes or investing in inclusive technology projects

Figure 6 - IIS Components and Functions of the Agricultural IIS in South Africa (Source: Author)

4.3. Inclusive innovations Targeting SHF in the South African Agriculture Sector

In the South African agriculture system several digital technologies have been identified that focus on supporting SHFs. Six out of nine interviewed technology companies aimed at improving the livelihoods of SHFs through e-agriculture. Whether or not a company was identified as focusing on inclusive innovation was based on their self-assessments, set goals and declared target groups. The organizational setup of these six companies varied strongly. Three startups, one medium-sized and one large size company as well as one NGO were identified. In total the five for-profit companies were responsible for one innovation each, while the NGO developed three different types of innovations to support SHFs. The eight innovations ranged from apps (4) over satellite data supported technologies (3) to IoT enabled technologies (1). Two of the satellite data supported technologies are still under development, while the remaining 6 are already in use. Table 2 shows the identified technologies.

Table 2 - Inclusive E-agriculture Technology (Source: Author)

	Type	Name	Company Type	Status
1	App	Khula	Startup	In use
2	App	Farmer2Market	NGO	In use
3	App	Connected Farmer	Medium Sized	In use
4	App	Greenfingers Mobile	Startup	In use
5	Satellite	Mobbisurance	Startup	In use
6	Satellite	Bankable Farmer	Large Company	Under Development
7	Satellite	Satellite forecasting	NGO	Under Development
8	IoT	Soil nutrient analysis	NGO	In use

The identified innovations all aim at targeting the overarching challenge of SHFs being excluded from the formal agriculture system. These innovations can be clustered into two different approaches to include SHFs in the agricultural system: (1) technologies adapting SHFs and (2) technologies adapting the system. Independently from its type, the first group of e-agriculture aims to support SHFs to conform to existing system requirements. The second group of e-agriculture aims to change current system requirements or disrupt the whole system to be able to include SHFs. Five of the eight innovations (three apps, one innovation using satellite data and one IoT device) are placed in the first group and the other three innovations (one app, two innovations using satellite data) are placed in the second group. More important than the intention of a technology to include SHFs into the system is its actual impact on the livelihoods of SHFs. Therefore, the identified technology groups are analyzed and assessed regarding their level of inclusion according to the ladder of inclusive innovations from Heeks et al. (2013). This allows to understand in which way the technologies support the development of SHFs and how effective they are in doing so.

4.3.1. Technologies Supporting SHFs to Conform to System Requirements

The first category of digital technologies aims to support SHFs by helping them to overcome challenges based on their own characteristics. These characteristics were for example the unorganized nature of the SHF sector, low production outcomes and the lack of farming records and certification. These often resulted in challenges to comply to quality and quantity standards of retailer organizations. In the following section, e-agriculture innovations are discussed that were observed to especially target these challenges.

In total five technologies were identified to support SHFs to better integrate into the current agricultural system. The first two technologies are apps which both aim at supporting intermediaries to manage SHFs. The third technology is an app, which serves as a self-assessment tool for SHFs and provides them with tips to improve their current way of farming. Lastly, one satellite imagery technology and one IoT device for soil testing were identified to improve the production of SHFs. This shows a wide range of technologies applied to support SHFs.

Technologies Supporting Intermediaries

The first two technologies are apps designed for intermediaries which accumulate produce from different SHFs and connect them to bigger retailers. The two identified apps were developed by the startup Greenfingers and the company Mezzanine in collaboration with the ICT company Vodacom. As explained by the companies themselves, the idea of these two apps is to target intermediaries as they are highly embedded actors and already have established connections between SHFs and retailers. Therefore, they play an important role to provide market access to SHFs (Interview 18 & 21). One of the companies stated that intermediaries are often considered unnecessary additional actors in the food supply chain, whereas they actually fulfill an important function to connect actors:

> *"Often middlemen don't get the credit that they need. They work with small farmers and they are often seen as the guys taking a piece of the cake. But without them, no big buyer is going to go individually to a small farmer and buy from that farm."* (Interview 21)

These apps support intermediaries in accumulating data about SHFs. Data regarding the location, the type of produce or the size of the farmer can be stored in a database. Additionally, one of the companies explained that transactions between retailers, intermediaries and farmers become more transparent (Interview 18). Each transaction step such as produce and cash flows can be tracked, reducing the potential exploitation of SHFs through intermediaries in the supply chain (Interview 18). Moreover, these accumulated track records also serve as a proof for economic activities of SHFs. This results in SHFs having better chances to obtain loans from banks to invest in the farm. The app also allows to build a digital identity around the farmer by storing information regarding training records, certificates and trade records. This digital identity makes it easier to proof the farmer's credibility and constancy in trade deals with retailers (Interview 18 & 21). Therefore, such apps allow intermediary actors to better manage their farmers and do business with retailers without the need for farmers to invest in or possess a smartphone themselves.

Besides the advantage of better promoting SHFs in the market, these apps target existing networks and therefore only improve the livelihoods of farmers connected to intermediaries. This is currently not the case for every SHF. Initially, these apps will mainly support intermediaries with their work, making it easier to handle different SHFs. Over time this may lead to increased capacities of intermediaries, which are then able to include further SHFs into their supply chain. However, the challenge remains to empower those SHFs which are excluded from the market and do not have access to any intermediary.

Interestingly, due to different reasons, these apps did not yet reach much traction in the South African market. In African countries where SHFs play an important part in the agricultural food supply chain such apps are well adopted. In South Africa, on the contrary, there is an abundance of commercial actors saturating the market, making the integration of SHFs less important (Interview 18 & 21). Additionally, some intermediaries perceive these apps as potential threats, which could make their role in the agricultural supply chain obsolete and therefore refuse to operate such tools (Interview 18 & 21). One company explained that intermediaries might have the feeling to have less influence in the value chain, but that the exact reasons for their perceptions remain unclear (Interview 18). Therefore, these innovations can have a positive impact but first need to be further adopted.

When looking at the inclusiveness of this solution, level 4 on the inclusion ladder can potentially be achieved. In general, the intention of the technology is to improve the livelihoods of SHFs (level 1). The developed apps are accessible to intermediaries which aim at supporting SHFs. This allows to still target SHFs without them having to bear high investment costs to adapt the app (level 2). However, not many intermediaries have adopted these apps in South Africa. According to one of the technology developing companies, once the technology is adopted, these apps have proven to improve the livelihoods of SHF (level 3). Moreover, the apps were developed in consultation with the targeted groups such as intermediaries and SHFs (level 4) (Interview 21). Nonetheless, the innovation does not lead to any systematic changes or resulted in the creation of a new system (level 5). Unfortunately, only SHFs that already have established connections to intermediaries benefit from this innovation. Farmers that are fully excluded from the market remain excluded and will only benefit once intermediaries include them into their supply chain.

Technologies Improving the Production of SHFs

Three technologies have been identified to improve the production of SHFs in terms of quantity and quality. All technologies were developed and distributed by the NGO Solidaridad. The first technology, is the use of satellite data for early detection of pests or mismanagement of plants. The farming land of SHFs is scanned through satellites and subsequently analyzed through image recognition algorithms. This allows to recognize changes in the landscape or plants early in order to take measures in time and safe the plants. The second technology is a soil testing IoT device which analyzes the composition of the soil. After such data is obtained the most suitable commodities can be planted. Moreover, it helps to understand which types of fertilizers or how much water is needed to obtain optimal yields. The third technology is an app that has been designed to improve agricultural skills. The app serves as a self-assessment tool for SHFs to understand if the farm complies to existing farming standards from the industry. Therefore, all technologies aim at optimizing the use of inputs to reach the highest outputs possible, while improving the quality of the yield.

As explained by the NGO itself, all technologies are designed to improve the overall production of SHFs (Interview 7). These diverse technologies allow SHFs to farm in more controlled conditions and help to ensure a consistent level of quality. This helps farmers to conform to the high standards and expectations of retailers (Interview 7). One big retailer stated that only once farmers can guarantee consistently high production outcomes and quality, they can be integrated into their supply chains (Interview 24). However, these models are strongly based on donor money provided to the NGO and are often not self-sustaining. Once no further funding is available to the NGO, no additional farmers can be supported by these solutions. Therefore, these technologies are able to strongly support SHFs to comply to high quality standards but can only reach a limited number of SHFs.

These types of solutions were found to be able to reach inclusion levels of up to level 5. However, there are several aspects which limit their availability. Generally, these technologies aim at improving the livelihoods of SHFs (level 1). Due to the financial support and advocated extension officers from the NGO itself, these technologies can be easily adopted by SHFs (level 2). However, the number of farmers that can be reached by these programs remains limited as these initiatives strongly depend on the availability of donor money. These technologies impact SHFs by enabling them to reach higher quality standards (level 3). Regarding the process, the project responsible explained that solutions were not developed in collaboration with SHFs but inputs through feedback loops were included (level 4). Moreover, these innovations reach level 5 on the inclusion ladder by employing local students to execute soil tests. Therefore, by implementing the technological solution further jobs are created. Underlaying knowledge frames and societal positions are not affected by these technologies (level 6).

4.3.2. Adapting the System to Integrate SHFs

The second category of digital technologies does not aim to help the farmer to be integrated into the existing system, but rather tries to change certain system requirements to make it easier for the SHF to integrate themselves. These system requirements are for example the need for collateral to obtain loans from banks or producing sufficient quantities of produce to supply a bigger retailer.

In total three technologies were identified to change system requirements or disrupt the system for SHFs to better integrate into the current agricultural system. Two technologies are based on satellite data and apps, which aim at adapting finance and insurance solutions to the characteristics of SHFs. The third technology is an app which aims at disrupting the overall system by creating a digital marketplace around the SHF.

Adapting Finance Related Requirements

In the current system the lack of track records or collateral excludes SHFs from access to finance or insurance. Therefore, farmers cannot invest in new technologies or land which makes it harder for them to compete with commercial farmers. To tackle this problem, two digital innovations aim at making SHFs bankable or more predictable for finance and insurance companies. The goal is to understand and accept different characteristics of SHFs to try and find a solution to integrate the farmer. A large data company focusing on such solutions explained that this can be done by using satellite data to track the expansion or consistency of SHFs' produce over the years (Interview 27). The startup Mobbisurance gave the example that by combining satellite data with weather data, risks faced by SHFs can be calculated and allow to insure crops (Interview 9). These two companies engage in the development of models which can include SHFs into the agricultural system by opening up the finance and insurance market.

Mobbisurance explained that to present most insurance companies aim for insuring crops for all eventualities which allows them to sell expensive and complex insurance packages to farmers (Interview 9). Most SHFs cannot afford these complex solutions and therefore remain uninsured. By combining geographical satellite data with timely accumulated weather data, individual solutions covering only smaller aspects can be developed for SHFs. The project of the big data company aims at gathering more and more data about SHFs to make them bankable. Observing the growth of a farmer over time can be used as a baseline for risk assessment, making farmers bankable without them possessing collateral (Interview 27). Such solutions allow SHFs to participate in the market and reduce system barriers. However, as explained by the data company, these novel solutions require third party organizations such as banks to accept these new business practices with SHFs (Interview 27). In general, a big interest in these novel solutions was observed. Nonetheless, the overall system needs to become more receptive for these solutions (interview 27).

These technologies can be ranked as level 6 inclusive innovations as the original way of doing business is aimed to be substituted by a whole new concept. First of all, there is a clear intention to include SHFs into the system (level 1). Additionally, some of the technologies such as the innovation by Mobbisurance can already be adapted by SHF (level 2). Whether or not these innovations have a positive impact will depend on the acceptance of other system actors. In case of a general acceptance of these new business concepts, the technologies open up the financial market for SHFs (level 3). As stated by the companies, SHFs were involved in the development of the technologies (level 4). The technologies provide farmers with access to finance and insurance and therefore change the current structure of the system (level 5). Lastly, these technologies suggest a new way of assessing the bankability of an individual, which reflects a changing knowledge-frame in terms of risk assessments (level 6).

Creating a Digital System around the SHF

The last technology is an app which aims at creating a digital marketplace around SHFs. This ICT enabled system allows SHFs to offer their abundant produce to the market, while at the same time benefitting from better access to other goods and services provided through the platform. This digital marketplace promises better supply chains around agricultural in- and outputs, logistics and job creation. The identified technology is the app developed by the startup Khula, which recently won the South African social entrepreneurship competition Chivas Venture (Interview 5). The general idea of the app is to coordinate the exchange of goods and services through a peer-to-peer platform. To better understand the overall idea of Khula, examples of well-known apps such as Airbnb and Uber were given. These challenged established industries such as the taxi and hotel sector by organizing individuals through one app offering similar goods or services. Khula aims at organizing the SHF-sector to compete with the commercial sector.

To enable such a digital system, the Khula app is designed for the direct use by farmers and retailers. Through this digital marketplace, farmers can offer their produce and see which goods retailers demand. This way, different SHFs can contribute smaller parts to a bigger order without the integration of intermediates in the supply chain. Once a bigger network of farmers is established, potential shortcomings of individual farmers can be compensated by others in the supply chain. Additionally, intelligent routes for efficient logistics can be calculated and send to available drivers nearby. This digital model does not only allow for an improved market access for SHFs, but also allows to unite with other farmers to buy production goods such as seeds, fertilizers or irrigation pipes in bulk. Additionally, discounts for licensing fees can be arranged. Through retailers posting their demands, farmers can learn and understand which goods are demanded and which prices can be obtained. Therefore, this digital marketplace allows SHFs to be better integrated in the agricultural supply chain.

As stated by Khula, the app mainly targets the niche of the organic food market (Interview 5). This niche market favors SHFs, as they have the ability to check each individual plant and identify pests sufficiently in advance. Big commercial farmers on the contrary often have to make use of pesticides to keep their fields under control (Interview 5 & 23). Such a niche also allows to pose higher prices, which can cover higher costs due to more complex logistics and storage. Additionally, mainly smaller retailers such as restaurants benefit from freshly harvested produce which can be provided in smaller quantities and on demand:

"these small emerging farmers, they would serve best for the ad hoc market. So ad hoc market might be your processors, (...) or even a restaurant. Restaurants don't buy 100 cages a day. They buy 10 cages of onions, they buy 10 cages of potatoes, they buy 10 cages of tomatoes, things that they can use now. And you do get small scale farmers that can only produce as much probably working on one hectare." (Interview 5)

However, such a model is not feasible for all types of SHFs. Due to small amounts of produce, distances have to be short to provide an economically feasible product. If a truck has to drive far for very little produce, the overhead costs are too high (Interview 24). Therefore, such a model works mostly for urban farmers which are located in the proximities of local retailers that pursue a vision to support local communities and provide fresh organic food (Interview 6 & 14). Within the current network over 2500 individual retailers and farmers have signed up, creating a dense network of urban farmers and retailers (Interview 5). Additionally, within this system a quality standard for agricultural goods needs to be fulfilled by all participants, due to the dependence on trustworthy relationships in these systems (Hamari, Sjöklint, & Ukkonen, 2016). Lastly, due to most trades being executed through one digital platform, it's owner gains increasing power over time. This results in the system being depended on the goodwill of the owner to not increase prices to participate on the platform.

This technology can be rated as a level 5 or 6 on the ladder of inclusive innovations. The general intention of this digital marketplace is to provide SHFs with increasing market access (level 1). The app itself is freely available for all SHFs, but requires them to possess a smartphone with internet access and therefore excludes certain groups of SHFs (level 2). One urban SHF reported increasing sales induced by the app (Interview 15), which demonstrates a positive impact. This corresponds to the claims of the startup and observations of local retailers on the positive impact of the app on SHFs (level 3) (Interview 5, 6 & 14). Khula explained that throughout the development of the app farmers and end-users were consulted (level 4) (Interview 5). According to the experiences of the interviewed SHF, the app is built as simple as possible making its utilization intuitive (Interview 15). By creating a whole new system around the SHF, the app reaches level 5 or 6. The digital marketplace offers space for new business models and offers room for further innovations.

4.3.3. Inclusiveness of Digital Technologies in the South African Agriculture Sector

The identified technological innovations aimed at overcoming the biggest challenge faced by SHFs, namely their exclusion form the formal agricultural sector. To include SHFs in the agricultural system, two overarching approaches based on e-agriculture have been determined. The first approach aims at supporting SHFs to better adapt to system requirements which makes their integration into the system easier. The second approach has shown to change these system requirements to facilitate the integration of SHFs into the system. This shows that the challenge of exclusion from the formal agricultural system can be approached from two different perspectives.

Technologies supporting SHFs to conform to existing system requirements strongly focus on the organization of SHFs, on market access and on production qualities and quantities. To better organize SHFs, intermediate actors are supported by apps, which helps them to manage SHFs and provide them with market access. However, these apps encounter significant barriers in the South African agriculture system, resulting in low adoption rates. Other technologies such as satellite data and IoT devices are applied to improve the quality and quantity of SHFs' produce to satisfy retailers demands. Such technologies are expensive and can only be provided to SHFs with the financial support of NGOs. These technologies demonstrate efforts to include SHFs into the system by organizing SHFs and improve their production standards. Nonetheless, it remains challenging for SHFs to fully conform to all system requirements, even when supported by technologies.

Other technologies based on satellite data or farmer-targeted apps do not try to change SHF characteristics, but aim at changing system requirements. Some of the technological innovations are promising approaches to include SHFs into the system. However, as these technologies target traditional business practices, system actors such as banks or retailers have to be willing to accept these novel business practices. As a general positive intention of many system actors has been identified these solutions may likely be adopted in the future.

The identified e-agriculture innovations were analyzed based on their level of inclusion regarding Heeks e. al. (2013) ladder of inclusion. In general, the technologies have shown high levels of inclusion. However, besides some technologies reaching high levels of inclusion for specific groups of SHFs, other groups of SHFs often remain excluded. Some technologies require SHFs to be located in certain areas and possess smartphones, while others strongly depend on the funding of third parties which can only support limited number of farmers. Due to the diversity of solutions more SHFs with different challenges can be supported in their integration into the system. Most of the analyzed technologies are currently in an early stage of development. Only once they are widely adopted in the system, they will reveal their true impact towards the integration of SHFs.

The analysis showed that both approaches can contribute to the integration of SHFs into the agricultural system. Individually, the approaches may not suffice to fully integrate SHFs in the system. Therefore, a combined approach, which adapts system requirements and supports SHFs to conform to certain system requirements, is needed to successfully integrate SHFs.

5. Conclusion

In this thesis, factors supporting or hindering the development and distribution of inclusive e-agriculture innovations in South Africa have been analyzed. Further their inclusiveness towards SHFs has been assessed. To execute this analysis, the South African e-agriculture IIS has been mapped out. This IIS consisted of inclusive system components derived from Foster & Heeks (2013) and enhanced by additional insights from inclusive innovation literature. Additionally, IIS functions have been conceptualized based on the functions approach by Hekkert et al. (2007) and Bergek et al. (2008). These conventional system functions were compared with insights from inclusive innovation literature and accordingly adapted. Through the application of this approach, the following research question was answered:

Which factors in the South African inclusive innovation system (IIS) hinder or support the development of inclusive e-agriculture innovations and how do they affect inequalities between SHFs and commercial farmers?

The question was answered by pursuing three subsequent steps. Firstly, main challenges SHFs face in the agricultural system were investigated by applying the IIS components approach. Secondly, factors that support and factors that hinder the development of e-agriculture were compared differentiating mainstream and inclusive innovation, in order to understand challenges for inclusive innovation. Thirdly, these technologies were analyzed regarding their responsiveness to the identified challenges. In the following, conclusions regarding each main analysis step are provided.

Based on the IIS component analysis, exclusion from the formal agricultural sector has been identified as the main challenge for SHFs. This exclusion was identified to depending on mainly two major key challenges. Firstly, characteristics of SHFs, such as their unorganized nature, exclude them from the formal sector. Secondly, system characteristics, such as high retail standards, complicate the integration of SHFs into the agricultural system. Next to these, the observed lack of knowledge about SHFs such as information regarding their location, their size or output impede the development of e-agriculture aimed at their empowerment.

Various characteristics of SHFs lead to their exclusion from the formal agricultural system. As stated, one major factor is the disorganized nature of SHFs. This does not only pose a challenge for the integration of SHFs into e-agriculture innovation projects but also poses a challenge concerning other types of inclusion projects. As marginalized groups often do not match the requirements of embedded system components, the needs of SHFs in decision making processes are underrepresented. Additionally, the lack of coordination between SHFs, in combination with their small size, leads to production outputs being too low to cover high logistics costs. Infrequent sales make consistent and coordinated supply chains even harder to meet and lead to a lack of track records. Lastly, SHFs often lack collateral, which is needed to obtain loans from banks for reinvestment into their farming business or in e-agriculture innovations. Therefore, a range of characteristics exclude SHFs from the formal agriculture system and complicate the development of SHF-oriented e-agriculture innovations.

Besides the named SHF characteristics, the overall market structure of the agricultural sector in South Africa can be seen as a barrier of entry. The presence of a large and well-coordinated commercial sector, combined with high requirements from retailers, make it hard for SHFs to compete in this market. Economies of scale, global and local G.A.P. certification requirements and strong and well-established relationships between commercial farmers and retailers make it even more difficult for SHFs to be integrated in the market. Besides governmental initiatives, such as the BBBEE, which compel retailers to also source from SHFs, the actual engagement remains low. This is often due to SHFs failing to meet quality standards. This may pose a high risk for retailers to market these products. Therefore, more actions from government and retailers are needed to support SHFs in their development towards living up to the high standards posed by the market.

A noticeable positive aspect, is the identification of formal and informal institutions geared towards the inclusion of SHFs. All actors showed awareness of the strong inequalities within the country and were motivated to actively engage to change the system towards the integration of SHFs. Additionally, formal institutions exist, which aim for the inclusion of SHFs into the system. This shows a general drive amongst all societal groups and actors within the system towards the integration and development of SHFs.

Within the IIS functions, several factors supporting or hindering the development of e-agriculture innovation were identified. The following hindering factors for the development of inclusive innovations were observed. Function 1 captured that most high-tech e-agriculture innovations are developed for commercial farmers. This is mainly due to the high costs of these technologies being a barrier for SHFs. Further, function 2 revealed that knowledge development often favors such commercially-oriented technologies over SHF-oriented technologies. Additionally, a lack of knowledge regarding the concrete needs of SHFs was observed. Therefore, technologies struggle to tackle these needs. Function 3 outlined that knowledge diffusion and exchange with SHFs appeared to be more challenging, as often communication channels to SHFs are not sufficiently covered and extension officers are sparse. Regarding guidance of search, function 4 emphasized that even though there are concrete plans and visions in place, these are often poorly executed. Function 5 pointed out that due to the economic situation of SHFs, they cannot heavily invest in novel technologies, which makes it difficult for these technologies to compete in a profit-oriented market. This is in line with the identified lack sufficient resources for the development of SHF-oriented technologies in function 6. Here banks and the government often do not provide funding to companies that aim at developing SHF-oriented technologies. Lastly, function 7 pointed out that there are high uncertainties regarding the usefulness and effectivity of these technologies, which resulted in large adoption challenges.

Besides these hindering factors, the functions also pointed out several supporting mechanisms which help in developing SHF-oriented technologies. Within function 1, activities and efforts to develop SHF-oriented technologies could be identified. Function 2 outlined efforts of smaller research organizations which research challenges of SHFs and aim at providing solutions to overcome these. Function 3 revealed that most technologies included or at least consulted SHFs throughout the development-phase to gain knowledge about their challenges. Function 4 captured the overall intention of various system actors to support SHFs and integrate them in the formal agricultural system. Within function 5 it was identified that most SHF-oriented innovations aim at being self-sustaining and participate on a profit-oriented market. Function 6 outlined that often NGOs or big corporations through startup competitions, provide funding to startups for the development of inclusive e-agriculture innovations. Lastly, function 7 demonstrated that the identified uncertainties are often overcome by developing first demo-versions that explain the usefulness of e-agriculture.

Several e-agriculture innovations intending to include SHFs emerged from this IIS. These digital technologies have been identified to respond to the biggest challenges faced by SHFs, namely their integration into the formal agriculture system. Overall, two potential ways to integrate SHFs into the agricultural system have been outlined. The first technological approach is to support SHFs in conforming with existing system requirements, while the second technological approach aims at changing present system requirement to the characteristics of SHFs. Ultimately two main approaches to the integration of SHFs into the agricultural system were observed.

The first approach helps SHFs to better integrate into the system. Here technologies have been identified that target intermediary actors to better manage SHFs and to integrate them into the agricultural supply chain. Moreover, technologies such as self-assessment tools and other technologies that help in improving farming practices of SHFs, were found. Therefore SHFs can be supported to conform to system requirements and to become better integrated into the South African agriculture system. Nonetheless, from a SHF´s perspective many system requirements remain difficult to conform to. The second approach targets system requirements and changes them to better integrate SHFs. The observed solutions aim at creating new models for credibility or insurance assessments, or at creating a whole online marketplace for SHFs to participate in the agricultural supply chain. However, this set of technologies requires embedded system actors to open up to these new ways of doing business.

Finally, all identified technologies targeted specific groups of SHFs without being able to focus on all specific types of SHFs. Therefore, a combination of the different technologies and approaches is necessary to meet most interests. Only with efforts from both sides, SHFs can be further integrated into the supply chain. This means SHF must strive to conform to system requirements, while current system actors must diversify and undertake novel ways of doing business in order to lower the barrier of entry to the agriculture market for SHFs.

6. Discussion

In the following, chapter 6.1 discusses the theoretical contribution to literature. Chapter 6.2. outlines practical contributions of this thesis. Limitations of this research are pointed out in chapter 6.3.. Finally, chapter 6.4. suggests future research fields related to this thesis.

6.1. Contribution to Literature and Theory

In this study, several contributions to IS and inclusive innovation literature have been made. First of all, IIS components from Foster & Heeks (2013) were further adapted with insights on inclusive innovation literature to be applicable to the specific case of e-agriculture in South Africa. Secondly, to analyze factors hindering or supporting the development of inclusive e-agriculture innovations, inclusive innovation system functions were developed. These were based on conventional IS functions from Hekkert et al. (2007) and adapted according to insights from inclusive innovation literature. The resulting IIS functions were then applied to the case of e-agriculture innovations in South Africa.

The conceptualization of IIS functions was needed to understand which factors support or hinder the development and distribution of inclusive e-agriculture innovations. Other existing frameworks were not able to outline these factors in a precise manner. Initially, the conventional TIS functions as suggested by Hekkert et al. (2007) and Bergek et al. (2008) allow to understand which factors hinder or support the development of mainstream innovation, but fail to capture inclusion related aspects that refer to the needs of marginalized groups. Literature on inclusive innovation, such as the ladder of inclusive innovation by Heeks et al. (2013), mainly analyze the impact of technologies on marginalized groups, but do not allow to analyze factors regarding the development and diffusion of novel technologies. Lastly, within the field of Science and Technology Studies, a subdomain called Responsible Research and Innovation (RRI) considers the impact of novel technologies on society already during the technology development phase (Owen, Macnaghten & Stilgoe, 2012). It focuses on the consequences of new technologies and suggests that they must respond to societal needs (Owen et al., 2012). The RRI has for example been conceptualized with an 'anticipation-inclusion-reflexivity-responsiveness' framework. This framework allows to capture whether a potential future setting is envisioned, all relevant end-users are included, different perspectives of included actors are reflected upon and changes are initiated to respond to certain needs (Eastwood, Klerkx, Ayre, & Rue, 2017). While this framework indeed allows to understand and redirect the development and distribution of novel technologies towards societal needs, it remains broad in its focus. The suggested IIS functions on the contrary, help to analyze specific factors related to the development and distribution of inclusive innovation, for example the availability of financial resources to all groups of society, or the emergence of inclusive markets.

These differences become more apparent when comparing this research of using the IIS in e-agriculture in South Africa to a research project applying the RRI approach. Similar to the context of this thesis, Eastwood et al. (2017), applied the 'anticipation-inclusion-reflexivity-responsiveness' framework of RRI literature to the context of 'smart agriculture' developments and their impact on society in New Zealand. The main findings were socio-ethical dilemmas such as data privacy, leading to society rejecting smart farming technologies and the lack of inclusion of citizens during the smart farming research and development phase (Eastwood et al., 2017). This shows that both approaches (IIS and RRI) may result in similar findings such as the lack of inclusion of certain actors, but focus on different specifics. On the one hand, the IIS focuses on more concrete aspects, for example the availability of funding being a finding in this research. The RRI, on the other hand, more strongly focuses on ethical aspects, such as data privacy concerns being a finding of a study on smart agriculture using the RRI. Therefore, to understand specific aspects throughout the development and diffusion of a technology, the IIS framework can provide concrete insights, while RRI rather provides broader insights into the responsiveness of technologies to societal needs.

Empirically applying the IIS functions approach in the context of e-agriculture innovations in South Africa guided the research towards first factors that could potentially be relevant for analyzing the development and distribution of inclusive innovations. Based on that, a rough but extensive overview of the e-agriculture landscape, including insights regarding inclusion and impact of technologies on SHFs was outlined. Here the established framework proved to be a useful tool to first map the different system components responsible for the development and distribution of e-agriculture, and afterwards analyze the functioning of the system regarding its efficiency towards developing inclusive innovation. Only within the first function, innovations did not appear to be incremental innovations from the informal market as originally suggested by the theoretical framework, but appeared to be disruptive innovations from startups and incumbents. Additionally, regarding function five, intermediaries have not been identified to currently play a crucial role for connecting SHFs to technologies. Rather technology companies directly targeted intermediaries, or connected to SHFs themselves. Still, the IIS functions provided a clear guidance throughout the research process.

For further validation and understanding of the novel IIS functions, it is suggested to apply them within more specific use cases, focusing on one type of e-agriculture only. Such an application narrows down the number of system actors involved and allows for a more in-depth analysis of this technology regarding its inclusiveness. This way, not only the inclusion towards one specific group, e.g. SHFs, can be captured, but a holistic understanding of the impact on various groups throughout the development and distribution process of the technology can be gained.

Applying the seven IIS functions allowed to gain in-depth insights regarding the individual focuses of the functions and the extent of their inclusiveness. However, it is not possible to gain an overarching view regarding the impact of the technologies on the inclusion of SHFs in the agricultural sector. Therefore, it was necessary to apply Heeks et al. (2013) ladder of inclusive innovation to assess the impact of the technologies afterwards. Only then it was possible to identify if the inclusive innovations were targeting the most pressing challenges of SHFs or if they need to be redirected during their development phase. Interestingly, assessing the impact and responsiveness of a technology is included in RRI literature (Owen et al., 2012). To improve the IIS functions, an eight IIS function, inclusive innovation impact, is suggested. This function could act as a feedback loop capturing the impact of the observed technology and assessing its responsiveness to the targeted socio-economic needs.

Novel research fields such as RRI and IIS that already during the development phase focus on the impact of novel technologies on society are currently receiving more and more attention (Eastwood et al., 2017, Planes-Satorra & Paunov, 2017). This shows that these novel technologies are entering more diverse sectors and are becoming increasingly embedded in our lives. This may be due to the fact that digital technologies such as e-agriculture are transforming traditional sectors such as agriculture into digital sectors. Therefore, technology needs to be developed in a system which considers the concerns and needs of all groups of society. The importance of societal concerns in technology development are also captured in novel trends such as CSV. In this case companies have understood that to remain profitable, their products should not only aim at high returns on investment, but should at the same time focus on societal concerns such as equality or sustainability. Only when including social responsibility in their business models, companies remain successful (Porter & Kramer, 2019).

6.2. Contribution to Society and Applicability

In this study, several valuable practical implications for inclusive e-agriculture have been identified. Firstly, this thesis provides an overview of state of the art inclusive e-agriculture innovations. Different types of technologies such as apps, satellite data and IoT devices were observed. Predominantly apps were diffused to the SHF-sector, which may be related to their much lower development and purchasing costs compared to other types of technologies. Besides higher prices, other types of technologies such IoT devices often target certain farming equipment, such as irrigation pipes, which many SHFs lack. The identified inclusive e-agriculture innovations, nonetheless, were observed to indeed have the capability to target some of the biggest challenges faced by SHFs. Apps, for example, provide SHFs with better market access, or the application of satellite data allows designing insurance solutions for SHFs. In this regard two main approach have been identified. Firstly, supporting SHFs to abide by system requirements and secondly changing system requirements to better integrate SHFs. Therefore, e-agriculture technologies have the capability to support SHFs.

Secondly, this thesis then suggests concrete factors that either hinder or support the development of the named inclusive innovations. These factors are useful for different actors such as policy makers, financial actors, NGOs or technology companies to further promote the development and distribution of inclusive innovation. Most important factors were the lack of knowledge about the actual needs of SHFs, the insufficient strict enforcement of existing policies, the sparse availability of funding for inclusive innovation projects, and adoption challenges due to uncertainties regarding the potential of e-agriculture innovations. Particularly in this case suggestions regarding technology adoption and policy enforcement are provided.

The adoption of technology has been identified as a crucial barrier for the up-taking of novel e-agriculture amongst all groups of farmers. As shown in the results section, Feder et al. (1985) relate many of these challenges to uncertainties regarding digital technologies in agriculture. Additionally, various studies outline that increasing knowledge amongst SHFs regarding the technology, its use and its usefulness can increase the rate of adoption. Jochinke et al. (2007) for example suggest that the engagement and collaboration of farmers during the development phase helps farmers to better understand the technology before investing in it. Similarly, in a study regarding technology adoption by smallholder farmers in developing countries, Mwangi & Kariuki (2015) identified that especially trialability and the alignment of the technology with their specific needs is crucial for the technology adoption process. Adegbola & Gardebroek (2007) studied the effect of information sources on technology adoption in agriculture and concluded that available information increases adoption rates. Similar findings were encountered for tissue cultured bananas in Kenya by Kabunga, Dubois & Qaim (2012). Therefore, agricultural training centers, potentially sponsored by private technology companies, may support knowledge and skill development of farmers, and decrease the barriers of adopting the technology. Such privately-sponsored training centers may help to compensate the low number of available governmental extension officers and can be used to demonstrate novel technologies in use. As stated by Adegbola & Gardebroek (2007) the source of information also influences the adoption decision. It will therefore be interesting to analyze the effect of information provided by private companies on the adoption of SHFs. In return, by sponsoring such agricultural schools, technology companies hope to experience a faster technology uptake, as well as increasing returns, which consequently allows them to reinvest in further technologies. This may result in an expansion growth of the overall agricultural and e-agriculture sector.

Regarding policy advice two major aspects were identified. Firstly, policies regarding the inclusion of marginalized groups such as SHFs, must be strongly enforced by laws and higher penalties for organizations. Currently, policies such as the BBBEE aim to compel retailers to source from black SHFs, still many retailers often do not follow the demanded numbers of black farmers in their supply chain. The additional tax income through increasing penalties can then in return be used to further support the development of SHFs, which can improve their standards, leading to decreasing barriers for organizations to engage with them. Additionally, besides having a clear vision of the inclusion of marginalized groups, a governmental strategy for e-agriculture, including concrete measures and measurements needs to be set up. This strategy needs to address concerns regarding the anticipated future role of SHFs in the agricultural sector and the conflict between the aim to create more jobs within the agricultural sector, while digital technology potentially aims to reduce the need of labor.

6.3. Limitations

Besides the intention to conduct a systematic and theory supported research to create an insightful study, certain limitations of this thesis were identified. First, data collection and analysis was conducted by only one researcher, which reduces the validity of the research. To compensate for this limitation, data triangulation was aimed for. Insights from semi-structured interviews were enhanced and compared to policy frameworks and other studies. Additionally, an expert within the field of inclusive innovation and systems theory was interviewed to improve the validity of the study.

The types and positions of the interviewed actors in this thesis is an additional obstacle regarding data validity. Within the different types of organizations, the goal was to speak to the most knowledgeable person in relation to the topic of inclusive e-agriculture innovation. While, in most small companies or startups, this was the chief technology officer of the company, in big multinational companies, project leaders of the specific projects were stronger related to the topic and therefore more knowledgeable. However, while the different positions of the interviewees in the organizations already posed an additional challenge, the most knowledgeable person was also not always available for an interview within the given time. For example, in one startup the chief technology officer had been contacted targeted as an interview partner, however during the field trip in South Africa, only the client success agent was available, who could not directly provide all technical details. Therefore, the diversity of positions the interviewees, influence their perspective on the discussed topic, and made a comparison more challenging.

Further, while focusing on the integration of SHFs, it was a challenge to interview a wide range of SHFs in order to capture their perspectives towards e-agriculture innovation. One SHF, who had already adopted one type of e-agriculture, was interviewed regarding his situation and experience with e-agriculture, represents only one perspective. Due to the high diversity amongst SHFs, ,further critical perspectives of SHFs, with different backgrounds are needed to fully ascertain and understand their concerns and preferences regarding e-agriculture. On the one hand, some SHFs may support the integration of e-agriculture technologies as they are aware of the potential advantages of the technologies. On the other hand, others may be concerned about changes in practices or potential automatization resulting in job losses. However, as outlined in the results section, SHFs are often very unorganized, which not only makes it difficult for inclusive e-agriculture companies to include them into the technology development process, but also complicates studying their perceptions in a research project. Therefore, a long-term ethnographic study can add further insights by learning about the actual perceptions of SHFs without only analyzing reflections of other system actors on SHFs.

Additionally, this research is primarily specialized on the inclusiveness of e-agriculture innovations towards SHFs, and therefore does not provide the analysis of effects of these innovations on other societal groups which may also be considered marginalized. The focus on SHFs as the targeted group of inclusive e-agriculture innovation was selected because of the importance of empowering this sector, based on the number of SHFs and the severity of inequalities between SHFs and commercial farmers. However, due to this limitation, the question remains if innovation can be fully inclusive. The development of e-agriculture can be inclusive or exclusive in many different ways. For example, e-agriculture can support SHFs that adapt a certain technology on the field, while it can also be inclusive by creating jobs for originally marginalized groups during the manufacturing process in the factory. Similarly, an innovation might create jobs for certain groups during the manufacturing process, but the implementation of the technology on the farm could make other jobs obsolete.

Lastly, within the TIS functions approach, system dynamics play an important role to understand the initiation of actions or development of the overall system (Hekkert et al., 2007; Bergek et al., 2008). This means that certain system functions may be active at different times of the technology development. Depending on the development of the system structure, the TIS can be placed in different 'phases of development' (Hekkert et al., 2011). These phases are called pre-development, development, take-off and acceleration phase and describe whether a technology is still in a prototyping stage or already widely distributed through established market structures. Depending on the phase, "it can be determined whether the innovation system is build up in a correct way and whether it can make the move towards the next phase" (Hekkert et al., 2011, p. 9). Due to the complexity and limited time within this study, these development phases have not been specified to inclusive innovations in an IIS and were not taken into consideration. Certain identified challenges, for example adoption challenges of certain apps in South Africa, may not necessarily be a matter of a system failure but due to the system still being in the development phase. Therefore the findings of this thesis remain to be analyzed based on the phase the e-agricultural IIS can be placed in. A more in-depth discussion on the phases of the TIS and IIS respectively can be found in the following chapter.

6.4. Future Research

The conducted research of inclusive e-agriculture innovation in South Africa serves as the baseline for both, future thematic and theoretical research directions. A first thematic direction can be the upcoming impact of inclusive e-agriculture solutions on the livelihoods of SHFs. During the research, certain technologies, which mostly aim to provide market access to SHFs were identified. However, most of these innovations emerged within the past few years and have not yet diffused to, or been widely adopted by, SHFs. Therefore, it will be interesting to observe, once these technologies have fully reached the market, what their actual impact over time will be.

Moreover, due to the focus on only one specific country within this research, findings can either be specific to inclusive innovation or to South Africa as a country. For example, the challenge of finding funding for the development of inclusive e-agriculture can either be due to innovation projects in South Africa generally being poorly funded, or due to the fact that inclusive innovation in general face the challenge of finding funding due to low returns on investment when targeting 'poor' consumers. Therefore, a comparative case study design between different countries will help to differentiate factors that can be generalized regarding inclusive innovation, and factors which are country specific and differ from case to case.

Next to these thematic suggestions, three main theoretical fields for future research have been identified. Firstly, the suggested IIS functions have only been applied in the context of various types of e-agriculture technologies and their inclusive impact on one type of marginalized group, namely SHFs. Therefore, the IIS approach has to be validated by conducting additional empirical studies. The focus on one specific type of inclusive innovation, for example by pursuing a case study design focused on a specific technology, will allow to gain a more holistic overview regarding the impact of the technology on various marginalized groups.

Secondly, further research regarding the conceptualization of the functions approach in the field of inclusive innovations is suggested. As already indicated, literature of the TIS functions strongly emphasizes the dynamics and development of the system itself. Hekkert et al. (2007) suggest to analyze the system setup based on a process approach or sequence analysis, to understand changes and developments of the system. Moreover, Bergek et al. (2008) differentiate between systems being in a formative phase or in a growth phase, which influences the way a system should be assessed. More specifically, Hekkert et al. (2011) explain that based on its development, a TIS can usually be placed in one of the five phases of pre-development, development, take-off, acceleration or stabilization phase. The TIS itself can be categorized into one of these phases, by observing which system functions are present and active at a certain time and may act as so-called motors (Suurs & Hekkert, 2009; Suurs et al., 2010). Analyzing the specific motors and development phases of the TIS allows to provide policy advice to further direct the development of the TIS towards the next phase. However, the dynamics of inclusive innovation may strongly differ to the dynamics of mainstream innovation. Therefore, an IIS may have its own phases, which are yet to be developed. Foster & Heeks (2013) for example explain that inclusive innovation often relates to incremental innovation, by adapting mainstream innovation towards the needs of marginalized groups, which suggests development phases from mainstream innovation to inclusive innovation. As seen in this thesis, this claim is not always correct as inclusive innovation can also emerge on its own. Therefore, the development of a new set of phases for an IIS is an additional field to be researched.

Lastly, it has been identified that the suggested seven IIS functions do not yet capture the impact and responsiveness of the developed technologies on social challenges. Therefore, an eighth IIS function capturing this impact is needed. Theories and frameworks within the field of RRI are built upon principles of inclusiveness and focus on the impact and responsiveness of novel technologies (Owen et al., 2012). To develop this eighth IIS function insights from the field of RRI may be consulted to create a function which can capture the impact of the technology and act as a feedback loop onto the other IIS functions.

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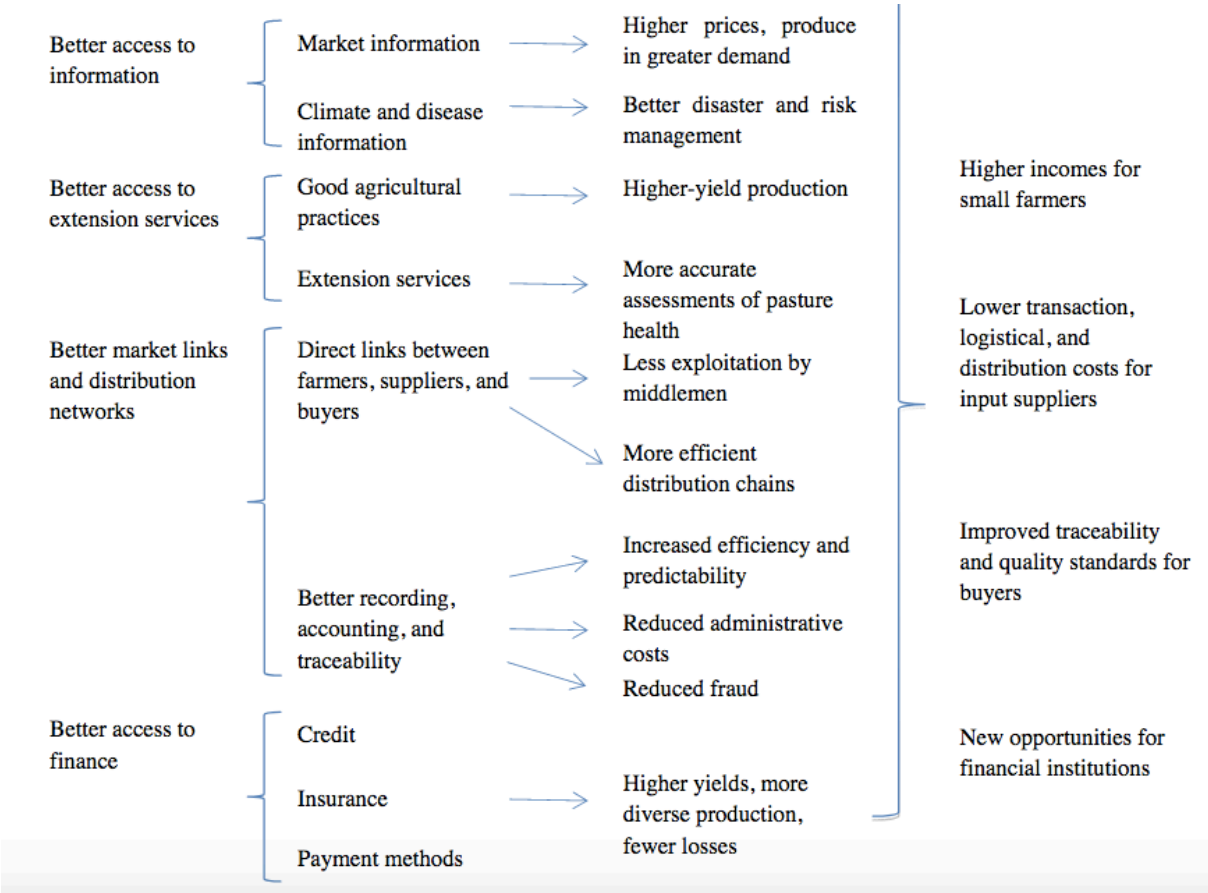
Appendix

Appendix 1 – Advances of Mobile Applications for Agricultural and Rural Development



Derived from: Qiang, C. Z., Kuek, S. C., Dymond, A., & Esselaar, S. (2012). Mobile applications for agriculture and rural development.

Appendix 2 – Strategic Policy Documents

General Policy Strategies

1	National Development Plan 2030	NDP
2	National Growth Path	NGP
3	Medium-Term Strategic Framework 2014-2019	MTSF
4	Broad-Based Black Economic Empowerment	BBBEE

Agricultural Strategies

5	Comprehensive African Agricultural Development Programme	CAADP
6	Integrated Growth and Development Plan	IGDP
7	Agricultural Policy Action Plan	APAP
8	Comprehensive Rural Development Plan	CRDP

ICT Strategies

9	National Integrated ICT White Paper
10	National e-strategy

Appendix 3- Interview Guide

1. Can you tell me a bit more about the project / technology in which you are engaged?
2. In which way is your innovation/project inclusive? Does it exclude certain groups?
    a. **Examples?**
        i. Intention of the project
        ii. Product/Impact
3. Can you tell me more about the process of the project?
        i. Involvement of other groups
4. Can you outline aspects/factors which were crucial for you (positive and negative) during the development or distribution of the innovation/project?
    a. **Examples?**
    b. Knowledge
        i. Technical
        ii. Inclusion/ problems
        iii. Lack of knowledge
    c. Networks and Collaborations
        i. Inclusion of marginalized group
        ii. Other partners
        iii. How did the collaboration work
    d. Steering of the project/vision
        i. Clear vision to inclusion, clear goal?
        ii. Role of policies, such as NDP
        iii. Internal drive?
    e. Market engagement
        i. Why to engage in a market with marginalized
        ii. Incentives to engage in this market?
    f. Origin of resources such as funding?
        i. Also restrictions to the funding (based on inclusive activities?)
    g. Challenge of uncertainty/legitimacy to work in this sector?
5. Future of inequalities between smallholder farmers and commercial farmers?
6. **Snowballing question**

Appendix 4- Interviewees

Interview ID	Name of Organization /Acronym	Duration	Type
Interview 1	Empire Partner Foundation	01:30h	Other
Interview 2	Smart Agri Solution	01:00h	Other
Interview 3	Shockwave Engineering	00:44h	Technology
Interview 4	BFAP	00:57h	Research and Education
Interview 5	Khula	01:21h	Technology
Interview 6	Pauli's Food	00:17h	Retailer
Interview 7	Solidaridad	00:47h	NGO / Technology
Interview 8	Solidaridad Extension Officer	00:15h	Extension Officer
Interview 9	Mobbisurance, interview recording lost	01:00h	Technology
Interview 10	Bhule Farmers Academy, interview recordings lost	00:45h	Research and Education
Interview 11	Plaas Media	00:46h	Media
Interview 12	XXXXXXXXX (Local subsidy of a multinational drink and brewing company)	00:25h	Retailer
Interview 13	Land Bank	00:50h	Finance
Interview 14	The Munching Mongoose	00:20h	Retailer
Interview 15	Smallholder farmer at Siyakhana Garden	00:18h	Farmer
Interview 16	Food Systems at University of Johannesburg	01:02h	Research and Education
Interview 17	Western Cape Government, Development and Support Program	00:30h	Government
Interview 18	Mezzanine	00:59h	Technology
Interview 19	Western Cape Government, Technology and Research	00:55h	Government
Interview 20	DAFF	00:43h	Government

Interview 21	Greenfingers	00:40h	Technology
Interview 22	Agri Western Cape	00:52h	Other
Interview 23	Radicle Group	00:54h	Technology
Interview 24	XXXXXXXX (Multinational Retailer for Consumer Goods)	00:53h	Retailer
Interview 25	Southern Africa Food Lab	00:18h	Research and Education
Interview 26	Aerobotics	00:48h	Technology
Interview 27	XXXXXXXXX (multinational mass media and information firm)	00:26h	Technology
Interview 28	GIZ (Gesellschaft für Internationale Zusammenarbeit)	00:30h	NGO

Appendix 5 – Coding Framework System Functions

Category	Subcategory	Description	Examples
Function 1. Inclusive Innovation Activities	1.1. Intention towards inclusive innovations (Level 1)	Identification of a general idea or vision towards including marginalized groups without mentioning a concreate measure or product.	*"We want to develop the farmer, smallholder farmers."* (Interview 20)
	1.2. Development of inclusive innovations (Level 2)	A concrete service or product is introduced which aims at supporting SHF, without showing it's impact.	NONE
	1.3. Impact of the innovation on the marginalized group (Level 3)	The impact of the service or product towards the SHF is mentioned	*" That's how much impact we have on the ground. So every 1 farmer that's on our platform, six other persons are impacted. The livelihoods are improved."* (Interview 21)
	1.4. Integration of the marginalized group in the process (Level 4)	It is outlined how the SHF has been integrated in the development process of the product and service, either based on (1) informing, (2) consulting, (3) collaborating, (4) empowering or (5) controlling.	*"I don't do anything without consulting the smallholder farmer. Because I'm always in talks with him so we are brainstorming together."* (Interview 1)
	1.5. Inclusive Structure (level 5)	The innovation does not only focus on improving the livelihood of the SHF, but includes a more embedded systemic approach.	*"Khula basically is an ecosystem. An eco-system of joint apps that are trying to, form something. A lot of people might want to call it a digital farm, but more of a joint inclusive farming system."* (Interview 5)
Function 2. Knowledge development	2.1. Technical knowledge development	The mentioning and explanation of acquiring purely technical knowledge	*"I had to develop some instrumentation, and monitoring a data logger. So you're running lots of tests, logging data, processing"* (Interview 3)
	2.2. Knowledge development regarding needs of SHF and marginalized groups (Level 2)	Knowledge about the need of SHFs is developed or, explicitly, the lack of such knowledge is mentioned	*"So there isn't currently a database of smallholder farmers, we don't know where they are, we don't know how many they are, and what their..., so we have an idea of what their challenges are on the ground"* (Interview 4)
	2.3. Knowledge development for marginalized	Knowledge is specifically developed for and provided to marginalized groups to	*"So we also use different extension approaches, where instead of me visiting 10, farmers, I get the 10 farmers to one place, which we would call a center of excellence,*

	group is (Level 3)	profit from it, or the lack of it is mentioned.	*and I'm able to reach more farmers in one go and therefore bring some efficiencies in how we do our work." (Interview 17)*
	2.4. knowledge development in interaction with SHF (Level 4)	The development in interaction with SHFs is mentioned, or the exclusion of SHFs from developing knowledge is mentioned	*"We have the banks, obviously, talking to them about their needs, but then we also have the farmer. Because without the farmer, there is no product.. So absolutely, we spend time talking to farmers in South Africa*" (Interview 27)
Function 3. Knowledge diffusion through networks	3.1. Aligned expectations	Efforts to exchange and drive knowledge creation in the same direction regarding the development of the agricultural sector.	*"So our main focus is influencing or commenting on policy, on new policy, existing policy and so forth. So we sit around a table, a lot of with decision makers, policy makers*." (Interview 22)
	3.2. Knowledge diffusion in networks of different actors except the marginalized group (Level 0)	Efforts to exchange and build knowledge together, collaborations in projects or research, without the inclusion of SHFs.	*"We work with different groups, especially with the University of Stellenbosch, and other universities, for example UCT, Cape Town University and the Nelson Mandela University in Port Elisabeth*." (Interview 19)
	3.3. One directional knowledge diffusion through networks from developers to SHF (Level 2)	Knowledge is directed to SHFs, but there are no feedback loops. SHFs are only informed about novel knowledge.	*"We are still coming like this is what the world has, please adopted it. But we still need to get that reverse feedback loop where they say, but we actually want this."* (Interview 7)
	3.4. Strong multidirectional exchange networks between various actors (Level 5)	Knowledge is created, shared and exchanged between SHFs and other groups in the agricultural sector through feedback loops.	*"But that actually dawned on me that there is expertise in the community that we could tap. And now the whole thing shifted to actually rearranging the insides of the community. So here is social innovation, and all that stuff, which started coming up, really made sense to me. So I realized there are a lot of farmers that can teach*" (Interview 16)
	3.5. Other collaborations to reach out to SHFs	Efforts to reach out to SHFs through intermediaries or other actors, to improve the reaching out to SHFs.	*"Reach out to farmers by farmers academies, and want to use existing networks, because they wouldn't know who and where the farmers are*." (Interview 9)
Function 4. Guidance of search	4.1. Clear vision towards inclusion (Level 1)	There is a clear vision communicated throughout the society	*"I think the policy level that government sets, places pressure on the big corporates in order to engage further. So you got a trickle-down effect, on policy level to big corporates, and then my role is that I'm like an implementation partner for this program."* (Interview 1)

	4.2. General agreement of the future of inclusion and development practices	There is a clear vision and agreement of how to include SHFs in the agricultural sector	NONE
	4.3. Vision created and adapted based on feedback loops with SHF (Level 4)	The vision towards the integration of SHFs is based on feedback from the SHF sector	NONE
	4.4. other	There are private initiatives towards inclusion, which is not coordinated with other system actors, and often including the need for government to stronger engage as well	*"Obviously, they are a lot of commercial white farmers, doing a lot from their side to make things work. But it's not enough. It's not enough. We do need government support to do that."* (Interview 11)
Function 5. Market Formation	5.1. Tech development based on donors and subventions	Donors support the development of novel e-agriculture by sponsoring first prototypes, or provide large grants	*"For some companies or small agribusiness that is doing good work, but they can't afford it. So the idea is to bridge a 24 month period, where GIZ it supports both training and education and support of users and farmers. And then license fee support. And then with the idea of this business, learning and taking up this new system"* (Interview 18)
	5.2. Market stimulated by funds (government, ...)	Government sees a need and supports the development by funds	NONE
	5.3. Market stimulated by corporate responsibility	Organizations engage in the market only due to reasons of CSR, to improve a certain situation	*"So we as a company see ourselves as a global citizen and a responsible citizen. So we decided to set some sustainability goals, from anything. From water stewardship to circular packaging, for example, so that we try and rotate and recycle as much of our products as possible. And in the agricultural space, we set some smart agricultural goals."* (Interview 12)
	5.4. Market stimulated by local challenges	Local challenges such as poverty, climate change or other challenges support the market creation of e-agriculture	*"And with a small scale farming, you find that there's a whole lot less waste, so we also have to think of the earth and what we produce. It needs to get used."* (Interview 14)
	5.5. Profit oriented market	The goal of the organization is to make profit by engaging in the market	*"So we are for profits. We have a group of investors who invest in the platform. So it's not that Nando's were our first client who paid the initial onboarding of the clients. But with the initial investment, we have a Board*

			of investors or directors who are still involved in campaigns, still putting money into it." (Interview 21)
	5.6. Market restrictions	Challenges, which make it hard to engage in the market, especially with SHFs.	"*The big opportunity these banks saw, but also the biggest challenge they saw was kind of tapping into the agricultural finance space at a small scale. On a small farmers scale, they also phrase it as an opportunity, but they weren't quite sure how to reach it, their infrastructure didn't really allow for loans of that size, or reaching potential customers*" (Interview 27)
Function 6. Resource mobilization	6.1. Donor Money	Donor money is mentioned in relation to funding the project or organization. Other challenges related to donor money are outlined, such as dependence on this money flow	"*So it's been donor funded, but for the data solutions, we really are trying to design things that are self-sustaining, which is why we are starting to sell when we can sell, like these soil testing services*." (Interview 7)
	6.2. Loans by banks	Financial means come from obtaining loans from banks, which will have to be payed back. Also requirements to obtain such loans are coded in this category.	"*We're a bank. So, you do an application, and you tell us, you come with a business plan, if we think it's a sound business plan, we provide you with finance. It's not free money, because our funding model, we don't get money from the government. We source our own funds from the likes of your world bank. And so that money has to be returned. So we also expect that from the people loaned money to*." (Interview 13)
	6.3. self-funding	No funds from other organizations are obtained for the development of the technology	"*Up to this, frankly, we haven't received any funding or government support*." (Interview 3)
	6.4. Awards	Awards from big cooperates or banks, for example for best social or environmental startup, are mentioned as a source of financing technology development	"*So last year, MTN, the biggest phone company in SA, maybe with Vodacom. But MTN usually host the app awards every year. So we won in two categories surprisingly. We thought we're going to take the best agricultural solution. And we did. But on top of that, we took the best App of the year.*" (Interview 5)
	6.5. Government funds	Governmental funds are mentioned as a means of financial support. Also their applicability or accessibility is discussed	"*The government recognized it and said, right, we need to actually give people some capital to run these farms. So they would give them capital*." (Interview 3)

	6.6. Funding by companies	Big companies fund and support the development of technology or research	*"Then there is private funding, where we do some work for private companies, for example, EAPSA or John Deere, or Monsanto"* (Interview 4).
	6.7. Human resources	Human resources are mentioned as a crucial resource for the development of e-agriculture	NONE
	6.8 Other	Lack of funding, or lack of resources are discussed	*"The emerging farmer, or the smallholder farmer, he/she doesn't have the finances to pay for it."* (Interview 1)
Function 7. Creation of Legitimacy/ Counteract resistance of change	7.1. Activities of legitimizing companies	Big companies providing additional legitimacy for e-agriculture projects, due to their engagement in the sector	*"When you contact, for instance, potential clients, and as soon as they see, even XXXX, but if they also see GIZ they say okay, we've heard about you, GIZ, it's a repeatable company, we could work with it. So definitely, it is a huge factor."* (interview 28)
	7.2. Acceptance of marginalized groups	Reasons and factors for SHFs to accept and adapt e-agriculture. Also SHFs seeing the benefits of using e-agriculture	*"So that app that they design is very good. Easy, simple, even if you don't know how to use the phone, it's easy for everyone. It's helping lots of farmers."* (Interview 15)
	7.3. Positive discourse	E-agriculture is mentioned positively in media or through other channels, which support the adopting and understanding of the positive impact e-agriculture can have	*"Everything we do everything, we write, is to make farming more profitable and more productive. So obviously part of our message has to be here is technology A, technology B, technology C, and this is how you can grow your farm with it. I think in terms of growth, definitely media is very important."* (Interview 11)
	7.4. Presence of resistance	Resistance of SHFs to adapt technology, or resistance of organizations to engage with SHFs are coded	*"Some of them, don't see a need of using the application or technology because most of them they've never been to school. So they don't even understand how this thing operates."* (Interview 8)
	7.5. Location of resistance	Actors and their motives of being reluctant towards using e-agriculture solutions, or integrating SHFs into the agricultural market	*"So why farmers would resist that is, again, maybe it's just change and that people don't like change. Or it could be, for example,... one example that I had last week is a farmer don't want to give out their ID numbers or mobile numbers, because they don't fully understand why you will get access to it. And in South Africa, very many people get social grants. And they, therefore hesitate to give out a an ID number, because that might get all the way to the grant provided department social grant, and then they might lose their grants."* (Interview 18)

	7.6. Activities to reduce resistance	Strategies to overcome resistance, for example by making technology use easy, cheaper, increase responsibilities or outline positive factors of the integration of SHFs or adaption of e-agriculture	*"So the common success, or the key ingredient is management buying into this change. They see enough the value that it can bring to them. And then they are willing to systematically deploy the solution and get adoption and get going".* (Interview 18)
	7.7. Uncertainty	Uncertainties about the effectiveness or usefulness of adapting e-agriculture solutions, which reduce technology adoption	"*You need to buy the tech and there is an initial cost. And that scares a lot of our farmers. And that's where technology comes in. And the initial cost, people are scared of making that first step. But once you've made it, your running costs are lower, and your production is much higher*." (interview 19)
8. Impact Type of Technology	8.1. Access to information	E-agriculture solutions which aim to provide access to additional information	*" And through these technology, we can get to a point where we can say, look, this, these are the practices that the farmer is practicing on his farm"* (Interview 7)
	8.2.Access to better extension services	E-agriculture solutions which aim to provide better access to extension services	*"So it's a mobile app with good quality content on how to plant potatoes, how to vaccinate your cow, weather, market pricing all of these things. So they have that in a mobile app. And we made that available to all the users*" (interview 18)
	8.3. Better Market links through networks	E-agriculture solutions, which create market links and provide better access to the market for SHFs	*"So it connects those orders and takes them here. So you get to pick up different products at different places. Even now in terms of the shop, it doesn't necessarily have to talk directly with the farmer in order to get produce."* (Interview 5)
	8.4. Better access to finance	E-agriculture solutions which provide better access to finance or insurances, for example by creating track records	*"It again, gives that farmer, a digital financial and production history."* (Interview 12)
	8.5. Empowerment through job creation	E-agriculture solutions, which also create other jobs, such as students doing soil tests, or additional drivers for improving logistics	"We can now get graduates that are studying agriculture to now do farm visit, or even better yet get internships to go work on certain farms." (Interview 5)
	8.6. Increased efficiency	E-agriculture, which aims at improving yield, or reduce inputs needed	*"So using digital technology, to enable our farmers to be more efficient, have more of a digital identity, etc."* (interview 12)
	8.7. Increased knowledge	E-agriculture, which gathers data about the SHF, so other	*"So we decided to introduce another app, which is called ODK, open data kit. So ODK registers farms. It will ask for the name, your*

	about the farmer	organizations can understand their needs better and improve their support	*age, how big is your land, where are you producing. And then it will ask the facilitator or extension officer to map the farm*" (Interview 8)
	8.8. Capacity building (reaching retailer requirements)	E-agriculture, which helps SHFs to acquire certificates, such as organic farming or global or local gap, or other certifications	"*They benefit because now we are building out a virtual CV for these guys, because we capture all the training workshops they attend*." (interview 21)
	8.9. Other - Better embedded ecosystem, in which goods are accessible	E-agriculture, which creates an economy around the SHFs, to embed and provide them with all needed resources as well as providing them with a market	"*They became to behave like one organization. Uber is not one organization. It is millions of small individual drivers. But they provide you the same consistency. How different are they from the organized taxi organizations? So essentially, that's what we are trying to get at. If we can get the farmers to practice at a certain minimum guaranteed level, in terms of reliability of delivery, consistency of delivery, reliability of practice, then you get him to the market*" (Interview 7)
9. Context Specific attributes	9.1. SHF attributes	Attributes, which are specific to SHFs, such as size, organizational attributes, sales, and others	"*And while they are some commercial players, often small farmers are left out of the value chain, because of you know, they can't meet the quality, quantity requirements often of big multinational companies. And because they are operating as individual farmers, and not as cooperatives, it's harder for just one company to go to 600 farmers to collect*" (Interview 12)
	9.2. South Africa specific attributes	Attributes, which are specific to the South African context, such as apartheid having effects up to today, government being perceive as corrupt, or geographical attributes, which effect the integration of SHFs	"*Our current state in SA right now, as you know, is that our government is so corrupted that nothing happens. So our state owned enterprises are suffering because of corruption*" (interview 5).
	9.3. Sector Specific attributes	Attributes, which are affecting both, the commercial and SHF sectors, such as an increasing farmer age, a decreasing famer population, youth not being interested in agriculture, etc.	"*Remember we have a youth that's not that interested in agriculture. Everybody wants to live in the city. Everybody wants a desktop job. So it's all about using technology, and new methods and keeping it interesting for the youth. So we can say it's very cool actually to be in agriculture. So that's another way we are using technology, to make it interesting for youth.*" (Interview 19