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THE CONTRIBUTION OF DIGITAL TECHNOLOGIES USED IN AGRICULTURE ON FOOD AVAILABILITY AND ACCESSIBILITY IN KAYONZA DISTRICT OF RWANDA: A CASE STUDY OF KOTWIDIKA MURAMA COOPERATIVE

A research project submitted to Van Hall Larenstein University of Applied Sciences in partial fulfilment of the requirements for the degree of Master in Management of Development, Specialization Rural Development (MOD) - Food and Nutrition Security (FNS)

By

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DEDICATION

To the Almighty God for his kind love and protection.
To my late parents, who bore me and raised me into the person, I am today.
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ACRONYMS

CFSVA: Comprehensive Food Security and Vulnerability Analysis

FAO: Food and agriculture organization of the United Nations

FCS: Food Consumption Score

MINAGRI: Ministry of Agriculture and Animal Resources

MOPA: Mobile Order Processing Application

NISR: National Institute of Statistics in RWANDA

QTY: Quantity

RAB: Rwanda Agriculture Board

SNS: Smart Nkunganire System

USAID: United States Agency for International Development

WFP: World Food Program

Kg: kilogramme

MT: Metric tonnes:

UPI: Unique parcel identified

DAP: Diammonium phosphate

ABSTRACT

Rwanda is a landlocked country situated in the Great Lakes region of East Africa. The government is landlocked and does not have other resources, so the population depends on agriculture as the main economic activity. It is from agriculture that the majority of the people get food for their survival. However, people in the country have been practising subsistence agriculture using traditional methods. This type of agriculture could not produce enough food to satisfy the consumption needs of citizens in the country. To address this, the government of Rwanda introduced digital technology (mobile apps) in agriculture to ensure food security in the country. Considering much efforts invested in this digital technology by the government, this study aims at describing the contribution that the use of digital agricultural technology in agriculture brings to address food unavailability and inaccessibility in Kayonza District, one of the districts of Rwanda in which this technology is used. The five specific questions of the study were: 1. how do farmers of Kayonza, KOTWIDIKA Murama Cooperative use mobile apps for food availability and accessibility? 2. What is the current food availability and accessibility status among farmers of KOTWIDIKA Murama Cooperative in Kayonza? 3. How has food availability and accessibility among farmers changed since the introduction of mobile apps in their farming activities? 4. What are the strengths and weaknesses in using mobile apps in agriculture for food availability and accessibility? 5. What threats and opportunities do farmers face in using agricultural mobile apps for food availability and food accessibility?

To achieve this study, we used a sample of 34 farmers and six key informants were selected. The study used primary data, which were collected using semi-structured interviews and focus group discussion of farmers, interviews with key informants, food consumption score and photo elicitations. It also used secondary data collected using the interpretation of district and sector agriculture departments' records. The results of the study showed that mainly the Smart Nkunganire System mobile app is used by farmers to order selected seeds and fertilisers, while the Mobile Ordering and Processing Application is used by agro-dealers to make demands of the agriculture inputs that are supplied to small farmers. About the use of Esoko in Kayonza, farmers indicated that they don't know it. It is the key informants who indicated that this app is there but is used in the district department of agriculture. It was found that people who introduced these mobile apps did not consider the illiteracy level of the farmers who were to use them. The use of these mobile apps becomes difficult for farmers who have low literacy levels as they have no or fewer reading and writing skills required to use them. It was also revealed that the use of mobile apps increases the yield for farmers who use them and raises the quantity of food available for consumption to the households and the surplus to supply to the market. They found that the strengths of using mobile apps are that farmers have the opportunity to connect with agriculture stakeholders and sponsors who help them to get high-quality seeds and fertiliser that are used in time to increase yield. Furthermore, the study indicated the weakness of these mobile apps as not adapted to the literacy level of farmers and only on selected types of crops, leading farmers to abandon the production of some crops that are necessary for a balanced diet and causing them to suffer from malnourishment and or under-nutrition diseases. It was further revealed that using these mobile apps allows (opportunities) farmers to move from subsistence agriculture to professional commercial agriculture by investment from the government and donors. However, it was found the threats of some farmers have the resistance to move to the traditional method on technologies. The researcher hence recommended fitting the digital technology on the literacy level of farmers either by providing special training on the use of the app to farmers who do not know how to read or to update these apps in a way that they can be used by every farmer including those who are not literate. In addition, MINAGRI should find how this technology can be adapted to the production of all crops and decentralise the Esoko apps to the farmers. And the farmers should be flexible to adopt the technologies.

Keywords: Digital technology, food availability and accessibility.

CHAPTER ONE: INTRODUCTION

1.1 Research context

Rwanda is a landlocked country situated in the Great Lakes region of East Africa. It covers a surface area of 26 339 km ^{2}, with a population estimated to be 13,243,751 and a population density of 525 per km ^{2} in 2021 (Worldometer, 2021). The livelihood of Rwandans depends much on agriculture because this sector contributes 90% to the food security of Rwanda's population (FAO, 2013). Rwanda is divided into four provinces, with Kigali the capital city taken as the fifth province of the country (Rwanda Ministry of Local Government , 2021). The five provinces are also divided into 30 districts; Kayonza, where this research took place, is one among these 30 districts of Rwanda and it is situated in the Eastern province. Kayonza has a population of 346 751 people. More than 90% of them depend on agriculture to get food for survival and income that they spend on other basic needs (KayonzaDistrict, 2018).

Agriculture in Rwanda, especially in rural areas, is crucial for ensuring food availability and accessibility to the population. According to the Worldbank (2013), agriculture accounts for 39% of the gross domestic product. Agriculture has great importance to the country and to the population in general, whereby 80% of the people get jobs from this sector in both rural and urban areas. The agricultural sector also contributes 63% to the foreign exchange earnings and 90% to the country's food needs. Although many Rwandans depend on agriculture for their livelihood, food security has not been reached because most of the population, especially in rural areas, still struggle with food shortages and malnutrition (USAID, 2018).

To ensure the improvement of the food security of its population, the government of Rwanda has introduced the use of agricultural technologies in the form of mobile apps, some of which have been easily adopted by farmers. These include Esoko, Smart nkunganire system (SNS) and Mobile Ordering Processing Application (MOPA). Esoko is a mobile application developed to be used by farmers in the search for markets of their agricultural products (Niyoyita, 2011). SNS is used by farmers to connect with agriculture partners for fertilisers and seeds provision, and MOPA is the improved application of SNS, which is used by agro-dealers to order and pay agricultural inputs online (Hopemagazine., 2021).

Rwanda is the first African country that adopted digital technology in agriculture, followed by Senegal (Weitske et al. 2020). According to Niyitegeka (2019), SNS and MOPA were introduced by Rwanda Agriculture and livestock Development Board (RAB) in a business partnership with the Bank of Kigali (BK) and are used to assist farmers and agro-dealers in ordering agro-inputs from suppliers, to process market payments and for saving. In addition, on February 5, 2020, RAB signed a partnership with the Food and Agriculture Organization (FAO) to implement a 3-years program aimed at supporting digital technology in the country's agricultural value chains to increase food supply in the country (Firmine, 2020).

Kayonza district is one of the districts in which mobile agriculture applications have been introduced since 2016. Mobile applications are given to farmers, especially those grouped in cooperatives, who used them in different ways to increase efficiency and effectiveness in agricultural food production (Pia, 2018). Cooperatives in Rwanda originated in form the colonial government that created them as institions which were used to implement policies. After this colonial time, independent government continued to use cooperative as the channel of supporting citizens in performing development actitivies. This exposed cooperative members to state regulation, which hindered the progress of cooperatives as economic

initiatives for meeting members' interests. Cooperative development was further disturbed by the 1994 genocide committed against tutsi that weakened all socio-economic activities in the country (MUKARUGWIZA , 2010). It is in 1998 different NGOs that supported the recovery of the country recognized the important role that cooperatives and pre-cooperative associations could play in social renovation and began to encourage the formation of these institutions. The efforts by these NGOs significantly helped in the increase of cooperatives in the post-genocide period. However, it was realized that the essence of cooperatives was being weakened due to the absence of a legal framework to guide the changes of the movement in the country. The Government therefore set up a team for cooperative advancement in 2005, in order to develop a legal framework and provide for the registration and promotion of the cooperative movement in Rwanda.

The cooperative organization is currently being supported by defferent stakeholders including local and international NGOs, Bilateral and multilateral donors and international organization (International Labor Organization , 2018). Digital technology, including mobile apps, therefore is one of the tool which has been introduced to help farmers in improving their agricultural production and reach wanted development. Cooperatives have been good channels trough which the government encourages the use of these mobile apps through subsidies and sapport that government give to farmers in relation to the use of mobile apps in production. The government of Rwanda takes cooperatives as a probable mean through wich employment generated and citizens can increase access to income-generating activities, change their business capacity through education and training; increase funds and investment, and increase social well-being. This can also ease special accent on gender equality, housing, education, health care and community development (MUKARUGWIZA , 2010) KOTWIDIKA Murama Cooperative is the largest cooperative of 127 farmers in Kayonza who are engaged in agriculture food production in support with Bk Teahouses, a private NGO affiliated to the BANK of Kigali that provides these farmers with SNS and MOPA mobile digital technology services to improve food production in Kayonza district, especially Murama Sector where this Cooperative operates (bkTECH, 2021).

According to the Comprehensive Food Security and Vulnerability Analysis (CFSVA, 2018), a survey was conducted by WFP (World Food Program), MINAGRI (Ministry of Agriculture and Animal Resources), and National Institute of Statistics in RWANDA (NISR) on the situation of food security in 2016. This study revealed that food security among Kayonza households is divided into levels; households who are food secure and are classified into two groups: The first class is 37.5% of households who are food secure and second of 29.8 per cent who are marginally food secure, meaning that they are at a high risk facing hunger due to their unstable source of food. The second level is 32.7 % of households who are food insecure and categorised into two different levels: 28 % who are moderately food insecure and the other of 4.8 per cent who are severely food insecure.

In addition the study conducted by Lokuruka in 2020 indicated that 48.7% of the rural residents and 22.1% of the urban population in Rwanda still live in food insecurity (Lokuruka, 2020). Kayonza district was identified as one of the districts that continue to demonstrate much of trials related to weather and topographical approachabilities such as drought and erosion. This hinders the residents of this district from getting enough food supply (physical access of food), and the district experiences much hunger and food insecurity together with related health embarrassments due to prolonged drought (Kayonza., 2018).

Nevertheless, the government of Rwanda tries to introduce technology in agriculture, most precisely digital mobile apps, as the solution to increasing food availability and accessibility among the population in the country. For instance, on the 3rd of December 2015, the Ministry of Agriculture and Animal Resources (MINAGRI), in partnership with FAO, had launched the digital agriculture system (the mobile applications) to bring agricultural services closer to rural farmers. These mobile applications started being used in Rulindo District and were extended to Kayonza District in 2016 to enable farmers to easily access the services concerning weather, crops, cure and feed livestock, agro-market places, e-nutrifood and fall Armyworm monitoring, as well as early warning system (MINAGRI, 2019).

On the use of digital technology in agriculture, Rwanda has been ranked 80/139 on the Network Readiness index of 2016, moving up with three places from 2015; it was also ranked 120/193 in 2018. Various services to facilitate the use of digital technology have been put into place through eight digital agriculture solution provider companies headquartered in Rwanda, but there is a total of 44 companies providing these services that are present in Rwanda. Some of them are market linkages, supply chain management, financial services, macro-agriculture intelligence, among others (Gutierrez, 2020).

1.2 Problem statement

The background of this study highlights the importance of agriculture to the livelihood of the Rwandan population in terms of food provision. It also indicated how digital technology was introduced in agriculture to improve food availability and accessibility in the country. It was emphasized clearly how much effort, in terms of money and infrastructures, are being invested in agricultural digital technology by the government, through the Ministry of Agriculture, precisely in mobile apps such as Smart Nkunganire System (SNS), Mobile Ordering and Processing Application (MOPA) and Esoko. These apps are given to farmers for free to help in improving the situation of food availability and access from agricultural production in rural areas, which, in general, was not enough for consumption needs of the population. However, Kayonza District local government may wonder whether the use of apps is improving the availability and accessibility of food among farmers in the district's rural areas. Kayonza often demonstrates weather and topographical challenges on food availability as indicated in the District's Development plan of 2018. It is from this perspective that this study has been conducted to describe the contribution (strengths and weaknesses) that the use of agricultural digital technology, specifically mobile apps, brings to the improvement of food availability and food accessibility vis-à-vis the situation of food during the time these apps had not started being used in agriculture. The target of the study was on Smart Nkunganire System (SNS), Mobile Ordering and Processing Application MOPA) and Esoko, the three mobile apps that have been introduced in the agriculture of Rwanda, as highlighted in the background. These apps are used by farmers, but the district does not have any information about their effectiveness in helping farmers to increase food security.

1.3 Problem owner

The problem owner is the local government of Kayonza District which is involved in the implementation of agricultural digital technology with the community of farmers to address food unavailability and food inaccessibility among the population.

This was based on the fact that there is no specific study that has been conducted to identify the gaps of knowledge on the contribution that digital agriculture technologies bring in improving food availability and accessibility in the Kayonza district. The knowledge gap has led kayonza residents to remain with food availability and accessibility problems that cause malnutrition. In contrast, agriculture digital technologies have been introduced to solve such food shortage problems in this district. This knowledge will help mobile app promotors, Kayonza District leaders to identify the loopholes found in these apps and their usage to find ways of improving them, making them more helpful in solving food availability and accessibility problems.

1.4 Justification of the study

This study aimed to describe the contribution of digital technology used in agriculture to food security, availability and accessibility, in Rwanda using the case study of KOTWIDIKA Murama Cooperative in Kayonza District.

It is expected that the findings of this study would help Kayonza District to gain knowledge about the strengths, weaknesses, opportunities and threats of using digital technology in agriculture in order to find better ways of making these technologies more productive. The research may also help farmers to know their strengths and weakness in the use of available technological tools to find ways of exploiting them to their maximum. The study results as well highlight the recommendations to policy makers, donors and other partners in agriculture who support digital technology in agriculture in Rwanda to enhance their contribution and adjust their interventions given to help farmers.

1.5 Research Objective

The objective of this study is to describe the contribution of digital agricultural technology used in agriculture to address food unavailability and inaccessibility in Kayonza District. It used the case study of KOTWIDIKA Murama Cooperative within the period of 6 years from 2016, when agricultural digital technology was introduced, up to 2021 (Ntirenganya, 2017). The situation of food availability and food accessibility of these six years was compared with ten years back from 2008 to 2018 when the crop intensification program under the land consolidation policy started being implemented in the country. (Governement of Rwanda , 2010). The researcher gained knowledge on agricultural mobile apps in increasing food availability and food accessibility in Kayonza District as its findings broughtout the strengths and weaknesses opportunities and threats of these mobile apps. These findings were then used by the researcher to formulate the recommendations that would help Kayonza district to improve the user of agricultural mobile apps by farmers.

1.6 Research main Question

What are the contributions of digital agricultural technology in addressing food availability and accessibility in the Kayonza District?

1.7 Research Sub-questions

1. How do farmers of KOTWIDIKA Murama use mobile apps for food availability and accessibility in Kayonza?

2. What is the current food availability and food accessibility status among farmers of KOTWIDIKA Murama Cooperative in Kayonza?

3. How has the food availability and accessibility among KOTWIDIKA Murama farmers changed since the introduction of mobile apps in their farming activities?

4. What are the strengths and weaknesses in using mobile apps in agriculture for food availability and accessibility?

5. What threats and opportunities do KOTWIDIKA Murama Cooperative farmers face in using agricultural mobile apps for food availability and food accessibility?

CHAPTER TWO: LITERATURE REVIEW

2.0 Overview

This chapter is the review of literature related to the use of agricultural digital technology, specifically mobile apps, in addressing food availability and food accessibility in rural areas.

2.1 Definition of key concepts

Key concepts: Digital agricultural technology, food accessibility, food availability

Digital agriculture: Digital agriculture is defined as the use of digital technology in agriculture to improve agricultural production as a way of fitting it to the needs of consumers (Agriculture Victoria, 2021).

Digital agricultural Technology In this study, Digital agricultural technology means the technologies developed to be used by farmers to increase the quantity of food supply and availability to fit it on people's consumption needs. And the focus was on Smart Nkunganire System, Mobile Ordering and Processing Applications used in Rwanda, and Esoko precisely in Kayonza District because they are the commonly known apps that are available and used by farmers in Rwanda.

Smart Nkunganire System (SNS): This is a mobile app developed by BK TechHouse (the department of Bank of Kigali in charge of technology and Innovation) with the collaboration of Rwanda Agriculture and Animal Resources Development Board (RAB). It is developed to link farmers with stakeholders who are interested in agro-input funding such as fertilisers, seeds and pestcides (MINAGRI, 2021)

Mobile Ordering and Processing Application (MOPA): This is an updated version of the Smart Nkunganire System introduced by Bk TechHouse with Rwanda Agriculture and Animal Resources Development Board (RAB). It is also a mobile phone application used by agro-dealers to directly make orders of agro-inputs from suppliers online without moving from their places (TecHouseLtd, 2021). The difference between Mobile Ordering and Processing Application (MOPA) and Smart Nkunganire System (SNS) is that SNS is used by small farmers to connect themselves with agro-dealers for easy agro-input funding while MOPA is a business-oriented used by Agro-dealers who order, purchase and sell agro-inputs to farmers (Akariza et al., 2019).

Esoko: This is defined as information and communication services for the agricultural market in Africa (Finder, 2021). In this study, Esoko refers to the mobile app developed and is used by farmers search and reach the market for their agricultural food production.

Food security: Food security exists when all people, at all times, have physical and economic access to sufficient, safe, and nutritious food that meets their dietary needs and food preferences for an active and healthy life (FAO, 1996). Food security is divided into four dimensions, including the availability of food, accessibility of food, utilization of food, and stability of food (FAO, 2020). The table below summarises the four components.

Table 1: Components of Food Security

Food availability	Food availability addresses the supply side of food security and is determined by the level of food production, stock levels, and net trade (FAO, 2020).
Food accessibility	This means the ability to access and to afford food, and this is influences by different factors such as having financial means for buying food, travel time for shopping, availability of healthy food, and affordable prices about transport and socioeconomic resources of food buyers (FAO, 2020) .
Food utilization	Utilization is commonly defined as how the body makes the most of various nutrients in the food (FAO, 2020).
Food stability	This the regular adequate food accessibility regardless of the conditions that may cause the risk of causing food uncertainties like weather conditions, political instability, and other economic factors that may influence food safety position (FAO, 2020)

Table 2: Components of Food Security

Source: (FAO, 2020).

The researcher in this study focused on two aspects of food security, namely availability and accessibility. This was because Smart Nkunganire System (SNS), Mobile Ordering and Processing (MOPA), and Esoko Apps that are the subject of this study have been introduced to help farmers increase food production and facilitate them to search for markets for production (FAO., 2018).

2.2 Food insecurity and vulnerability information and mapping system

Food insecurity exists when people are undernourished because of not having physical access to food and because of their social or economic inadequate access to adequate food and or poor food utilization. Food-insecure people are those who have food intake which falls below their minimum energy requirement and those who display physical symptoms resulting from energy and nutrient deficits caused by insufficient or unbalanced diet or the body's inability to utilise food properly. On the other hand, food vulnerability is the range of factors that place individuals at risk of becoming food insecure. The degree of food vulnerability is determined by their disclosure to risk factors and their ability to manage with or resist tense situations (FAO, 2020).

Conceptualisation and operationalisation of digital technology (mobile apps) into the food security framework

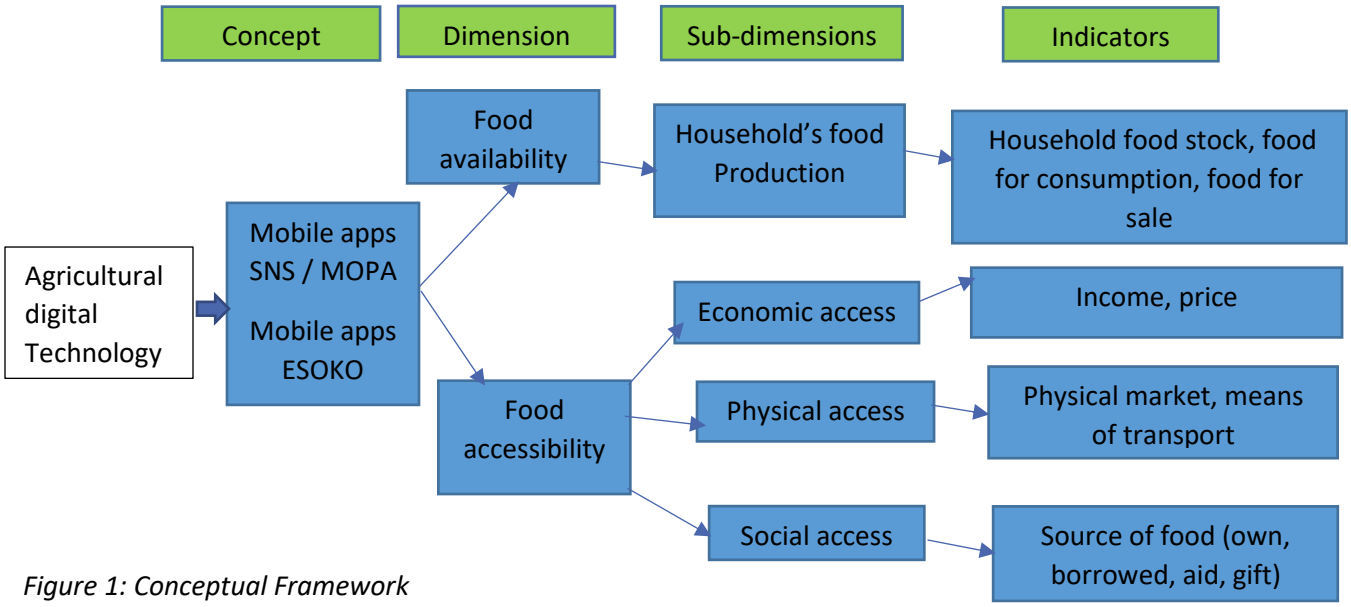

Figure 1: Conceptual Framework

Source: Author, 2021

Determinant of food availability:

According to Masters Australian Food Security Research (center, 2014), food availability concerns the supply and trade of food. In addition, WFP, 2009, explains food availability as the quantity of food that is present in a country or an area from all means of domestic production, imports, food stock, or food aid. This study focused on the amount of food supplied through domestic production.

Food supply

This is the availing of enough food for household consumption needs and on the market for buyers to buy (Sudan Federal Food Security Technical Secretariate, 2017).

Food trade

This is where households can meet their consumption need from their products and the extra is taken to the market for income generation. Sometimes farmers decide to hold or sell what they have produced for cash generation (Barichello, 2002).

Dimensions of Food Accessibility

According to the Australian Food Security Research Centre (AIFSRC,2014), food accessibility involves economic and physical access to food. On the other hand, the World Food Summit defined food access as physical, economic, and social-cultural access. The study focused on the physical and economic dimensions of food accessibility.

Physical food access

This is demonstrated by the condition in which food is produced in one part of a country but in an ineffective or non-existent movement infrastructure implying that food cannot be distributed to other areas having the problem of food shortage (Marion, 2011). Physical accessibility also involves elements such as travelling to shopping, availability of healthy food, and food prices (InTeGrate., 2018).

Economic food access

This means that people can be able to have the financial means to buy enough food for household consumption (OXFAM, 2007). It also implies the access to transport and socioeconomic resources of food by buyers (InTeGrate., 2018).

Socio-cultural food access

This is when food is physically available, and individuals have financial means to buy it for their needs but their social norms, briefs or gender obligations do not allow them to consume such available type of food (Riely et al. 1995)

The study will be examining the physical and economic accessibility because it is conducted within the same cultural setting, and it is dealing with finding out how digital technology contributes to food availability and accessibility from agriculture. This implies, therefore, that the focus here is on the quantity available for consumers utilization and financial means for those who are involved in agriculture to buy food that they do not produce from the market.

2.3 Theoretical review

According to tot Olutayo (2021), the theoretical review is the process of looking into existing theories and establishing the relationship between them and the topic of the study to draw the new inference. The researcher in this review concentrated on the work of a writer who wrote about the role that agriculture play in food availability and food accessibility. The review also includes the role of agricultural digital technology in improving food availability and food accessibility.

2.3.1 Agriculture in the livelihood of people

Worldwide, agriculture has been proved to be the production sector that sustains the livelihood of a large population on the globe (Dave et al., 2019). For instance, according to the United Nations (2016), agriculture was feeding 2.6 billion of the world population in 2016. It will have to provide an additional 1.5 billion people in 2030, of whom 90% will be living in developing counties. But again, it is argued that the world will need to increase agriculture by 60-70% to feed 9 billion people who will need food by 2050 (UN, 2016)

2.3.2 Digital technology in agriculture for food availability and accessibility

Worldwide, the introduction of digital technology came as a solution to the inefficiency and ineffectiveness that is found in agricultural production (ThoughtForFood, 2021). Farmers, especially in rural areas, use traditional methods which are less productive, leading to a shortage of food and causing food insecurity in the world. The digitalisation of agriculture, therefore, was introduced to change every part of the agro-food chain (Nicola et al., 2019).

With digital technology, Mobile apps are used in agriculture in various ways for helping agriculture in achieving sustainable development. Some of the ways mobile apps are used, especially in developing countries, are conveying services such as providing market information and transaction services for producers and traders, weather information, peer to peer learning and financial facilities like payment, loan and coverage (Sourcetrace , 2021). This was supported by (FAO, 2021) starting that mobile platforms connect farmers to markets and financial services.

Ndubuisi (2021) also indicated that digital technology opens massive unexploited abilities for farmers, investors, and businesspersons to increase the efficacy of food production and utilisation in Africa. And Rachel et al.(2021) argued that digital technologies in agriculture improve the quantity and quality of agricultural output while using minimum inputs. They further added that digital technology provides higher agronomic information about weather data and price statistics that are used by farmers to improve their decision making and management of their resources. This also results in improving farmers profitability and income as these technologies facilitate rapid recoding, analysing and dissemination of data from their agriculture activities.

For digital technology to be successful, farmers should have financial means of buying mobile phones as well as skills and knowledge of using them. Farmers should also have enough mobile connections and internet access (FAO, 2020). In addition, the World Bank indicated that digital technologies give intended results when farmers have land tenure security (World Bank, 2019)

A study conducted in Niger to examine the impact of technology on agriculture price dispersion on the period of five years between 2005 and 2006, using the case of mobile phones found that mobile phones contribute to the reduction of price in Niger agricultural product market between 10 and 16% (Aker, 2010).

Another study was conducted in India by Fafchamps and Minter in 2010 to investigate the effects of mobile phone-based price information services on agricultural prices and found that the use of mobile did not have any effects (Fafchampd, M.&Minen, B. 2011).

About the challenges of digital agriculture, a study conducted by FAO (2019) in different countries found that in rural areas, where education and literacy are generally lower, mobile phones tend to be used primarily for communication and social media, and this presents a significant challenge to the introduction of digital agriculture applications as it requires more advanced digital knowledge and skills to use agriculture mobile apps. The same study also revealed that low ownership of smartphones accompanied by high cost of internet and limited networks become barrier to using digital technology in rural agriculture.

2.4 Strengths, Weaknesses, Opportunities, and Threats (SWOT) of digital technology in agriculture

SWOT is a tool for categorising and analyzing internal strengths and weaknesses and external opportunities and threats that figure current and future operations to help develop strategic goals. In this study, the SWOT tool was used to analyse how digital technology, especially mobile applications, contributes to food availabilities and accessibilities.

2.4.1 Strengths

Using digital technology in agriculture, especially mobile apps, has various strengths which enhance agriculture productivity. These strengths include weather forecasting, transparency and traceability whereby mobile apps help in removing inefficient processes in the supply chain for food safety. Mobile apps help as well in crop information as they are used to fetch soil data from various resources that result in bringing precision to farming activities. Thay are also use for farm and land management enabling farmers to identify and loom diseases to prevent them from destroying crops using pesticides, fertilisers, and some other vibrant processes ((9 Series Handcrafted Technology Solution, 2021). According to veronica and Francisco (2020), using digital technology increases precision in the input used and raises the net return and operating profit in agriculture. They further argued that using digital technologies has the benefit the environment because they help in maintaining the sustainability of farm production (ibid).

2.4.2 Weaknesses

The use of digital technology has been found with the weaknesses such as not being adapted to the level of farmers' education and training while majority of them have low education and insufficient financial resources to get electronic devices like mobile phones (Veronica & Francisco, 2021).

2.4.3 Opportunities of using digital technology in agriculture

There are different opportunities related to digital technology, especially mobile apps used in agriculture. Some of these opportunities to transform smallholder and family farms by helping them to gain power and relevance through connecting and collaborating with others in cooperatives. They also help farmers connect with donors and sponsors who provide them with quality agriculture inputs (Matheus , 2020). In addition, farmers who use mobile apps have the opportunity of better access to information, better connection with market and distribution networks, better access to agriculture extension services and betted funding opportunities (Constantina, et al., 2016)

2.4.4 Threats of using mobile apps in agriculture

Various threats recognized in the use of mobile apps in agriculture, especially in Africa, are insufficient access to infrastructure such as transportation networks, few opportunities to study and agriculture practices as well as litre information about crop prices ((Agro-Intelligence , 2015). In addition, the language barrier has also been identified as the threat of mobile apps whereby these apps require a translation which leads to dependency that reduces acceptability and popularity (Kalyan & Neela , 2020)

CHAPTER THREE: RESEARCH METHODOLOGY

3.0 Introduction

This chapter presents the methodology used in this study. It presents the study area, research strategy, and research design. It shows the data collection technique, sampling design, and sampling method. Lastly, the chapter indicates the sample size, data analysis, and ethical considerations.

3.1 Description of the study area

The research was conducted in the Kayonza district of Rwanda which is one of the districts that use digital agricultural technology to ensure the food security of its population (MINAGRI, 2019) and because this district is the problem owner of the current study.

Kayonza district is one of 30 districts in Rwanda and one in seven districts of the country's eastern province, with Mukarange as its capital city. Kayonza is a rural district made by 12 sectors covering 1,935 km^2. Its population was 346751 in 2018, with a population density of 177.86/Km^2 (KayonzaDistrict., 2019). The dominant economic activity in this district is agriculture and livestock and 92.7% of its population lives on these two activities. The fertile soil of the District presents an opportunity for agriculture (Mugabo, 2018). The research has been conducted with the KOTWIDIKA Murama cooperative of farmers, which operates in Murama sector of Kayonza District. KOTWIDIKA Murama Cooperative is a cooperative of 127 farmers who came to work together to produce maize and beans in the Murama sector of Kayonza District and has its headquarters in Muko Cell of Murama Sector in Kayonza (KI, Murama Sector, April 20, 2021). The cooperative is composed by 50 men and 77 women who do their farming activities on 66 hectares. This cooperative was selected because it is the biggest cooperative of farmers in Kayonza district that work in agriculture production and have adopted mobile apps since 2016. This group of farmers was also selected based on available facilities to reach out to them for data collection. In addition, it is with this group of farmers that Kayonza District granted permission to the researcher to work with since they are the ones who have been pioneers of using these apps in the district.

Figure 2: Map indicating the location of Kayonza District in Rwanda

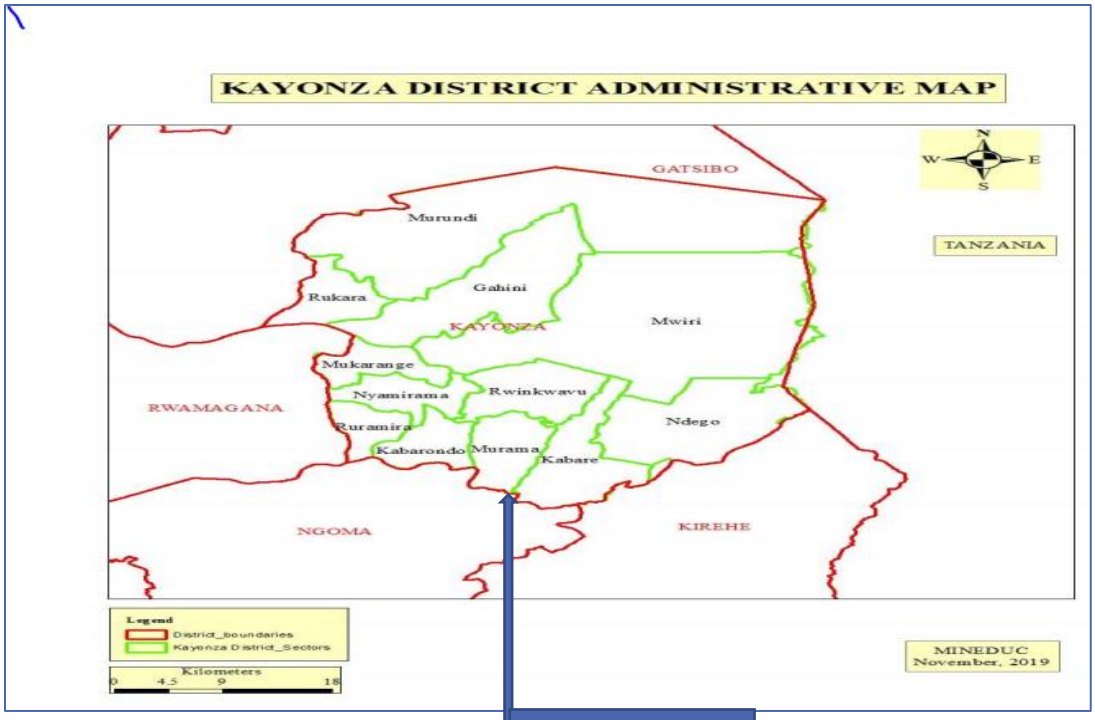

Figure 3: The map indicating Murama Sect

3.2 Research strategy

The present study used a case study research design. A case study is defined as an in-depth study of a particular situation, and it is useful for systematic testing of theories and reproduction works in the real world (Martyn, 2021). It was selected by the researcher in this study because it was seen as suitable in describing the use of digital technology in addressing problems of food insecurity in rural areas of Rwanda using the case of KOTWIDIKA Murama Cooperative in Kayonza District. After all, it allows in-depth and multi-faced investigation techniques that helps the researcher to get various information (Laws, et al., 2013). The research design uses qualitative approach to collect data from respondents.

3.3 Research Design

In this research, the researcher started with laying down the background of the problem, followed by the identification of the problem. The researcher then proceeded with the desk study, setting the research objectives and research question, reviewing the related literature as well as identifying the research methodologies which were to be used in data collection. The researcher set the background and selected a research assistant who went into the field to collect data. After the collection of data, gathered information was recorded, organized, summarised, analysed, and interpreted. Lastly, there was the discussion of findings, after which the researcher made the conclusion from the findings and gave recommendations.

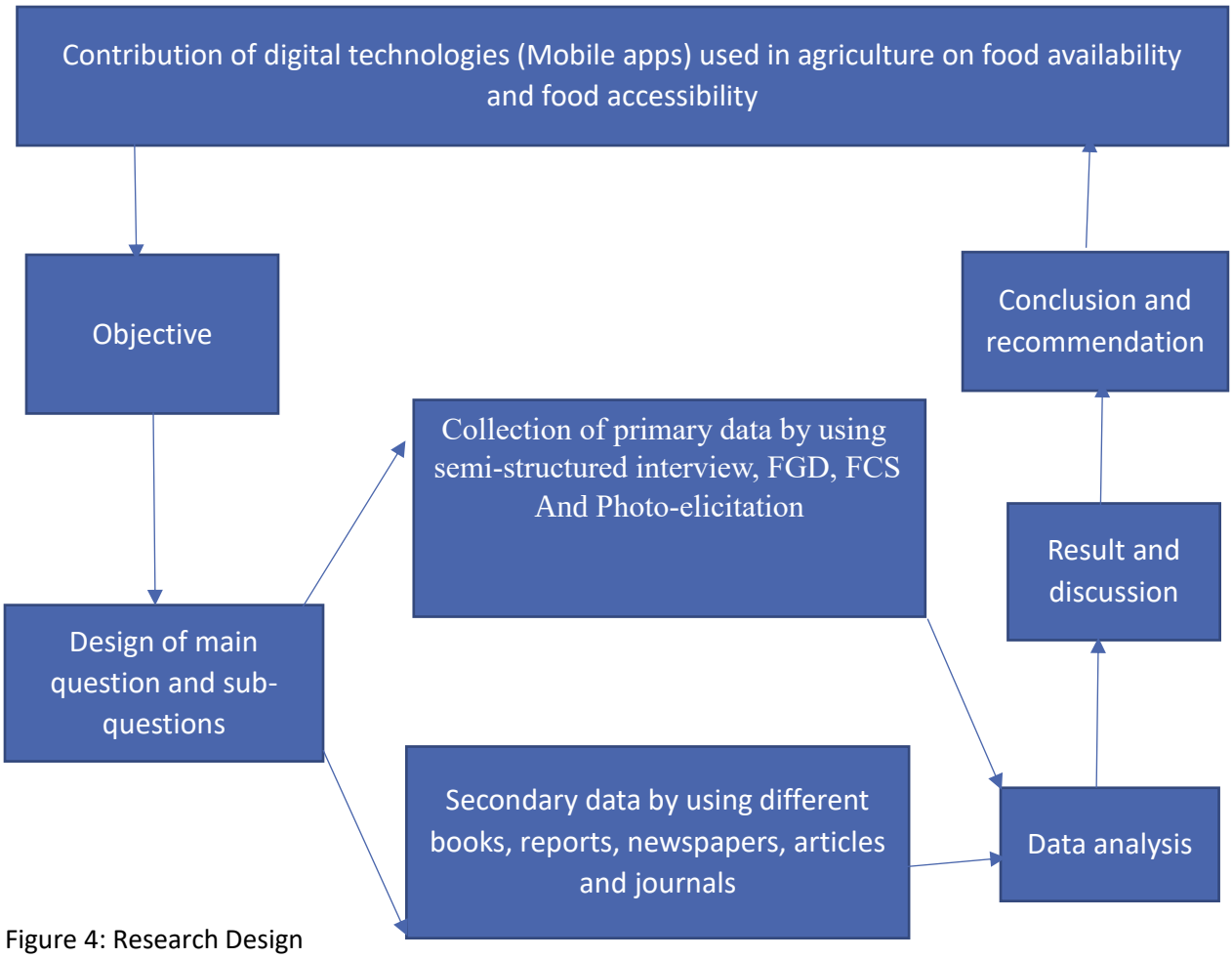

Figure 4: Research Design

Source: Researcher 2021

3.4 Research methodology

In this study, the researcher used qualitative methods. The qualitative method is a method that is used to collect non-numerical data to understand concepts, opinions, or experiences and can be used to collect deep information about a problem and can help to generate a new idea (Bhandari, 2020). The researcher selected this method to help in getting different opinions and experiences lived by farmers in the use of agricultural mobile apps and how these agricultural mobile apps contribute to food availability and accessibility. The agronomist of Murama Sector introduced the researcher through skype, and the research assistants face to face with the respondents.

3.5 Data collection technique

The study used the triangulation method through the exploration of primary data and secondary data. Triangulation is a process of explaining human complex behaviours by combining various methods to give more understanding to readers (Helen & Roberta , 2019). The sources from which primary data were collected are individual farmers, farmers' focus groups, and key informants. The use of triangulation helped in ensuring the credibility of findings and helped in reducing biases in collected data (Laws et al.,

2013). The tools used to collect data were semi-structured interviews, food consumption scores, photo-elicitation and focus group discussions used for farmers and interviews conducted with informants.

Primary source

In primary source exploration, the researcher used focus group discussion, Semi-structured interviewing, and photo-elicitation. Skype and WhatsApp interviews have been used as means through which the researcher used to conduct interviews with key informants. The researcher ensured that both men and women are represented by selecting an equal number of both genders in the sample size. Participatory tools have been used during the process of collecting data, whereby participants were given room to present their points of view freely. The ranking and participatory scoring tool was used during focus group discussion and dealt with ranking and scoring in which respondents were given different options choose from. The researcher gave them when she wanted them to indicate the types of crop and apps they use. The researcher sent a research assistant who conducted focus group discussions and semi-structured interviews with the respondents on her behalf. The research assistant was used because the researcher could not travel to conduct these focus group discussion and interviews due to the restrictions imposed on travelling by countries for the prevention of the spread of the COVID-19 pandemic. In addition, the researcher conducted video call interviews with six key informants, using skype and WhatsApp.

Focus group

Two Focus group discussions have been conducted with 16 farmers of KOTWIDIKA Murama Cooperative. The two focus groups were formed based on gender, one of 8 women and another of men, to ensure equal participation and to get diverse gender experience. The formation of groups in separate genders was also based on the researcher experience of female cultural shyness and reservation to give their contributions when they are with men. The discussion guide, as found in annexe 3 has been used and was a form of various topics drawn from research questions and organised in the forms of other questions to facilitate discussion and help members to share their experiences. Each group was then given a moderator (research assistant) who organised the discussion among the group members and a secretary who takook notes of points from group members during the discussions.

Semi-structured Interviews

Semi-structured interviews have been conducted with 18 members of KOTWIDIKA Murama Cooperative. These people were selected using the combination of convenience and saturation sampling techniques. Saturation sampling is the process of selecting a number of respondents from whom the researcher believes will provide the maximum of needed information, and no further information can be obtained from an additional subject. On the other hand, convenience sampling is the selection method that deals with choosing respondents whom the researcher is sure that they are easily approachable (Saunders, et al., 2017). The researcher, followed this principle and selected 18 members of KOTWIDIKA Murama Cooperative who were met by the research assistant and accepted to participate in the study with no condition. To get the specific farmers, the research assistant reached the field when farmers of KOTWIDIKA Murama Cooperative were having the meeting to organise the harvesting activities. The research assistant then explained the objective of the study to them, ecplanation after which he requested those who were willing to provide information to indicate their commitment by registering. After the registeration , the research assistant selected those who registered in the first 18 numbers as participants.

To ensure equal gender representation among the above 18 interviewees, 9 were women, and the other 9 were men. The researcher decided to use 18 respondents in the interviews in order to have deep information, which is also manageable to analyse within the available research timeframe. Interviews were conducted to collect relevant supportive information to data gathered from focus group discussions. The checklist and semi-structured interview guide were the instruments used in conducting these interviews.

Skype and WhatsApp interviews with the key informants

These are applications used to communicate between people through voice and video calls with the help of the internet (Collins, 2021). These two platforms were used alternatively to conduct video call interviews with possible key informants and WhatsApp group for those who could not be reached on skype. That is, where skype was not applicable, WhatsApp group has been used to reach respondents. The researcher preferred to conduct the interviews with the key informants on her own because their number was small, and it was easier to reach them through video calls and or whatspp group chart. This could not be easier with SSI and FGD participants as the findings indicated that some of them cannot use mobile phone well because of their low level of education. In addition, the was need for internet connection for video calling and this could not afforded by everybody.

Photo elicitation

Photo elicitation is the use of images to generate verbal communication using factual images (Xanthe , et al., 2017). Pictures have been taken to farmers who were met in the field using mobile apps and demonstrating how these apps work. After taking these pictures, the research assistant sent them to researcher who observed farmers in the field (home) working with mobile apps in their farming. There were also screenshots of open mobile apps in usage by farmers, taken to show how farmers can use mobile apps. Some other photos were also taken from harvesting farmers to demonstrate the level of food availability. Other photos were taken in the household's stores to illustrate the quantity of food available for consumption and the surpluses that are available to be taken to the market.

Food Consumption Score

Food consumption Score (FCS) is an index developed by the World Food Program (WFP) in 1996 and is used to test the household food consumption habit and frequencies (WFP, 2008). This document gives information on food items consumed at the family level within the past seven days. It also provides information on food groups consumed like main staples, pulses, vegetables, fruits, meats, fish and milk, among others, as well as the sources of these food groups (Marivoet , et al., 2019). It has been used to evaluate the current situation of food consumption which occurs in household consumption habits among KOTWIDIKA Murama Cooperative Farmers and resulting from the use of digital technology in agricultural production. It helped in knowing well the changes that have been occurring in farmers' consumption, since they started using digital mobile apps in relation to consumption situation before the use of mobile apps. It was used to respond to the second sub-question of the study, which aims at evaluating the current situation of food situation among farmers in Kayonza District. About the procedures followed to use the food consumption score, the research first grouped food in different categories of importance and each category was attributed weight. The researcher then determined the consumption frequencies of each food and these were multiplied by their weight to determine the consumption score.

Secondary data

Secondary data concerned the analysis of reports from Kayonza District's agriculture department. It has been done to confirm data that was collected from primary sources, that is, data from focus group discussion, semi-structured interviews and key informants interviews. From these documents, the researcher studied the official records of Kayonza district agriculture department about food production of different eight years before the use of digital technology, that is from 2008 to 2015 and six years from 2016 to 2021 since digital technologies started being used in agricultural production. The data from these secondary sources was then the supplement of information collected from the primary source to make a well-grounded conclusion.

3.6 Sampling design

The researcher used purposive sampling for both ordinary respondents and key informants. This is defined by (McCombes, 2019) as the sampling that involves a non-random choice of respondents based on suitable conditions permitting the researcher to easily get information. It was selected because the researcher found it to be a helpful selecting farmers who are using mobile apps as they are the ones to be in good position of having relevant information to the research questions.

3.7 Sampling method

A combination of convenience and saturation sampling methods was used to select farmers who use mobile apps and are in the position of providing needed information to the research questions. On the other hand, purposive sampling was combined with snowball sampling to recruit the key informants. The purposive method is the sampling method that is done base on the judgment of the researcher to select respondents who are well known to be in the position of having needed information (Ames, et al., 2019). It has been used on target the key informant whose work and businesses are related to agriculture and the use of mobile apps. Snowball is the sampling technique in which participants are used to recruiting others (Naderifar, et al., 2017) . It has been used to help the researcher using the first identified Key informant (one from the Murama sector) to reach other potential key informants (from the district, MINAGRI, RAB and Bank of Kigali).

3.8 Sample size

The sample size was composed of 18 respondents for Semi-Structured interview and 16 respondents for Focus group discussion who were selected purposively from 127 members of KOTWIDIKA Murama Cooperative and six key informants. The researcher decided to select this number of a participant because she viewed it manageable considering the qualitative method which was used as well as the cost of data collection. For instance, the research has been conducted when it was in a hard time of COVID-19 pandemic an it was hard to travel and meet many people as planned. This goes with the fact that the research has two months on to finish her academic program, an it implies that she needed to meet a small number of people from whom she could get manageable information. In addition, the researcher was convinced that the information to be collected from these participants could be sufficient to make relevant inferences from it.

The researcher also used six key informants, who were selected using the combination of purposive sampling and snowball sampling and was conducted by the researcher to give more supporting information to those that were collected form other tools. Purposive mthod was used to target people

who have the work in relation with agriculture while Snowball method was used because the researcher had no much information about all the officials in charge of agriculture from the district level to the ministry of agriculture and animal resource. She, therefore, used the people she knew, who work at the sector level, and these helped her to know and reach their co-workers at a higher level of district and the ministry . The key informants who were needed include one Officer of Murama Sector, one officer from of Agriculture at Rwanda Agriculture and Animal Resources Development Board (RAB), one officer from the Ministry of Agriculture and Animal Resources (MINAGRI, on representative of Bank of Kigali (BK), one person from KOTWIDIKA Cooperative and the one officer from Kayonza District.

3.9 Data collection process

On 28 July, I conducted a WhatsApp video call meeting with the research assistants and who were together with the Murama Sector agronomist to organise how data collection could be done. The same day I requested the research assistant to find two farmers, to whom we administered a pilot WhatsApp video call interview model for him to get the idea of how he could do it. After my WhatsApp video call interview model with one farmer, the research assistant also conducted another with the second person while I was following to ensure that he mastered the process. In addition, I wrote an email to the mayor of Kayonza District requesting permission to conduct the study with the residents of this district and I was was granted this permission on thirteenth of June, 2021.

After getting the permission, I called Murama Executive Secretary on 29th July 2021 to explain about the study, the reason it was to be conducted, and the impact it may bring to food availability and accessibility among the residents of the sector. On 10th August, I also communicated to the district and Murama sector agriculture departments requesting them the information about agriculture records that I used in secondary data. On 5th August, the research assistant went to find the sector agronomist who helped him to contact the members of KOTWIDIKA Murama Cooperative. On the 9th of August, the research assistant, assisted with sector agronomist, randomly selected 18 farmers who could participate in semi-structured interviews and 16 who participated in focus group discussion. The research assistants conducted the interviews for three days, starting from 10th August to 12th August. On 13th August 2021, the research assistant conducted the FGDs in which two groups, one for eight men and another for eight women, were formed. I also conducted interviews with the key informants, whereby three were conducted on 12th August, and the other three were conducted on 13th June 2021.

3.10 Data analysis

The researcher used content analysis to analyse data that was collected from photo observation, focus groups, and semi-structured interviews. On the other hand, narrative analysis was utilised for the data that was collected from interviews with the key informants. The researcher categorised collected data according to their themes using codes. After categorising them them under similar themes , they were gathered and analyse together to draw common meaning from them.

Table 3: The table showing the umary of reseach question, data collection methods and tool used to collect data

Sub question	**Expected information**	**Data collection method**	**Source of information**	**Data processing**
1. How do farmers of KOTWIDIKA Murama use mobile apps for food availability and accessibility in Kayonza?	- Various ways in which mobile apps are used in agriculture	-Semi-structured interview guide	Farmers Focus group	- Coding
		- (FGD)	Famers	- Content analysis
		Semi-structure interview via Skype/WhatsApp	Key informants	- Coding
		-Photo elicitation	Famers	- Content analysis
2. What is the current food availability and food accessibility status among farmers of KOTWIDIKA Murama Cooperative in Kayonza?	-Actual situation of food availability among farmers -Actual situation of food accessibility among farmers	-Semi-structured interview guide	-Farmers -Focus group	- Coding - Content analysis
		- FGD	Farmers	- Content analysis
		FCS (Food consumption score)	Farmers	
		-Semi-structure interview via WhatsApp/ Skype	-Key informants	- Coding
		Photo elicitation	Farmers	- Content analysis
3. How has the food availability and accessibility among KOTWIDIKA Murama farmers changed since the introduction of mobile apps in their farming activities?	-Types of changes in agricultural food produced locally -Types of changes in local food consumption Types of changes in local food sold and bought in the market by farmers	-Semi-structured interview guide	-Farmers	- Coding
		- FGD	-Focus group members	-Comparison -content analyses.
		-semi-structured interview through WhatsApp/ Skype	- key informants	- Coding

		District agriculture records and reports.	Kayonza district reports and other records	
		-photo-elicitation	Farmers	Comparison -content analyses.
4. What are the strengths and weaknesses in using mobile apps in agriculture for food availability and accessibility?	-Various success and gains were achieved in agriculture from using mobile apps - Failures losses got from using mobile apps	Skype/WhatsApp interview	Key informants	Coding
		Semi-structure interview	Farmers Key informants	Coding
		Focus group discussion.	Famers	Content analysis
5. What Opportunities and threats do KOTWIDIKA Murama Cooperative farmers face in using agricultural mobile apps for food availability and food accessibility?	Challenge facing farmers in using agriculture mobile apps	-Semi-structured interview guide	-Farmers	- Coding
		- FGD	-Focus group members	- Content analysis
		- Skype/ WhatsApp interview	Key informants	- Coding

Source: Author, 2021

3.11 Ethical Consideration and confidentiality

For ethical consideration, the researcher sought a letter from the kayonza district permitting her to research with farmers. The researcher ensured that the purposes of the research are explained deeply to respondents. The researcher also introduced herself to respondents and presented the consent form, which was signed by each one of them. She also assured all respondents that the information given was to be used for academic purposes only. On the issue of privacy, the researcher used the code to record the answers from interviews and guaranteed to them that no name of respondents was to be mentioned in the recording of information. Furthermore, the researcher ensured that the measures for the prevention of COVID-19 were adhered to and respected. This includes wearing a mask well, washing hands before and after exchanging research materials (research instruments), and respecting social distancing of 1.5m.

3.12 Limitations

The researcher met some limitations in conducting this study. The most encountered were the fact that in Rwanda, the population is categorised according to the social-economic status and source of income. These categories are called "**Ibyiciro by'ubudehe**" in Kinyarwanda (local language), and the government then considers these categories to help citizens in terms of financial support and health insurance. Therefore, based on this categorisation, respondents were reluctant to provide to answer to provide information to the researcher because they thought that this information was to be used in categorising them, and they were afraid of being put in the wrong category. However, the researcher tried to explain the objective of this study deeply, and they ended up accepting freely and voluntarily to provide needed information. The second limitation was the internet connection, which was not good. It was a barrier to communicating efficiently with respondents because it took a long time to reach them.

Furthermore, there was a limitation of lockdowns. The time of collecting data became short, which led the researcher to increase the number of research assistants and their training. It then increased the budget above what was planned by the researcher for data collection. There was a limitation of getting the rate of increase that mobile apps bring to agriculture production because so many other factors influence production.

CHAPTER FOUR: RESEARCH FINDINGS

4.0 Introduction

The research was conducted with 34 farmers, of whom 18 were involved in semi-structured interviews, 16 participated in two focus group discussions. The interview and focus group discussion was conducted with the support of the research assistant. The researcher also conducted the video conference and WhatsApp call to interview six key informants. There were also photo-elicitation, and food consumption score which was used and this chapter presents the findings got from the combination of all these data collection techniques.

4.1 Profile of respondents

4.1.1 Respondents in semi-structure interview

The semi-structured interview was conducted on 18 farmers from KOTWIDIKA Murama Operative who were given codes from SSIRp1 to SSIRp18. Below table below indicates the profiles of respondents according to their gender, age, level of education, and the land area on which they do their agriculture activities.

Table 4: Profiles of the respondents in SSI

No	Respondents code	Gender	Age	Education level	Size of land cultivated
1	SSIRp1	Female	36-45	Not completed primary school	501-2500 m^2
2	SSIRp2	Female	36-45	Not completed primary school	501-2500 m^2
3	SSIRp3	Male	26-35	Completed primary school	501-2500 m^2
4	SSIRp4	Female	46-55	Not attended school	2501-5000 m^2
5	SSIRp5	Male	26-35	Completed primary school only	501-2500 m^2
6	SSIRp6	Female	36-45	Not completed primary school	2501-5000 m^2
7	SSIRp7	Male	36-45	Not attended school	2501-5000 m^2
8	SSIRp8	Male	36-45	Not attended school	501-2500 m^2
9	SSIRp9	Female	46-55	Not attended school	2501-5000 m^2
10	SSIRp10	Male	46-55	Not attended school	2501-5000 m^2
11	SSIRp11	Male	36-45	Not completed primary school	2501-5000 m^2
12	SSIRp12	Female	56 and above	Not attended school	2501-5000 m^2
13	SSIRp13	Male	46-55	Not completed primary school	2501-5000 m^2
14	SSIRp14	Female	36-45	Completed primary school	2501-5000 m^2
15	SSIRp15	Male	46-55	Not attended school	2501-5000 m^2
16	SSIRp16	Female	56 and above	Not attended school	2501-5000 m^2
17	SSIRp17	Male	56 and above	Not attended school	2501-5000 m^2
18	SSIRp18	Female	36-45	Not completed primary school	2501-5000 m^2

Source: Author, 2021

Table 4 represents the profile of respondents in semi-structured interviews according to their gender and ages. It shows that gender was distributed equally, whereby among 18 participants, there were 9 (50%)

and 9 (50%) females. The researcher had decided to use equal gender distribution to ensure that information got about food availability and accessibility captured the points of view of the two genders equally. This was because the researcher believed that male experience on food availability and accessibility is different from how females experience is based on the responsibilities of men and women in the Rwandan community.

About SSI age, it indicated that five females out of 9 were aged between 36 and 45 years old, two were in the age between 46 and 55 years old while the other two were in the age above 56. On the other hand, two men out of 9 were aged between 26 and 35 years old; four were between 36 and 45 years, two were in the age between 46 and 55 while 0ne was above 56 years old.

Explaining the information from SSI, the focus group discussions members and key informants indicated that young people do not like agriculture because it is taken as the work for none schooled people from the village who are poor and are less civilised.

"*Our young men and women do not want to hear them being told about agriculture because they consider it as the job of poor people who are less civilised. Instead, they prefer going to cities where they can have flexible jobs"-(FFGD*).

" It is difficult to convince young people to go in farming because they consider it as neglected work for poor people and them do not want to remain poor"-(MMFGD).

"Young people want white-collar jobs and consider agriculture as a dirty job"-(KIKC).

The findings on the SSI respondent's level of education was distributed as follow: 5 female out of 9 have not completed primary school, 3 of them did not attend school, and only one completed primary school. On the other hand, two males out of 9 have completed primary school, while seven of them studied primary school but did not finish it.

The findings also indicated the area of land cultivated by each SSI participant. It showed that 5 out of 18 respondents, that is, 28% cultivate the land area between 501 and 2500m^2 while 13 (72%) others cultivate the land area between 2501 and 5000m^2.

Some photo elicitations were taken to show how the research assistant conducted semi-structured interviews with farmers, and below is a sample of those photos that were taken.

Photo 1: The research assistant interviewing with farmers

Source: Fieldwork, 2021

Photo 1 shows one of the interviews conducted by the research assistant with a farmer in her home.

4.1.2 Respondents in focus group discussion

Two focus group discussions were used, one for eight men and was given the code (MMFG), the shortening of Male Focus Group Members and another group was for eight women, given the code (MFFG), meaning Members of Female Focus Group.

Men focus group discussion Female Focus group discussion

Photo 2: Research assistant with focus group members

Source: Fieldwork, 2021

Photo 2 indicates the focus group discussions which was being conducted with the supervision of the research assistant. At the left hand of the photo, it is the FGD of men and at the right is the FGD of women.

4.1.3 Profile of the key informants

The researcher conduct the interviews with six informants whose descriptions are presente in table 5 below.

Table 5: The profile of key informants

Key Informants Code	Description
KIM	Key informant from Minagri
KIRAB	Key Informant from RAB
KIKD	Key informant from Kayonza District
KIMS	Key Informant Murama Sector
KIC	Key informant from cooperative
KIBK	A key informant from the Bank of Kigali

Source: Auther, 2021

4.2 Ways in which mobile applications are used by farmers

4.2.1 Farmers' Knowledge about the existence of mobile apps

The findings from all 18 participants'responses from SSI confirmed that famers know about the existence of mobile apps. This was confirmed by 14 out of 18 respondents in SSI who indicated that they use SNS only while four showed that they use both SNS and MOPA.

" I know that there are mobile apps use in agriculture and we also use SNS in our cooperative"- (SSIRp1-SSIRp18).

Reposts from the two focus group discussions also supported the answers from SSI that farmers know about the existence and use of mobile apps, as shown in their responses below.

"We *know that mobile apps are used in agriculture because we use them in our cooperative for the past six years* "(MFGM).

"Mobile *apps are used by many farmers herein Murama sector, because the government wants us to be smart in our agricultural activities*. *We also use SNS to get seed and fertilisers of different quality depending on wishes of farmers we choose the variety of seeds and type of fertilizer we want "* (FFGM).

The researcher asked the question to the key informants in order to know how farmers are assisted in having more information and knowledge about the use of mobile apps. Two Key informants have indicated that digital technology is supported through sensitisation and training to farmers as the vital means to solve the problem of food shortage and hunger, which is found in many parts of the country.

"*We have decided to put our full support in digital agriculture technology to support farmers who have always been seen as people involved in cheap work. This perception resulted from the little production that farmers were getting. We, use intensive campaign through sensitisation and training to encourage farmers to use agriculture as a way of practising professional agriculture that will give more yield and solve food problem in families and the whole country*"-(KIBK & KIRAB).

"*Digital technology, through mobile apps, has been introduced in rural agriculture to solve the problem of food shortage and hunger which has prevailed for a long time in the country*"-(KI M).

4.2.2 The use of mobile apps by farmers

Another question was asked to find out how many farmers use mobile apps. From their responses, all 18 (100%) respondents confirmed that they use Mobile apps in their agriculture activities.

This was confirmed by the members of the focus group discussion as shown by the extract below that are collected from their responses:

"[…] we as cooperative members use SNS in our agriculture……."- (MMFG).

"We have been given and trained to use SNS"- (MFFG).

The key informant who represented the cooperative members also confirmed that farmers use mobile apps in their agriculture activities.

"We *have been given SNS mobile apps that facilitate us to make order of seeds and fertilisers from agricultural input supplies*"(KIC).

Other key informants also supported that farmers use mobile apps, as demonstrated by respondents given by MINAGRI and RAB key informants.

"Mobile *apps were given freely to farmers by the Ministry of Agriculture through Rwanda Agriculture Development and Animal Resources (RAB). There was also some support from other stakeholders interested in agriculture, such as NGOs like One Acre Fund and private companies like the Bank of Kigali.*

"It was after initiating these apps in cooperatives that all farmers, including individual farmers, were given access to use them" (KIKD).

"*Farmers have been using mobile apps, and we see that they give big contribution to production. Before giving these apps to all farmers, they were initiated in cooperatives, after training some of their members who went and also trained their cooperative mates. After seeing that they were giving results, they were then allowed to all farmers who wanted to use them but especially those working in cooperatives*" (KIRAB).

The key informants from MINAGRI and RAB indicated that the Ministry introduced mobile apps to be used by cooperative because when farmers work in cooperative it is easier for the ministry to plan for training their members, but also cooperative adherents can put together their land to implement the government's policy of land consolidation.

"*Mobile apps were introduced and encourage to be used by farmers in cooperatives because it is in cooperatives that the government can find it easier to plan for training of farmers, it is through cooperative the implementation of government land consolidation policy will be easy because farmers who are in cooperative will themselves come together and join their individual land to use them in common. In addition, it will facilitate stop disorganised agriculture practised by farmers who mix together more than two crops to be produced on the same land at the same time, but the yield comes out insufficient. Cooperative, therefore, are advised to choose one selected crop on which they can get quality selected seeds and use better fertiliser and pesticides to increase the yield*" KIM & KIRAB)

On the other hand, the information from the cooperative key informant indicated that using mobile apps in cooperatives helps members to learn from one another and boost the production to the increase that cannot be realised by one individual farmer working alone.

" *It is difficult for some farmers in here to our place to understand the importance of working in cooperative because of a long time that people have been working as individuals. But for us who have joined cooperative using mobile apps, we are experiencing the good thing of working tighter because we learn from each other, those who do not know how to read and write are assisted by those who have these skills, which could be difficult when someone works alone. Working in cooperative also gives the chance of getting different donors who invest in supporting agriculture activities because they come targeting farmers who are in cooperative than those working individually*"- (KIMS)

4.2.3 Types of mobile apps used in Kayonza District among SNS, MOPA and Esoko

The researcher asked the question in the semi-structured interview to know whether farmers in Kayonza District use all the three mobile apps which have been introduced in the countries. All 18 respondents 100% affirmed that they use SNS. But, it was also found that 4 of them, that is, 22%, are farmers, but they do agro-dealing activities as well, supplying agro-inputs to their fellow farmers using MOPA. This means among 18 participants, 14 use SNS only while four remaining use both SNS and MOPA. On the other hand, it was found that none of the farmers uses Esoko the app because they indicated that it is only used by the government to monitor how prices vary to different markets of the country. Nevertheless, farmers in focus group discussion of women indicated that if they could also have access to this Esoko app, it would be helping them to know better markets that have favourable prices where they can sell their production surplus or buy what they don't produce.

"We use SNS to produce, but sometimes when we have more surplus, it is hard for us to benefit from it because of the poor market we have in our region. What can help us to have value as farmers also are to give access to Esoko, which we hear is used by MINAGRI to know prices on the markets? This may also help us to know prices that eat various markets in the country, and we can decide where to sell our surplus for us to earn more money. Or we can find markets where we can go to buy at prices that favour us"- (FFGD).

The responses from the SSI interview were supported by the key informants and focus group participants.

"*MOPA stands for Mobile Ordering Processing Application. It is a mobile App used by Agro-dealers to order and sell agricultural inputs (improved seeds and inorganic fertilizers). SNS stands for Smart Nkunganire System. It is a new digital tool used to link farmers and stakeholders involved in the sponsoring agriculture schemes that deal with fertilizers and improved seeds, among others*"-(KIM).

"Our farmers in Murama sector commonly use SNS to link them with different shareholders in agriculture and MOPA which is used by agro-dealers who order and sell agriculture inputs and output in and outside the sector"- (KIMS).

4.2.4 Skills of farmers on using mobile apps

A question was asked to find out whether farmers know how to use available mobile apps. All the 18 interview respondents demonstrated that they had been trained on how to apply these apps. They also added that every farmer had been given a registration number of SNS, which is used as the identification number, and it is used in every season for entering the system for ordering seeds and fertilisers. For those who are agro-dealers, they indicated that MOPA, which is used in agro-dealing, has the option of using code or email. The person who uses it is the one to choose which option is sweet for him/her to use.
"*The knowledge and skills I have on using SNS mobile app are based on how to enter by click *774 # and follow the instructions to order seeds and fertilizers used to increase agricultural production"- (SSIRp1. SSIRp9, SSIRp12, SSIRp15).*
"The knowledge and skills we have on the use of mobile apps are to order seeds and fertilizers that we use in our farms to increase our productivity" (SSIRp 2, SSIRp3, SSIRp16).

*"For us agro-dealers who sell seeds and fertilisers, we distribute them to our fellow farmers using MOPA by dialling the code (*SNS12345#), or we can use email. For me, I use my email: kamonyojbosco@gmail.com" (SSIRp16).*

Photo 3: A farmer in an interview showing the research assistant how they use mobile apps

Source: Fieldwork

Photo 3 indicates the research assistant interviewing a farmer who was showing him the process they pass through in using SNS mobile app.

Nevertheless, although farmers indicated that they all use mobile apps, they showed that not all of them know how to operate these apps because they require reading and writing skills, and it is difficult for farmers who do not know how to read and write to use them.

"Even if some of us have been trained to use these apps, but it is difficult for those who do not know how to read and write. For them to use the app, they look for the fellow farmers who know how to use it for help" (FFGM).

" *Mobile apps are good, but many farmers do not know how to read and write. They have the problem in using them and their time of planting delays as they should wait until they find people to help them*" (MMFG).

The key informants and focus group participants also confirmed that farmers who use mobile apps in Kayonza had got some training in using these apps.

"*Farmers in cooperative have been given basic knowledge on the use of the available apps. The tools are designed in such a way that simple farmers who know how to read and write can use them. For instance, farmers themselves run SNS for registration and validation by dialling *774# and follow the instructions that are given. The farmer keeps the provided code and presents it to the agro-dealers at the time of buying inputs. On the other hand, at the cooperative level, the person in charge of following how mobile apps are used has advanced skills to handle the data at the cooperative level, such as the number of farmers registered, the quantity of given inputs required, and a related amount to be paid to the supplier. Farmers acquire knowledge and skill of using mobile apps through regular training organized at sector, cell, and*

village levels. In addition, there is other basic knowledge passed to farmers through radio spots and TV programs" – (KIM, KIBK).

*"Famers know the use of these mobile apps because on SNS, we use the code *774#, and we follow the instructions given. On Esoko, we use the code *7656# and also follow the instructions given electronically on the mobile screen. However, this knowledge is not enough, especially for some farmers who want to have agro-dealing activities because MOPA, which is used in these agro-dealing businesses, sometimes needs the use of email, and many farmers do not know using emails.*"- (KIRAB , KIBK).

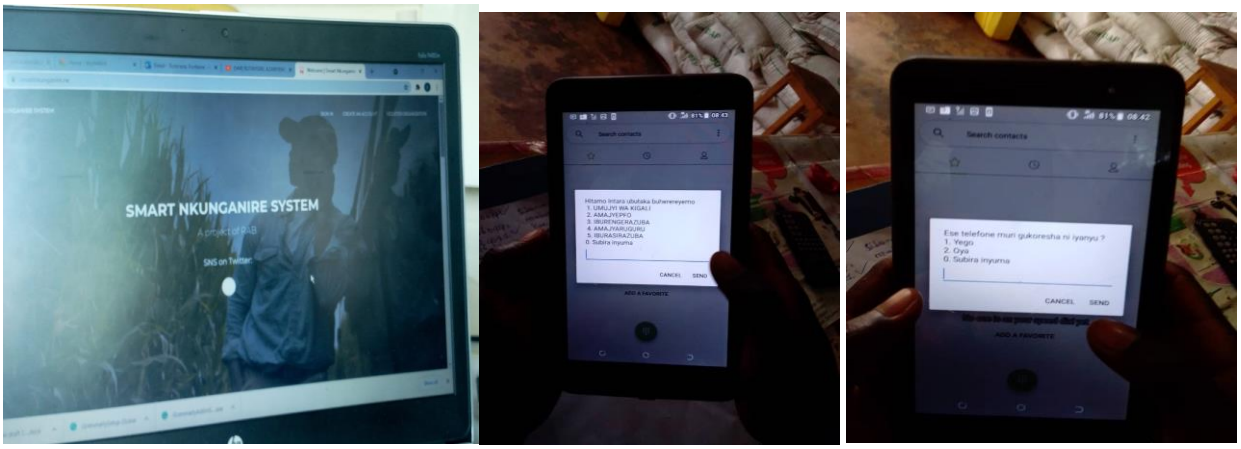

Photo 4: Illustration of electronic SNS instructions given to farmers after dialling the given code

Source: Author, 2021

However, some farmers have demonstrated that it is difficult for some farmers to learn about the use of these apps as they are illiterate or have a low level of education.

"It has been easier to some farmers who have attended the school because they already know how to use other mobile apps and have quickly adapted themselves to the use of these agriculture mobile apps. But it has been difficult to train those who have never been to school because they cannot know how to read the content of the apps. What they do is to use their children or relatives or friend farmers to help them use these apps"- (KMS).

"The knowledge that we have is not enough, but we are from time to time given training on how these mobiles are used"- (KIC).
"*The knowledge and skills of our cooperative members on the use of available mobile apps is based on how we apply and use selected seeds and fertilizers using SNS mobile app. we get through agro- dealer, farmer promoters, and local leaders. This knowledge and skills are enough for SNS mobile app*"-(MMFG).

"*The knowledge and skills of KOTWIDIKA Murama cooperative members on the use of available mobile apps is based on how to apply and use selected seeds and fertilizers using SNS mobile app. We get this knowledge through cooperative leaders, cooperative members, agro-dealers, farmer promoters, local leaders. This knowledge and skills are enough for SNS mobile app. However, we need training on other mobile apps"-(MFFG).*

"I need some help from my neighbors who assist me anytime I need to use SNS to get seeds and fertilizer for maize" – (SSIRep7).

About how the knowledge is acquired, some respondents indicated that they get the knowledge from the training given to them by cooperative leaders and members, farmer promoters, agro-dealers, local leaders.

*"Farmers in cooperative have basic knowledge on the use of the available mobile apps. These tools are designed in such a way that from the basic knowledge required by simple farmers to the complex ones required by apps designers and managers. For instance, for SNS, the literate farmer runs him/herself registration and validation by dialling *774# then following the instructions. The farmer only keeps the provided code to be presented to the agro-dealers at the time of buying inputs. On the other hand, at the cooperative level, the person in charge has advanced skills to handle the data at the cooperative level, like the number of farmers registered, the quantity of given inputs required, and a related amount to be paid at the supplier. Farmers get knowledge through regular training organized up to lower levels: sector, cell, village or smaller groups through trainers at different levels. Moreover, farmers get also basic knowledge through radio spots, radio and TV talks regularly scheduled"-(KIM, KIBK).*

Farmers were asked when they have started using mobile apps in their farming activities, and their responses are summarised in figure 8 below.

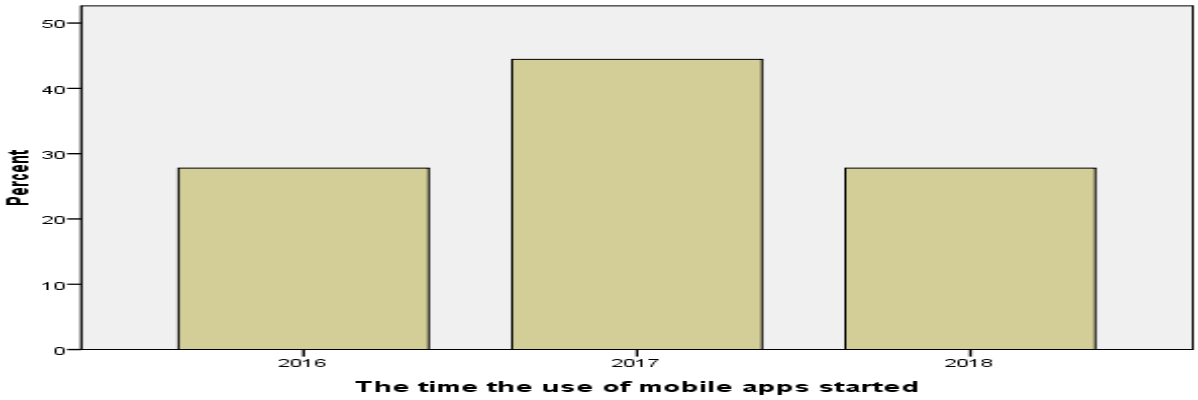

Figure 5: The year farmers started using mobile apps in their farming activities

Source: Researcher, 2021

Figure 5 indicates that 28% of semi-structured interview respondents were using mobile apps since 2016 when the apps were introduced in their cooperative, 46% of were using mobile apps since 2017, while 25% have started using them in 2018. However, the key informant from MINAGRI indicated that Esoko started being used in Rwanda in 2012 while SNS MOPA Started being used in 2016.

All focus group discussions indicated that some farmers started using SNS at the time it was introduced in Kayonza District in 2016 because it was initiated in their cooperative.

"We *started using mobile apps in 2016 when it was introduced in our cooperative after it was selected as the pilot of using this app*"- (MFGM).

"Majority of us started using SNS immediately when it was introduced in our cooperative in 2016"- (FFGM).

The key informants from the Kayonza district and Murama sector also indicated that SNS was introduced in this district in the year 2016, while MOPA started one year after in 2017.

"Mobile apps started being used in this district in 2016 when it was first piloted in one cooperative, after which it was then given to many farmers, including individual farmers. However, this was SNS only because MOPA, which is used by agro-dealers, came after in 2017. Before its introduction in this districts, farmers were ordering input through RAB and take a long distance to go to ask in the officer of the sector"-(KIKD).

" Few of our farmers started using mobile apps in 2016 when it was piloted in the KOTWIDIKA Murama cooperative. Others received in the years that followed after confirmation of its use"-(KIMS).

4.2.5 The number of years spent by farmers using mobile apps

Farmers were given a closed-ended question to demonstrate the interval period in which they have been using mobile apps. This was to help find out whether people who adopt the use of mobile apps use them for long or abandon them after some time. Figure 6 summarises what came out from their responses.

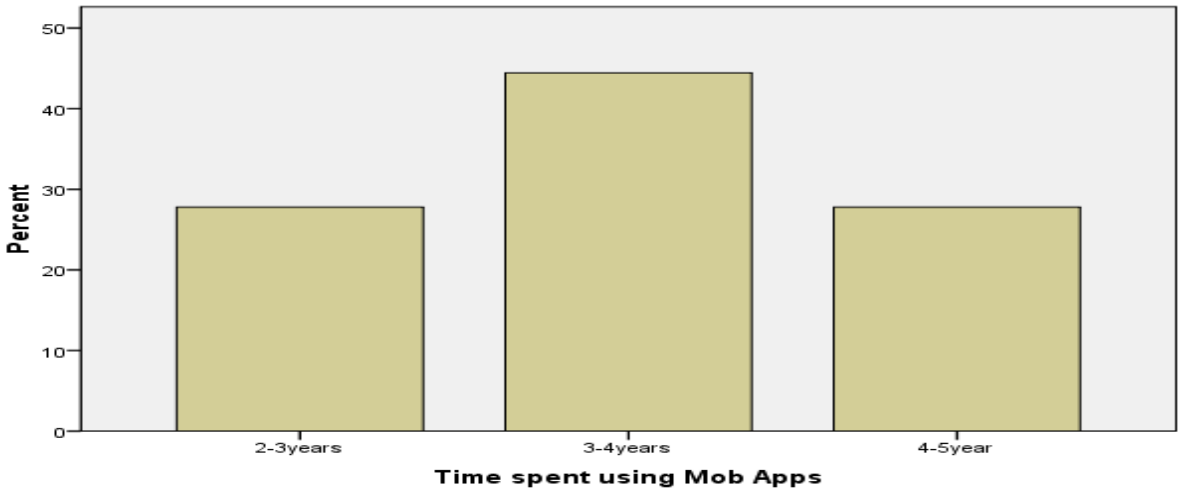

Figure 6: The number of years spent by farmers using Mobile apps in their agriculture activities

Source: Fieldwork, 2021

From the responses given by semi-structured interview participants, it was revealed that 25% of respondents were using Mobile apps for the time between 2 and 3 years, 47% were using mobile apps for

the time between 3 and 4 years, and 28% have used these apps for the time ranging between 4 and 5 years. This information indicated that as time goes on, more farmers join the use of mobile apps, and those who have joined them before continue using them.

Table 6: The types of crops on which mob apps are used:

Type of crops	**Frequency**	**Per cent**
Maize and Beans	2	11
Maize, beans and tomatoes	16	89
Total	**18**	**100**

Source: Fieldwork, 2021

Table 6 shows that among 18 respondents in the semi-structured interview, 2 (11%) use SNS mobile app to order fertilisers and selected seeds of maize and beans, and 16(89%) use SNS mobile app to order fertiliser and the seed of maize, beans, and tomatoes. On the other hand, all the key I informants and focus groups participants indicated that mobile apps are also used to get selected seeds of certain cereals and vegetables selected by the MINAGRI through RAB.

"*Mobile apps are used to support farmers in getting agro-inputs at a subsidized price. For instance, farmers use SNS apps to order selected seeds of beans, maize, and certain types of vegetables that have been selected by MINAGRI through RAB, and they are the ones that farmers are advised to produce using these apps. They also use these apps to order industrial fertilises such as Dap and Urea that we mix with organic manure from an animal.*"-(KIM).

"*The main crops for which we frequently order their seeds using SNS app are beans and maize but some time we use it to get other seeds such as soybeans, vegetables (tomatoes), cassava, wheat, and rice as well as industrial fertiliser*……"-(KIKD).

"For our sector, we have been given different options, and we can use SNS to order seeds and fertilisers for Irish potatoes, soybeans, vegetables among others" (KIM).
Concerning the ways agriculture mobile apps are used by farmers, respondents indicated that these mobile apps, especially SNS and MOPA, are used to order quality improved seeds and fertilisers that are utilised by farmers to increase production.

" *Every season, I apply seeds and fertilizers by using SNS to increase agricultural production hence household food availability and accessibility in the area"- (SSIRp1-SSIRp18).*

"[…….] use of available mobile apps is based on how to apply and use selected seeds and fertilizers using SNS mobile app"-(MMFG and MFFG).

The information summarized in annexe 7 and annexe 8 indicates the statistics collected from Kayonza District and Murama Sector Agriculture records. They indicate how the number of farmers who adopted the use of SNS mobile apps in Kayonza District and Murama Sector has been increasing since 2016 when the mobile app started being used in this place till 2021. The tables also present how farmers increased the land area cultivated using these mobile apps facilities as well as the number of seeds and fertilisers

every year. The use of SNS indicated in the tables above also revealed the increase in the use of MOPA since farmers, who participated in the study, showed that agro-dealers get seeds and fertilisers that they supplied to small farmers through the use of MOPA.

4.3 The situation of food availability and accessibility

The statistics summary in annexe 5 were collected from Kayonza district's agriculture and indicates the records which were done for 14 years between 2008 and 2021. These statistics indicate how the production of maize and beans have been constantly very low eight years before mobile apps were introduced in agriculture, the years 2008 to 2015. But after the introduction of SNS and MOPA mobile apps in 2016, the yield started increasing significantly. The key informants confirmed that the use the mobile apps contributed highly to this production increase because they helped farmers to get and use selected seeds and good fertilisers in time.

"There is a great change brought about by the use of SNS and MOPA mobile apps as a way to improve agricultural food availability and accessibility in Kayonza district. The use of these mobile apps has reached almost all farmers and has greatly eased access to inputs. The use of agro-inputs, in the form of selected seeds and good fertilisers, has increased food at the household level and boosted the level of yield produced by farmers to the same area of land which was not produced before" (KIRAB).

"*The use of mobile apps brought remarkable changes in production level, and when walking around farm gardens, one can see it with his/her eyes. This increase resulted from the increase in the number of farmers who adopted the use of selected seeds and industrial fertilisers. In addition, the use of apps facilitated the comparison between the input and output that come from agricultural activities. Today we can know the land area cultivated and the agro-input used; we can evaluate the level of yield in a given season and compare it with previous seasons. I can testify that residents of Kayonza District have food available and accessible to them. The only challenge we are still facing is that farmers have not yet started getting appropriate markets for their harvests surplus and sell them at low prices. However, I believe that the time they Esoko will be introduced to them, the problem of the market will also be solved.*" (KIKD).

The researcher consulted the agricultural production records of the district agriculture department and got the information summarised in the table found in index vi. This information indicates that between 2008 and 2015, when mobile apps had not yet started being utilised, maize was cultivated in the area between 550 and 6200 ha and produced between 555 and 8000 tones. Beans were cultivated in the area between 7000 and 10000 ha; the production was 2000 to 4000 tones. On the other hand, from the time mobile apps started being used in 2016, these quantities increased in such a way that the area on which maize is cultivated reached between 4000 and 12500 ha, and production reached between 5000 and 35000 tones. The area on which beans are cultivated increased to between 5000 and 20000 ha whereas production increased to between 1500 to 17000 tones.

This supported what came out from the responses of some SSI respondents:

" In season A of this year 2021, I got the harvest of 780kg on the land area of 3000m^2 while the time before I started using SNS I was not producing beyond 370 kg on this area "- (SSIRp1).

In season A of this year 2021, I produced the amount of maize equivalent to 7400Kg on the land area of 25100m^2 while before using mobile apps I was always producing between 3700 and 4000kg only "-SSIRp15).

4.3.1 Food for household consumption

All Respondents in semi-structured interviews, that is, 18 out of 18 (100%), indicated that before the use of mobile apps, agricultural yield was very low because farmers used bad prepared organic manure and poor quality of seeds which could not give enough harvests. But, the production increased with the use of SNS apps as farmers can get quality inputs in terms of selected seed, industrial fertiliser and pesticides used to increase yield. This yield increase also led to the increase in food for household consumption, as indicated by some of the responses below received from farmers.

"Every *season, I cultivate using selected seeds and fertilizers that were ordered through SNS. This has given me to have more yield, and I have enough food to eat in my home*"-(SSIRep 5).

The above information was supported by the key informants and focus group members.

"[……] *the use of agro-inputs has increased at households level and boosted the productivity of planted crops leading to more food available for home consumption*"-(KIMS).

"[…..] *It is well remarkable that farmers who use mobile apps have now increased agriculture production in all the three agriculture seasons A, B, and C and boosted the level of food consumed in families"-(*KIKD).

"[….] *there has been an increase of agricultural production due to the use of selected seeds and fertilizers*"-(MMFG and MFFG).

The information of food availability in the households was confirmed by what was found in the stores of farmers as some of them are shown in photo four below of the photo elicitations taken from the stores of two households.

Store of household SSIRp11 *Store of household SSIRp14*

Photo 4: A picture taken in stores of two different farmers of KOTWIDIKA Murama Cooperative

Source: Fieldwork, 2021

On the other hand, respondents indicated that before the use of mobile apps, farmers were doing their farming activities using unselected seeds and poor quality fertilisers. This could not give a good harvest, and farmers were always living in food insecurity.

"Before the introduction of agriculture mobile apps in farming activities, majority of farmers used the traditional methods of production without any fertiliser and resulted in producing low output. But after the introduction of agriculture mobile apps, it was noticed that food availability and accessibility at the household level and in the market increased with the increase of production"-(KIMS).

"*Agriculture mobile apps have been introduced in farming because, before farmers were using traditional methods which produced less and it was difficult to produce enough food for satisfying Rwandans' consumption needs*"- (KIRAB).

The result from the food consumption score represented in figure 7 below also confirmed that there is more food for consumption in the household because it indicated that 13 households, among 18 households who participated in the semi-structured interview, have the consumption score situated in the acceptable category, 4 out of 18 were in the borderline category, and only one was having the poor consumption score (FCS, 2021).

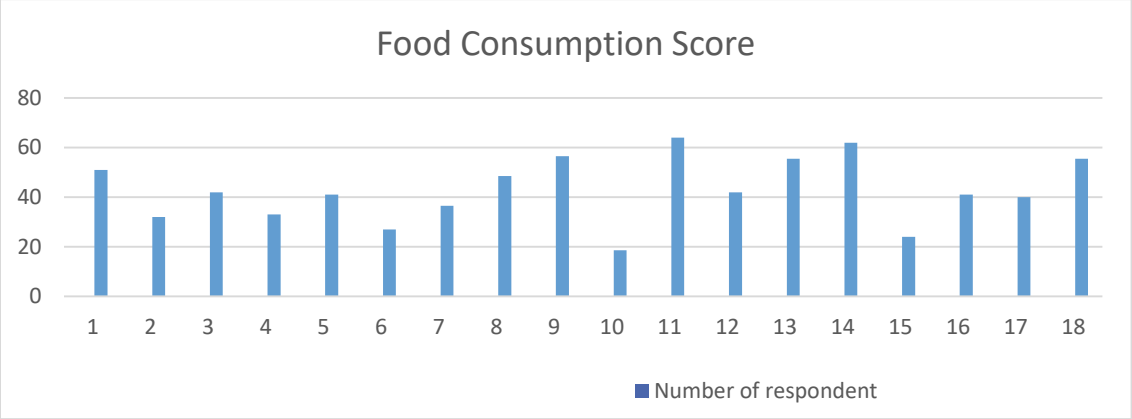

Figure 7:Food consumption score for various agriculture products

Source: Researcher, 2021

Table 7:Food source of 18 participants in semi-structed interviews

Food source	Number of respondents	Percentage
Own Production only(2)	1	6
Purchase only(1)	0	0
Barter (3)	0	0
Borrowed (4)	0	0
Gifts(5)	2	11
Aid(6)	1	6
Others(7)	0	0
Own Production and Purchase (8)	14	78

Source: Researcher, 2021

Table 7 contains the information about the food source of farmers. 14 out of 18 (78%) indicated that they get food from their production and purchase, 2/18 indicated that they received for from gifts. It is only

one person who indicated that her household consumption comes from her production alone and another one who gets food from aid.

4.3.2 Food availability at Kayonza market

All respondents who participated in the semi-structured interview have indicated that they have various marketplaces where they go to buy and sell agricultural food products. They further specified that the nearest market, where they can access easily, is located at 30 min time walking while the furthest is at 3hours walking. Photo 5 indicates some photo elicitations which were taken in Kabarondo market, the nearest market where farmers were selling some of the produce foodstuffs from their farm gardens. It is the illustration of how farmers, after satisfying their home consumption, have surpluses remaining which is taken to the market to earn money.

Photo 5: Famers selling their yield in Kabarondo Market including maize, beans bananas, cassava…:

Source: Fieldwork

Respondents also indicated that, in general, prices of agricultural food products on the market had been reduced, and local buyers can afford them when they go to buy food from the market. However, they also highlighted that they have the challenge of getting to the markets located far away from Kayonza when these markets have lower prices than those at their nearby places. This is because their only way of reaching those markets is by walking due to bad roads that do not favor transport companies to put public transport facilities in this place area.

" *The most available agriculture food that is abundantly available on our market at an affordable price for the time being are Beans, Maize, Irish potatoes, cabbage, eggplants, tomatoes, groundnuts, cassava, rice, carrots, banana, sweet potatoes, yams, sugar, Fruits like Avocadoes, orange, papaya, passionfruit, citrus, banana and others*"-(SSIRp1-SSIRp18)

"*Since I started using SNS, every harvest, I get at least 200 kg of maize and 90kg beans exceeding what we consume at home, and it is taken to the market to get money for other needs. This was not possible before because even what we were investing in our farm garden could not be produced*"- (SSIRp3).

"*Every harvesting season, I cannot miss 500 kg of maize and 300kg of beans that I take to the market and earn money, but I go to sell the leftover after satisfying all home consumption*"-(SSIRP18).

"*The foodstuffs available on the market are found at a lower price, so it is easy for farmers to buy what has not been produced as there is an increase in agricultural production whereby surplus is taken to the market to get money. There are different food products on the market as the farmers use different agricultural inputs to increase production. The more the increase of agricultural production, the more the surplus for the market and more income to farmers. This means that there is a great change in Price, market and income after the use of mobile apps compared to what was there before using these mobile apps*"-(MMFG).

"*There are different agriculture food products on the market as we use different agricultural inputs to increase production. The more we increase agricultural production, the more we have a surplus to take to the market. This, therefore, helps us in gaining surplus income that we use to buy what we have not produced from our agriculture. It means that there is a great change on Price, market and income after the use of mobile apps compared to the time we were not using them*"-(MFFG).

Photo 6 is a photo-elicitation taken in the Kabarondo market and illustrates various agricultural foodstuffs that are taken by Famers to this market from their production surplus.

Photo 6: Variety of agricultural foodstuff produced and sold in Kabarondo market

Source: Field study, 2021

4.4 Changes in food availability and accessibility in Kayonza due to the use of Mobile apps

All participants in the study indicated that there had been significant changes in food availability and accessibility in Kayonza. They further showed that these changes resulted from the introduction of mobile apps, which led to the increased harvests and food for home consumption as well as helping farmers to get more production surplus that they take to markets.

"*Before using SNS, the agricultural production was not enough to satisfy our home consumption. But after using SNS, there is an increase of production from which we get the surplus that is taken to the market for us to get money which we use for other needs. The mobile apps help farmers to obtain household food. In addition, the increase of production and availability of food at the household level has led to increasing food in the market, making the price affordable to residents of this area. Today it is easier for a farmer to access food from local production either from the own production and or from the market*"-(SSIRp1, SSIRp6, SSIRp14).

"The mobile apps help farmers to apply seeds and fertilizers which contribute to the increase of production food variety due to the increase of household income which is used to buy what they don't produce"-(SSIRp5, SSIRp8, SSIRp10, SSIRp 16).

"*Before the use of mobile apps, we as the members of cooperative were buying seeds and fertilizers at a high price, and even sometimes we were not using these inputs because we could not be afforded to buy them all times; it was therefore making the harvest to be very low. The use of mobile apps reduced the price of seeds and fertilisers, by subsides making them affordable for farmers. Today farmers use good agriculture inputs, and it increased, and more food are available and accessible for local consumers*"-(MMFG).

"*Before using Mobile apps, the agricultural production was not enough to satisfy the household consumption this time that SNS is used, the production increased, and farmers get what to consume in their homes and more surplus production which the take to market. The increased surplus taken to the market boosts their income and helps them to buy other foodstuffs that they don't produce from their agriculture*"- (MFFG).

The key informants also indicated that their use of Esoko helps farmers to have the idea of price differences at various markets in the country, and they can know where to sell their yield at prices which gives them more income and or know where to buy what they have not produced at favourable prices. However, they also indicated that this Esoko facility has not reached in Kayonza district for farmers to use it.

"*Although Esoko has not yet reached in Kayonza District, apart from SNS and MOPA, these Esoko apps provide with farmers information about different prices of various markets in the entire country. They can then use this information to know the location of cheap markets where they can go and buy what they don't produce or the markets where they can sell their production surplus at favourable prices, but up to know the farmers do not have information about the Esoko" –(KIRAB and KIM)*.

Figure 8 is a graph summary of the Esoko report indicating the prices of agricultural foodstuff on the different markets in the whole country. It illustrates how one product was sold differently at various markets in 2020, and farmers use this information to locate the markets which are suitable for their needs and financial capacity. However, as indicated above by the key informants from MINAGRI, this Esoko mobile app is used by different officers in the country, but not yet started using this technology by the farmers

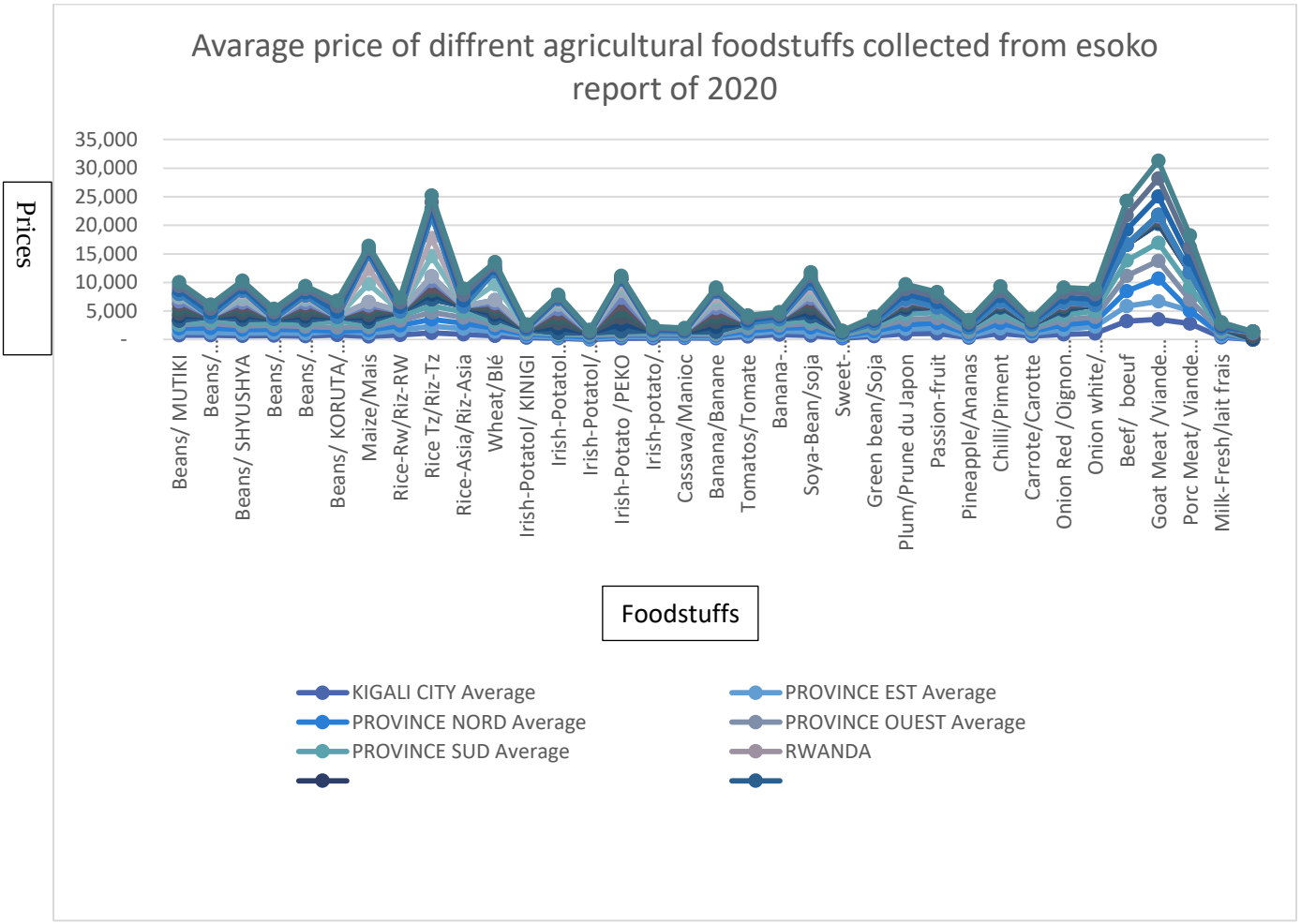

Figure 8: The graph from sample prices of various agriculture foodstuffs collected from different market places of Rwanda using Esoko in 2020.

Source: ESOKO MINAGRI REPORT, 2020

Annex 6 contains the information about the prices of various agricultural products found in the Kabarondo market in the eight days between 5th and 12th of August 2021 and was indicated using Esoko apps from the district agriculture department. It works as the facts that there are various foodstuff available in this area and residents who want buy can access this information from home if Esoko is used.

4.5The Strength, Weakness of agriculture mobile apps usage

4.5.1 Strengths

The findings from information given by 18 framers in the semi-structured interview revealed that using SNS and MOPA to order and acquire agro-inputs helps farmers to connect easily with stakeholders and donors who support agriculture activities. These mobile apps save their time; they facilitate farmers to get and use quality agro-inputs.

" *SNS connects us easy with different partners that give support to our agriculture activities and helps us to get input we use quickly and at low cost, sometimes for free*" – (SSIRp3, SSIRp10, and SSIRp15).

"*Using SNS helps us to get seeds and fertilizers on time with the government subsidies. It reduces the cost of transport for us because we do registration and application for seeds and fertilizers order everywhere by using our mobile phones and they are brought closer to our places. It as well facilitates control in our cooperative as it helps our cooperative leaders to see how cooperative members use seeds and fertilizers to increase agricultural production. But also it has reduced corruption and fraud in distributing seeds and fertilizers to farmers because every farmer is given the quantity requested using a mobile phone and electronic report it is sent to different offices established by MINAGRI to control agriculture operations from the sector level to the MINAGRI level "*-(SSIRp1, SSIRp2, SSIRp6, SSIRp8, SSIRp9, SSIRp13, SSIRp14, SSIRp16,).

These strengths were also highlighted by members of focus group discussion, which indicated that mobile apps help them to get selected seed and good fertilisers used to get high production that they had never had before these apps came.

"*The introduction of Mobile apps in the farming activities facilitated us to get selected seeds and fertilizers which help us to increase the harvest. Today, we have enough food available for our homes, and we have the access that we sell to the market for our cooperative's personal development and development. This e, which we did not have before these apps came*. We have the leaders (staff) who have the knowledge and skills to teach us how to use mobile apps in agriculture- (MMFG).

"*The use of selected seeds and fertilizers play a big role in increasing our agricultural production. We get enough food to eat in our homer and surplus that we take to the market from which find money to solve other need*"-(MFFG).

In addition, the key informants also indicated other strengths found in the use of mobile apps, including the government's good agriculture policy, quality ICT facilities and the personnel which is trained to help farmers. They further indicated that the apps facilitate easy to follow up as the electronic reports of operations are immediately sent to different centres established by MINAGRI to follow up these activities.

"The use of mobile apps helps in Speeding up the flow of messages from stakeholders up to the farmer. It also facilitates the government and donors to reach farmers easily through agents who are closer to them, it directly links farmers with stakeholders and helps farmers to receive key advisory messages from stakeholders. Mobile apps also help us to avoid corruption and fraud because, before these apps were introduced, inputs suppliers and farmers used fertilisers in bad ways. For instance, before the use of mobile apps, some fertiliser was sold to people who are not farmers who were using in making local beer (KIM).

"*SNS and MOPA help farmers to get good seeds and fertilisers in time and has removed the works of using vouchers papers filing as everything is now done kept electronically"(providing the report on land cultivate, inputs requests and used farmers); we also have a good agriculture policy which includes ICT in agriculture* as well as people who have been trained to train farmers-(KIMS).

"There is a good government policy which aims at developing farmers, and the introduction of these apps was one of means to facilitate them get easy inputs and advice. Farmers are also given trained personnel who help them to use these technologies accompanied with good ICT infrastructures"-(KIKD).

"*Mobile apps have eased the registration of land to farmers because every farmer uses the land registration which is given and kept in the land authority. This helps to know farmers who may want to register the land, which is greater than what they have with the aim of getting much input than what they require. When this fraud is discovered, the registration is rejected*"-(KIMS).

4.5.2 Weakness

The findings from data collected indicated that mobile apps are not friendly users by farmers with low levels of education, that is, those who do not know to read and write. In addition, respondents showed that mobile apps are difficult to be used by farmers who do not know how to read and write, where 6 out of 18 respondents indicated they are unable to use these apps on their own unless they are assisted by their children or fellow farmers in the cooperative. It was also indicated that mobile connection and internet connection are among the weaknesses that are experienced in the use of these apps, and this is accompanied by the fact that they are limited to the production of few selected crops on which sometimes farmers delay to get their inputs due to slow network.

"*Technologies we are given to use needs people who know to read and write. For people who do not know how to read and write like me, we wait until we get people who can help us like our children and when children are not there, like when they are in schools, we have to wait until our fellow cooperative members have finished with their own for them to come and assist us. This really delays us in planting and sometimes causes our crops to be destroyed by the sun or heavy rains*. "-(SSIRp3, SSIRp4, SSIRp7, SSIRp10, SSIRp12, SSIRp16).

"*Because of land consolidation, we have to produce one crop on the same land, and the given apps are used for the production of some selected crops. As the donations and funds are given by the government and donors only come to support farmers who produce those selected crops, most farmers have started abandoning to produce other crops which are not supported for those supported ones for them also to receive funds. I can therefore say that in the future we shall be feeding one type of food which may cause malnutrition to us*"- (SSIRp2, SSIRp10, SSIRp18).

" Our place has the problem of mobile network connections to the point that one may want to make an order of agriculture inputs and the system freezes for the whole week without responding"-(SSIRp4, SSIRp4, SSIRp17).

The weaknesses highlighted by the respondents in semi-structured interviews were also confirmed by the report got from the focus group discussion. Below are what was given in these reports:

"*The illiteracy of some of the farmers in our cooperative makes it difficult to use mobile apps and sometimes delays agriculture activities leading the crops to be destroyed by the sun of much rains. This also affects the production and caused famine that we experience from time to time*"-(MMFG).

"*Sometimes there are delays in getting seeds and fertilizers because of some cooperative members who are unable to use mobile phones and or the network problems*"- (MFFG).

Some of the weaknesses indicated by the SSI participants and FGDs have also been highlighted by the key informants as indicated below:

"*We have reports from various cooperatives which show that mobile apps are easy to be used by their members who do read and write*"-(KIMS)

"There *is a weakness of mobile apps of being used only on selected crops to which farmers receive some subsidies. This cause majority of farmers to abandon some crops which are also necessary like fruits and their production decreases*"-(KIKD).

4.6 opportunities and threats of agriculture mobile apps usage

4.6 .1 Opportunities

The opportunities found in the use of these mobile apps are the facility to practice modern agriculture, which gives farmers to increase the yield and get enough food for their household consumption and surplus to sell for income.

"*By adopting the use of mobile apps, we have got the chance to get funds and subsidies from the government and other donors who support agricultural activities like Bank of Kigali whereby they provide us with selected seeds and fertiliser for free of at low cost. There are times even when they give mobile phones to some farmers who cannot afford them*" – (SSIRP 3, SSIRp5, SSIRP11, and SSIRp14).

Seven SSI participants and reports from the two focus group discussions also indicated that mobile apps facilitated better collaboration between farmers and agriculture stakeholders.

"*Mobile apps facilitate the easy connection between us farmers and agriculture stakeholders. This easy connection allows us, farmers, to get a different piece of advice from these people and to get quality input from them which we use to improve our farming" – (SSIRp 6, SSIRp8, SSIRp12, SSIRp14, SSIRp115, SSIRp18*).

"*The opportunity we have got from using mobile apps they have helped us to understand the importance of working in a cooperative. This is because different donors who came targeted to support farmers who work in cooperatives. This, therefore, gave us more connections and improved our farming from traditional to modern agriculture"-(FFGM)*

" Using mobile apps help us to have more and easy connection to RAB and other donors like Bank of Kigali which provide our various cooperative support including training, quality inputs and advice"-(MMFG).

There are other opportunities identified by the key, including education for all, soil conservation, investment established by the government and stakeholders in agriculture, and the international agreements signed by the government to use technology in agriculture.

"The *opportunity of mobile apps is the investment put in technology by the government, decentralization of decision of technology use up to small farmers, government policy to boost technology use in agriculture, and investment in training human resource who are used to train farmers on the use of these technologies we have the signed international agreement to use technologies in agriculture like FAO " –* (KIRAB & KIM).

"SNS helps us to have good collaboration with stakeholders in agriculture sector like Tubura, Hinga weze, KIIWP. We also have government support of giving us mobile phones for as to get apps that we use in our agriculture activities"-(KIMS).

"Using *mobile apps gives opportunities of using small land to produce more while others part are kept in fallow. This leads to soil conservation and gives a chance to people growing animals for find grazing areas or other natural plants can grow*" (KIM, KIMS).

" Using mobile apps in agriculture encourages farmers to use small land which gives more yield while other remaining parts can be used for other activities like animal grazing and natural parks" (KIRAB).

4.6.2 Threats

The study also found that a low level of education with digital illiteracy is the barrier to many farmers using mobile apps and leads some to resist their use. There are also financial barriers that cause some farmers not to afford to buy a mobile phone.

"*There are bad transport means which does not allow us to reach the markets at the far place resulting in us selling our products at low prices*"- (MFFG).

"Although the government tried to give free mobile phone to some few farmers who represent other, *we are still having the challenge of many farmer's limited access to mobile devices as most of the people involved in these activities are poor farmers from the village. There is also the problem of illiteracy among some of those farmers who have phones which leads to an inability to use mobile apps efficiently. They are also the resistance of farmers to change for using the technologies, poor infrastructure of connection connection*"- (KIC & KIM).

"*The system still has some limitations because it cannot be used by people who do not read and write. Some of our farmers also have limited financial means which they use to solve they major basic need, and it is difficult for them to buy mobile phones*"- (KIM).

Furthermore, all 18 participants in SSI indicated poor transport means and bad roads that do not facilitate them to move freely for selling their production surplus or buying what they don't have. This leads their products like vegetables to deteriorate in farm gardens and causes significant losses to farmers.

"*Roads are still very bad, and there are not transport means that facilitate farmers to take the surplus from their production to better markets*"- (MMFG,& MFFG).

Photo 7: The road to Murama Market

Source: Fieldwork

The key informants from the district indicated that mobile apps use experiences the threat of climate change which sometimes destroys the crops and lead to less production than was expected. On the other hand, the key informant from the sector indicated that the use of too many chemicals and industrial fertilisers destroy the soils and kill some other living things.

" *There is a threat of climate change, whereby some time we have too much sun which lasts for a long period and destroys the crops leading to the reduction of yield*" (KIKD).

" *The use of mobile apps has lead farmers to use many chemicals and industrial fertilisers that destroy the soil and other living species like an insect*"(KIMS).

Table 8: Strengths, weaknesses, opportunities, and threats of using mobile apps (SWOT)

Internal	
Strengths	**Weaknesses**
• Connect farmers with agriculture stakeholders and donors • Saving time • Using quality inputs • Increasing production and prevents fraud and corruption • Good agriculture policy, ICT facilities, and trained personnel • Providing easy the report • For land registration using SNS, farmers use land registration number, which is register in the land authority. This helps to reduce fraud of farmers who may want to register the amount of land they don't have because when it is done, the one who does it is discovered. The system rejects their registration, and s/he cannot make any order of agricultural inputs. • Farmers who know-how have some reading knowledge and skills are used to help their fellow using mobile apps.	• Unfriendly to non-literate farmers • Limited Mobile network and internet connection • Limited to the production of some crops • Delaying inputs to those who do not know how to use them
External	
Opportunites	**Threats**
❖ The investments of the government and donors ❖ Subsidies from the government and donors ❖ Good collaboration between farmers and agriculture Stakeholders ❖ Soil conservation ❖ Program of education for all ❖ The government has signed and implements International agreements on the use of technology in agriculture.	❖ Illiteracy and low education ❖ Climate change ❖ Poor transport means ❖ Limited financial means for farmers ❖ Some farmers resistance

Source: Author, 2021

CHAPTER 5: DISCUSSION OF FINDINGS

5.0 Introduction

In this chapter, the researcher discussed the findings presented in chapter four, which facilitated drawing the appropriate conclusion that will help achieve the research purpose.

5.1 Ways in which farmers use mobile apps

The findings of this study revealed that farmers in the Kayonza district are aware that mobile apps are used in agriculture. They added that SNS apps started being used by farmers in 2016 while MOPA started being used in 2017. However, it was revealed that, although Esoko has not been yet introduced to farmers in Kayonza, it was interoduced 2012before SNS as indicated by the key informants from MINAGRI and RAB. This led the researcher to wonder why the government invested effort in making known the apps that farmers use to produce, but it failed to introduce to them the app that could help them to search the market for their production while this app was even in use before the introduction of other apps. It was also discovered that young people are not involved in farming activities because they consider it as work of poor people who are neglected, with low education and less civilisation.

About the mode of using apps, it was revealed that, to both SNS and MOPA, farmers are given codes which are dialed to enter in the apps, and after dialing the codes, they get electronic instructions on the phone screen that are followed to request agriculture inputs they want to order. In addition, there is an alternative way of using MOPA whereby users can choose to use either the code or email to enter it. As for the function of these mobile apps, it was found that simple farmers use SNS to connect them with stakeholders and donors in ordering the quantities of selected inputs such as seeds, fertilisers, and pesticides that they use in their farm gardens. On the other hand, MOPA is used by input suppliers who ordered and sell agro-inputs to small farmers, while Esoko is used to know the daily prices of agriculture products to various markets in the country. These findings concurred with the argument of Sourcetrace (2021 who stated that mobile apps are used in agriculture for various serviced, including the provision of market information, weather information, and input acquisition. It also confirmed what FAO reported in 2021 that mobile apps platforms are used in connecting farmers

On the knowledge and skills that farmers have in using mobile apps, the results of the study showed that some farmers, in cooperatives, are given basic knowledge on how apps are operated and are sent to train others. However, it was also revealed that these apps are difficult to be used by farmers who have not attended the school and have less or no knowledge of reading and writing, when they don't have immediate assistance. This was in line with the findings of the research conducted by FAO in 2019, which indicated that for digital technology in agriculture to reach intended results, farmers should have enough reading and writing skills and good digital literacy.

The researcher's point of view on the findings above, was that there is less campaign done to sensitise young people for helping them to understand the importance of agriculture in their families and in their country. This would to help them to have active participation in this economic activity sector to make it continuous in generationsand to have people who will be doing it in the future.Otherwise the future generation might face a severe problem of food, if young people continue with the currently indicated mentality. In addition, since some farmers are shown to be passive in the use of mobile apps brcause of

their inability to operate them, these technologies are not exploited to their full capacity while these may be fully used if these mobile apps are adapted to the level of every Farmer.

5.2 Food availability and accessibility situation among farmers from the time they started using mobile apps

The findings got from the data collected using various tools, indicated that from the time farmers started using mobile, food become more available and accessible both in households and in the market. Farmers affirmed that mobile apps such as SNS and MOPA facilitate them to obtain selected seeds and better fertilisers that lead to an increase in the harvests, compared to what was produced when farmers were using traditional methods before the introduction of these mobile apps. I have also indicated that apart from SNS and MOPA used to facilitate in increasing production, Esoko also is there to facilitates in indicating everyday prices of various products in different markets of the country where farmers can sell what they produce and or buy what they want at favolable prices. These findings validated Ndubuisi (2021) argument, which stated that digital technology opens massive unexploited abilities for farmers, investors, and businesspersons to increase the efficacy of food production and utilisation in Africa.

The above findings also supported the argument of ThoughtForFood (2021), which stated that the introduction of digital technology came as a solution to the inefficiency and ineffectiveness found in traditional agricultural production. Furthermore, the findings found that high production leads farmers to get surplus foodsfuffs taken to the market and reduces prices of agricultural food to the demand of people who have not produced enough and those who have low financial means to afford buying. The finding, therefore, Conclude with those from the study conducted in Niger by Aker in 2010, which revealed that mobile phones contribute to the reduction of price in Niger's agricultural product market between 10 and 16%. However, there was inconsistency in these findings because there are where respondents indicated that inadequate transport facilities refrain them from selling for buy from the market they want.

Comparing the findings of the FIVIMIS, we find that farmers in Kayonza district are not either in food insecurity or food vulnerability because the results that came out from all instruments used, indicated that farmers have food available in their homes. They also have food surpluses that are take to the market. However, these findings did not show the sustainability of this food availability and accessibility among farmers.

5.3 Changes occurring in food availability and accessibility among KOTWIDIKA Murama farmers since the time they started using agricultural mobile apps

The findings, which came out from data collected using various tools, indicated that mobile apps bring a remarkable increase in food availability and accessibility among farmers who have adopted using mobile apps. This increase was attributed to the quality of agro-inputs such as selected seeds, fertilisers, and pesticides ordered and received through mobile apps and are used in agriculture. In addition, it was found that more surpluses are got from the production and are taken to the market for farmers to earn money which they use to buy what is not produced. These findings approved the argument of Rachel et al.(2021), who stated that digital technologies in agriculture improve the quantity and the quality of agricultural output while using minimum inputs. The findings also confirmed those of Aker in 2010, which indicated that using mobile apps in agriculture reduces prices of agriculture commodity in the Niger market. However, the study also revealed that farmers do not have good roads and favourable means of transport

to take their harvest to the appropriate markets or buy what they want from the markets that favour them.

In addition, it was also revealed that, although they are notable changes in food availability and accessibility due to the use of agriculture mobile apps, these changes have been limited by some people who are still resisting to use the apps and and those who are unable to use them. These findings on the changes brought by mobile apps in production disapproved the results of the investigation conducted by Fafchamps and Minter (2011), who led the study to assess the effects of mobile phone-based price information services on agricultural prices and found that the use of mobile did not have any effects

5.4 strengths and weaknesses found in using mobile apps in agriculture for food availability and accessibility

5.4 .1 Strengths of using mobile apps in agriculture for food availability and accessibility

Below are the strengths that were found by the study in to the use of mobile apps in agriculture:

- ✓ The use of mobile apps Connects farmers with agriculture stakeholders and donors easily and fast.
- ✓ The use of mobile apps saves farmers' time because they order and buy agro-input online using their phones.
- ✓ Mobile apps help the farmer to get and use quality ago-inputs which lead them to get more production. Mobile apps use used with good agriculture policies of supporting farmers through training and subsidization of agro-inputs which encourages farmers to practice modern agriculture.
- ✓ Provide easy and fast reports about land cultivated, crops, farmers, fertilisers seeds used. Help to keep the data of agriculture of every season in good conditions
- ✓ It was also found that there is a good agriculture policy of using apps to prevent frauds in input distribution and support farmers. With this policy, farmers have to register their land using the land registration number saved in the Land Authority. With this registration system then, farmers who want to register more land than they own are rejected.

These findings on the strengths of mobile apps approved what was discussed in the literature of 9 Series Handcrafted technology Solution (2021). This argued that using mobile apps brings precision in information sharing and quality operations. The researcher's comment on the strengths revealed was that these mobile apps are beneficial to move farmers from the image given to agriculture conceved as neglected job for poor people to agriculture which is business-oriented.

5.4.2 Weaknesses of using mobile apps in agriculture for food availability and accessibility

The weaknesses which were found from the use of mobile apps are that:

- ✓ Mobile apps are unfriendly users to people who have never been to school because these apps require the knowledge and skills of reading and writing. This was overlooked by people who introduced mobile apps to farmers in rural areas like those in Kayonza, whose majority did not attend school.
- ✓ Mobile apps also were found to have the weakness of depending on the mobile network and /or internet connection whereby these apps cannot be operated. The use of mobile apps that rely on the network, therefore, was demonstrated as a big barrier to the farmer who has chosen to produce the monoculture that depends on the apps.

- ✓ It was also revealed that mobile apps were limited to production of some selected crops and some others are ignored. This was taken by respondents as the problem that may lead people to an unbalanced diet and malnutrition in the future.

  It was also found that using mobile apps delays getting input and planting activities to those farmers who cannot use them on their own and need assistance from others who sometimes are not available to assist them when they want service.

  These weaknesses of mobile apps are connected to what was highlighted by Veronica and Francisco (2021). The major disadvantage of mobile apps is that they are not adapted to farmers' education and training. At the same time, those who are involved in this activity are people who have not studied and have insufficient financial means. Comparing the strengths and weaknesses of mobile apps, the researcher commented that they are favouring farmers know how to use them while those with insufficient knowledge and skills are disfavoured the same way it was highlighted by some respondents in SSI.

5.5 Opportunities and threats of using mobile apps

5. 5.1 Opportunities of using mobile apps in agriculture

The findings of the study revealed that using mobile apps in agriculture is connected with the opportunity below:

- ✓ There are investments put in place by the government and other stakeholders to boost the activities of farmers who use mobile apps.
- ✓ There are subsidies given to farmers by the government and other stakeholders in agriculture.
- ✓ Mobile apps promote good collaboration between farmers and stakeholders.
- ✓ Mobile apps help in soil conservation and environmental protection
- ✓ There is a program of education for all that equips young people with knowledge and skills which will improve the use of mobile apps in the future.
- ✓ They are international agreements that are signed by the government in favour of farmers**.**

  These opportunities revealed by the research confirmed those ones highlighted by Matheus (2026), who indicated that mobile apps help farmers to gain power and relevance that come from connection and collaboration that farmers have with others through these apps. The findings also approved the statement of Constantina et al. (2016), who argued that mobile apps give better access to information, better connection with the market and distribution network. Farmers have certified, through their responsiveness, to have some of these opportunities such as accessible communication and connection with donors. This therefore may be a positive side of these apps for farmers to make agriculuture more productive and increase their production for more food and income, both at the individual level and in their cooperatives.

5.5.2 Threats of using mobile apps

The threats that have been identified with the use of mobile apps by the study in agriculture are:

- ✓ Illiteracy and a low level of farmers' education make it difficult for some farmers to operate these apps.
- ✓ Climate change with too much sun or heavy rains that destroy crops and neutralise the contribution of mobile apps in increasing the yield.
- ✓ Poor transport means that delay ordered inputs to reach farmers and or becomea barrier for them sell their surplus production in good markets or to buy from the market which favour them.
- ✓ Some farmers have limited financial means to buy mobile phones and cannot access apps.
- ✓ They are farmers who resist using mobile apps.

Some of these findings above on the threats of using mobile apps concurred with some arguments found in the Agro-Intelligence of 2015. This stated that using mobile apps in agriculture faces the threat of insufficient access to infrastructure and few opportunities to study about bet agriculture practices. Mobile apps also face the problem of famers having little information about crop prices. Despite these threats identified by the findings, all participants in the study indicated that mobile apps are fruitful and are productive.

5.6 My reflection on the role I played in the study as a researcher

5.6.1 Research process and methodology

This research was conducted during the difficult time of Covid-19, whereby people worldwide have difficulties to move for visiting others, to have meetings, and to go for other field activities. I therefore started this research with fear that it could not finish at the right time since I could not move to Rwanda for data collection. It was also difficult to send a research assistant because many parts of the country were in lockdown. Nevertheless, increasing people's vaccination has eased the internal movement and resumed many activities, including farming. The resumption of farming activities facilitated me to send the research assistant who met respondents to collect data on my behalf.

The research focussed on describing the contribution of digital agriculture technology on food availability and accessibility in Kayonza District. I chose to conduct my study in this district because I was confident that farmers use the mobile apps and I believed that people could give me the needed information. However, I had some doubts about getting some record information. Usually, farmers do not record what they invest in farming activities as well as the outcomes the get. In addition, Rwandans are classified into social-economic classification (Ibyiciro by'ubudehe in Kinyarwanda), and the government does this based on the income of people in the country for helping citizens in development. I was therefore afraid that this could cause farmers not to be willing to share the information with the fear of being put in the wrong social category, which can hinder their opportunities of support that the government provides to vulnerable people. Nevertheless, I ended by gaining the trust of farmers and managed to get enough information from them. Some records from the district's departments of agriculture were helpful for the study's conclusion.

5.6.2 The quality of Research findings

For triangulation purposes, data collection was done using interviews with farmers, focus group discussions, interviews with key informants, document analysis, and food consumption scores. The work was not easy for me to coordinate the activities since all of them were done online. Sometimes the communication was difficult because of less network, but finally, the work went well. After collecting data, I used my previous qualitative data analysis skills, the skills I got from the research design implementation done in this course, to analyse them. I, therefore, analysed data qualitatively. The research findings from all these methods were related and consistent and led my conclusion to be reliabile and valide for the research.

The whole process of collecting data strengthened my teamwork and interpersonal skills. It also created in me more understanding about the role of teamwork and collaboration that make the work easier when people join their efforts to handle different tasks in same work.

I realised that the research is not forthright work that can be done in a relaxed way. Instead, it is a process that requires much attention to details and takes time to achieve its objective. In addition, the researcher must make sure that s/he is in the field to explain the study for good understanding of people who participate in it. I also realised that in case research assistants are used, the researcher needs to have a close follow-up to ensure that the correct data are collected.

The research unveiled the situation of food availability and accessibility among farmers who are using mobile apps in Kayonza and exposed its strengths, weaknesses, opportunities, and threats. The surprise found in these findings were that Esoko app, which reached the country for the first time in 2012, has not yet been introduced till today, while SNS, which came after if five years later in 2016, is already familiar to them. Another surprise was that when I started this research, I was expecting to find that mobile apps do not contribute anything to food availability and accessibility, but in the end, I found that farmers who use them, even those who are said to have difficulties in operating them and require assistance to use them, affirmed to be experiencing the excellent contribution in the yield and food increase. Lastly, I was amazed by how farmers are ready to help each other in using technology in agriculture and how they use it to fight fraud in their activities to share agro-input transparently.

The findings of this study have been communicated to Kayonza District and Rwanda Agriculture and Animal Resources Development Board. Therefore, I am convinced that if the recommendations given are respected, they will improve the use of mobile apps as well as food availability and accessibility.

The current study improved my communication skills, interpersonal skills, coordination and leadership skills, critical thinking, and time management. I also understood data analysis skills, which might help me in my career and other research that I may undertake in the future.

CHAPTER 6: CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

This research was conducted to describe the contribution of digital agriculture technology to food availability and accessibility in the Kayonza District of Rwanda. The study used the case study of KOTWIDIKA Murama Cooperative to look into the strengths, weaknesses, opportunities and threats of these mobile apps. Below is the conclusion the researcher drew from the findings:

The research found that in Kayonza district, two mobile apps are used: SNS, which is used by small farmers, and MOPA, which is used by some farmers who at the same time are are farmers and agro-input suppliers to their fellow farmers. The two apps are used to order seeds, fertilisers and pestcides of quality that are used to enable farmers produce quality yields. To used mobile apps, farmers are given the mobile code which is dialled to follow the electronic instructions that allow them to access the app settings. In addition, agro-dealers are also given the option of using emails as an alternative way to entering into the app system in case the code have problems like the network. Nevertheless, it was found that farmers in Kayonza have not yet known about Esoko app because it is used only by MINAGRI and RAB to control prices in the markets but has not yet been introduced to farmers.

Secondly, there was an investigation on the current status of food availability and food accessibility among farmers. The findings got from the interview conducted with farmers and key informants, and FGDs on this point were that farmers have enough food available and accessible for household consumption and the excess taken to the markets. This was also tested using a food consumption score that found that the majority of households to which FCS have been used, was having a consumption score which is in acceptable category. There were also some photo-elicitation taken from the stores of farmers which indicated that famers store food to be used the time they are waiting for the new harvests.

Thirdly, the study sought to find out how food availability and accessibility changed among farmers since the introduction of mobile apps in their farming activities. The information collected from respondents using different tools revealed that there is much increase that occurred in agriculture foodstuffs both in the households consumption needs and in the market because of using digital technology in form of mobile apps. This was supported by various photos elicitation taken in the market of Kabarondo, and confirmed by the production statistics collected from the Kayonza district's agriculture production records of various years that showed that agricultural food production has been changing in increase and the increase became more remarkable in the years when farmers started using mobile apps.

About the strengths, weaknesses, opportunities, and threats of using mobile apps in agriculture for food availability and accessibility, the study found that mobile apps have the strengths of helping farmers to avoid fraud and corruption; they provide easy reports about the land cultivated, fertilisers and seeds requested and used and crops to be produced. There were strengths of having a government that forms the personnel which is willing to help farmers on how to use the apps through training. Mobile apps were found with the strength of connecting farmers and agriculture stakeholders easily and fast. However, mobile apps demonstrated some weaknesses such as not being user-friendly to people who have never

been in school and do not know reading and writing. Mobile apps rely on mobile networks and/or internet connections which cannot be afforded by all farmers, among others. About the opportunity of mobile apps, there are investments put in place by the government, donnors and other stakeholders, the subsidies that are given to farmers by the government, and other stakeholders in agriculture. They provide good collaboration between farmers and stakeholders. Also, mobile apps help in soil conservation and environment protection whereby small land can be used to produce more, and the program of education for all that equips young people with knowledge and skills that will improve the use of mobile apps in the future and it is accompanied by the international agreements are signed by the government in favour of farmers. Nevertheless, there wee also some threats which were identified and they include the illiteracy and or low level of farmers' education; the climate change with too much sun or heavy rains that destroy crops and neutralise the contribution of mobile apps in increasing the yield; poor transport means, limited financial means of farmers to buy mobile phones and get apps as well as farmers who resist using mobile apps.

6.2 Recommendations

The objective of this study was to describe the contribution of digital agricultural technology to address food unavailability and inaccessibility in Kayonza District of Rwanda using the case study of KOTWIDIKA Murama Cooperative. It considered the period of 6 years from 2016, when agricultural digital technology was introduced, up to 2021. The study was conducted to bring out the strengths, weaknesses, opportunities, and threats of using digital technology in agriculutre and to give recommendations that will help Kayonza district in improving the use of agricultural mobile apps by farmers for more food availability and accessibility among the residents of this district.

Recommendation to Kayonze district

The researcher recommended to Kayonza district leaders to invest many efforts in the literacy of people. There should be a special program, like evening studies, for teaching grown-up people who have not attended school and have no other chance to go for formal education.

Recommendation to policymakers

One of the findings of this study was that available apps are used on few selected crops on which farmers are supported by the government and other stakeholders in agriculture. This causes farmers to abandon the production of other essential crop, including different kinds of vegetables and fruits such as eggplant, cabbage, onions, and carrots, among others. This may lead people to have only one type of food available for the future consumption and may suffer form malnutrition. My recommendation to policymakers therefore, is to do deep research and find how mobile apps can be used to produce more crops, others than those which have been selected and are supported to be produced today, to help in the production of more variety.

I also recommend that,because farmers indicated the using mobile apps have been noticed to be increasing the yield, policymakers should ensure that farmers have appropriate stores for keeping well-produced agricultural foodstuffs and transport facilities that can help them to take their surplus to appropriate markets and avoid the food wastage which might occur these two facilities are inappropriate.

Given that less mobile connectivity and internet networks were found to be the barrier to the use of mobile apps, I recommend that there should be a deep study on how quality collaboration may be done between policymakers, network providers and farmers to provide efficient mobile networks and internet connections which are accessible to all farmers who want to use this available technology without having their activities disturbed.

Policymakers also should study how the Esoko app may be decentralised to farmers so that, they too can use it to search for better markets which favour them to sell their yeild's surplus at encouraging prices or buy what they don't produce at prices that they feel is fair in relation to their financial means.

Recommendation to farmers

It was revealed that some farmers resist using agriculture mobile apps and deny giving their lands to cooperatives for efficient exploitation. This leads some lands in Kayonza to be underexploited and continues to affect the level of food availability and accessibility when comparing what is produced and the number of residents who are consumers in this district. My recommendation on this point is that farmers should be willing to be flexible enough to drop their traditional farming method and adopt technology that facilitates them to practise modern agriculture which contributes to a high increase of food availability and accessibility in their homes and their region of Kayonza in general .

6.3 Area for further research

This study focused on describing the contribution of digital technology, especially mobile apps, on only two dimensions of food security, namely availability and accessibility. The general findings of the study were that the used agriculture mobile apps contribute to the increase in food availability and accessibility. A further study, therefore, should be conducted to evaluate who the use of this digital technology affects food utilisation and food stability where there are used.

REFERENCES

Ames, H., Glenton, C. & Lewin, S., 2019. Purposive sampling in a qualitative evidence synthesis: a worked example from a synthesis on parental perceptions of vaccination communication. *BMC Medical Research Methodology ,* pp. 1-9.

Naderifar, M., Goli, H. & Ghaljaie, F., 2017. Snowball Sampling: A Purposeful Method of Sampling in Qualitative. *Strides Dev Med Educ ,* 14(3), pp. 1-6.

9 Series Handcrafted Technology Solution, 2021. *Revolutionising the Agriculture Industry whith Mobile APPlications.* [Online] Available at: https://www.9spl.com/blog/revolutionnizing-agriculture-industry-mobile-applications[Accessed 06 September 2021].

Agro-Intelligence , 2015. *Mobile Apps and the African Farmer: Potential, Challenges, and Limitations.* [Online] Available at: https://gro-intelligence.com[Accessed 06 September 2021].

Aker, J., 2010. *Infromation from market near and far: The impact of mobile phones on agricultural martets in Niger..* s.l.:Amercian Economic Journal: Applied Econiomics 46-59.

Barichello, R., 2002. *Trade and Food Security: Conceptualizing the Linkages Expert Consultation.* Rome: American University in Cairo.

Bhandari, P., 2020. *An introduction to qualitative research.* [Online] Available at: https://www.scribbr.com/methodology/qualitative-research/[Accessed 7 6 2021].

Bhandari, P., 2021. *Scribbr.* [Online] Available at: https://www.Scribbr.com[Accessed 22 July 2021].

bkTECH, 2021. *Smart Nkunganire System.* [Online]Available at: https://www.smartnkunganire.rw

center, A. i. f. s. r., 2014. *Food security and why it matters.* [Online]Available at: https://aifsc.aciar.gov.au/food-security-and-why-it-matters.html[Accessed 15 05 2021].

Collins, C., 2021. *Collins.* [Online] Available at: https://www.collinsdictionary.com/[Accessed 7 6 2021].

Constantina, C., Maria, N. & Sotiris, K., 2016. Studying Mobile apps for Agriculture. *IOSR Journal of Mobile Computinf &APplication (IOSR-JMCA) ,* 3(6), p. 2.

FAO., 2018. *Food and Agriculture Organization of the United Nations.* [Online]Available at: https://www.fao.org

FAO, 2013. *The State of Food and Agriculture: Food syatem for better nutirtion.* s.l.:FAO, Accessed on June 05,2021, from from http://www.fao.org/3/i3301e/i3301e.pdf .

FAO, 2020. *Food Insecurity and Vulnerability Information and Mapping System.* Rome : Editorial Group:FAO Information Division.

FAO, 2020. *The State of Food Security and Nutrition in the World: Transforming food Systems for affordable Hearthy Diets.* s.l.:AFO, Accessed on June 08,2021, from http://www.fao.org/3/ca9692en/CA9692EN.pdf.

FAO, 2021. *e-agriculture.* [Online] Available at: www.fao.or/e-agriculture/new/news-digital-agriculture.com[Accessed 26 07 2021].

Finder, W., 2021. *What is "esoko".* [Online] Available at: https://findwords.info/term/esoko

Governement of Rwanda , 2010. *Ministerial Order NO 14/11.30 of 21/2/2010 Determining the Model of Land Consolidation. Accessed on July 01,2021 from https://urbanlex.unhabitat.org/.* s.l.:GoR.

Gutierrez, D. e. a., 2020. *Digital Afgriculture Profile in Rwanda.* Accesseed from www.fao.org/3/cb2502en/CB2507EN.pdf: FAO.

Helen , N. & Roberta , H., 2019. Triangulation in research with exampls. *BMJ Journal Accessed on August 31, 2021 from https://ebn.bmj.com/content/22/3/67.*

Hopemagazine., 2021. *SNS-Mobile Order Processing Applciation set to ease argo-dealer' transaction.* [Online] Available at: www.hope.mag.com

InTeGrate., 2018. *Interdisciplinary Teaching about Earth for a SUstainable Future.* [Online] Available at: https://serc.carleton.edu

International Labor Organization , 2018. Rwanda Toward Private Cooperative Enterprises and Business Entities for Socio-Economic Transformation. *CoopAFRICA,* 12(22), pp. 1-4.

Kalyan , M. & Neela , M. P., 2020. Mobile apps in agriculture and allied sector : An extended arm for farmers. *HIND AGRICULTURAL RESEARCH AND TRAINING INSTITUTE,* Volume 14, p. 2.

Kayonza., 2018. *SECOND DISTRICT HEALTH STRATEGIC PLAN 2018/2019-2023/2024,* Accessed from http://www.kayonza.gov.rw/fileadmin/templates/document/DHSP_Final_2024_KAYONZA.pdf: Kayonza Distrct.

KayonzaDistrict., 2019. *Environmental and Social Management Plan FOR CONSTRUCTION OF 100 CLASSROOMS AND 140 LATRINES UNDER QUALITY:Final Report ,* s.l.: Kayonza DIstrict.

KayonzaDistrict, 2018. *Kayonza Distrct Deveolpmen Plan 2013-2018: Final Draft.* Final Version ed. s.l.:Kayonza DIstrict.

Laws, S., Harpper, C., Jones, N. & Marcus , R., 2013. Research for Development.2 edition . In: London: SAGA.

Lokuruka, M., 2020. *Food and Nutrition security in East Africa (Rwanda, Burundi and South Sudan): Status, Challenges and Prospects.* London: DIO:105772/intechopen.95037.

Marion, N., 2011. *Towards a food insecurity multidimensional index (FIMI).* Roma : Tre Roma Univerita Deglistudi .

Marivoet , W., Becquey , E. & Campenhout, V. B., 2019. How well does the Food Consumption Score capture diet quantity,quality and adequacy across regions in the Democratic Republic of the Congo (DRC)?. *Food Security ,* Volume 11(5), p. 1029–1049.

Martyn, S., 2021. The Case Study Design have e volved over the past few years as useful tool for investigating trends and specific situations in many scientific disciplines. *Explorable.com.*

Matheus , C., 2020. *Meet IZagro: A Brazilian Startup Unleashing the Power of Digital COmmunities to improve Farmer Livelihoods.* [Online] Available at: https://throughforfood.org[Accessed 06 September 2021].

Ministry of Trade and Industry , 2018. *Private Cooperative Enterprises and Business ,* Kigali : Ministry of Trade and Industry .

Mugabo, J., 2018. *Kayonza District Development Plan.* Kayonza: Kayonza District.

MUKARUGWIZA , E., 2010. *The hope for rural transformation : A rejuvenating cooperative movement in Rwanda.* Dar es Salaam: Internatioanl Labor Oranization.

Ndubuisi, E., 2021. How Digital Technology is Changing Farming in Africa. *Harvard Business Review.*

Niyoyita, R., 2011. *ITC in Development: The search for Hidden eSoko among Rural Amall Scale Famers of Rwanda.* Netherlands: Internatioanl Institute of Scocial Studies.

OXFAM, 2007. *Market Analysis Tools in Rapid-Onset Emergencies Phase One Report,* s.l.: s.n.

Pia, N., 2018. The role of land consolidation in improving crop yields among famer households in Rwanda. *Journal of Development Studies,* p. 55.

Rachel, A. B., Abed, A. K. Y. & Rami, Z., 2021. *Digitilization for Sustainable Agri-Food System:Potential Status, and RIsks for the MENA Region.* Beirut: AMerican Univrsity of Beirut.

Rwanda Ministry of Local Government , 2021. *Republic of Rwanda: Governement.* [Online] Available at: https://www.gov.rw/government/administrative-structure[Accessed 31 August 2021].

Saunders, B. et al., 2017. Saturation in quialitative research:exploring its conceptualisation and operationilisation. *Springer,* Volume 52(4), pp. 1893-1907.

Sourcetrace , 2021. *HOW MOBILE APPS ARE HELPING AGRICULTURE IN ACHIEVING SUSTAINABLE DEVELOPMENT?.* [Online] Available at: https://www.sourcetrace.com/blog/mobile-apps-for-agriculture/ [Accessed 25 July 2021].

TecHouseLtd, B., 2021. *About Rural Solutions Portal.* [Online] Available at: ttps://ruralsolutionsportal.org

ThoughtForFood, 2021. *The world's largest and most diverse agri-food-tech innovation challenge: How do we feed 10bn people on a hotter planet?.* [Online]Available at: thhps://wwthoughtforfood.org

UN Global Compact , 2017. *Project Breackthrough.* [Online]Available at: htts://breakthrough.unglobalcompact.org[Accessed 06 Semtember 2021].

UN, 2016. *SUstainable AGriculture Press Brief,* Accessed from https://www.cbd.int/idb/image/2016/promotional-material/idb-2016-press-brief-agro.pdf: UN.

Veronica, S.-R. & Francisco, R.-M., 2021. From Samart Farming toward Agriculture 5.0: A Review of Crop Data Management. *Agronomy ,* Volume 46022, p. 2.

WFP, 2008. *Measures of Food COnsumption: Harmonising Methodologies ,* Rome: WFP-FAO.

WFP, 2009. *Emergency Food Security Assessment Handbook.* s.l.:WFP.

World Bank, 2019. *Future of Foof- harnessing Digital Technologies to improve Food System Outcomes ,* s.l.: World Bank .

Worldbank, 2013. *Agricultural Development in Rwanda.* [Online]
Available at: https://www.worldbank.org/en/results/2013/01/23/agricultural-development-in-rwanda [Accessed 11 5 2021].

Worldometer, 2021. *Rwanda Population (Live).* [Online]Available at: https://www.worldometers.info [Accessed 15 May 2021].

Xanthe , G., Kerry, . I., Ashley , K. & Michael , H., 2017. Visual Methodologies in Qualitative Research:. *International Journal of Qualitative Methods: Retrieved from https://journals.sagepub.com/doi/pdf/10.1177/1609406917748215 on June 07,2021,* 16(8), p. 2.

ANNEXES

ANNEX 1: Food Consumption Score (FCS) form

WFP's Food Consumption Score

9.1 Food consumption data collection module

The following table presents an EXAMPLE of the Food Consumption module, which should be adapted to each context.

The question should be phrased like the following[10]:

*I would like to ask you about all the different foods that your household members have eaten in the **last 7 days**. Could you please tell me **how many days** in the past week your household has eaten the following foods?*
(for each food, ask what the primary source of each food item eaten that week was, as well as the second main source of food, if any)

Food item	DAYS eaten in past week (0–7 days)	Sources of food (see codes below)	
		primary	secondary
#.1 – Maize			
#.2 – Rice			
#.3 – Bread/wheat			
#.4 – Tubers			
#.5 – Groundnuts & Pulses			
#.6 – Fish (eaten as a main food)			
#.7 – Fish powder (used for flavor only)			
#.8 – Red meat (sheep/goat/beef)			
#.9 – White meat (poultry)			
#.10 – Vegetable oil, fats			
#.11 – Eggs			
#.12 – Milk and dairy products (main food)			
#.13 – Milk in tea in small amounts			
#.14 – Vegetables (including leaves)			
#.15 – Fruits			
#.16 – Sweets, sugar			

Food source codes:

Purchase =1	Own production =2	Traded goods/services, barter =3
Borrowed = 4	Received as gift= 5	Food aid =6
Other (specify) =7		

The Food Consumption Score (FCS)

	Food Items (examples)	Food Groups (definitive)	Weight (definitive) a	Sum of consumption frequencies - see data sheet(s) (max value is 7) b	Food group scores (a times b) c
1	Maize, maize porridge, rice, sorghum, millet pasta, bread and other cereals Cassava, potatoes, sweet potatoes, other tubers, plantains	Main staples	2		
2	Beans, peas, ground nuts and cashew nuts	Pulses	3		
3	Vegetables, leaves	Vegetables	1		
4	Fruits	Fruit	1		
5	Beef, goat, poultry, pork, eggs and fish	Meat & Fish	4		
6	Milk, yoghurt, other diary	Milk	4		
7	Sugar, sugar products, honey	Sugar	0.5		
8	Oils, fats and butter	Oil	0.5		
9	Spices, tea, coffee, salt, fish powder, small amounts of milk for tea.	Condiments	0		
				The food Consumption Score (sum of column c)	**0**

The Food Consumption Group

Typical threshold values

Food Consumption Score	Profile
0-21	Poor
21.5-35	Borderline
> 35	Acceptable

As discussed in the Technical Guidance Sheet thresholds need to be tested and possibly modified based on the context and dietary patterns of the population in question.

ANNEX 2: Semi-structured interview questions for farmers

I am Claire Ruterana, a master's student in management of development with a specialisation in food nutrition and security at Van Hall Larenstein University of applied science in the Netherlands. I am conducting a research thesis to complete my studies on the contribution of digital technologies used in agriculture on food availability and accessibility in the Kayonza district of Rwanda: a case study of the KOTWIDIKA Murama cooperative. This will help the Kayonza District because much effort is put into the use of digital technology, especially mobile applications, in agriculture to improve solve the problem of food security among the population. Yet, it has been demonstrated that no research has been carried out to examine whether these mobile applications as giving the intended results. This study, therefore, will provide knowledge about the challenges faced by digital technology users in agriculture to find ways of assisting them in overcoming those challenges. I would like to request your support in answering the questions below concerning this research topic to help me formulate the recommendation to the Kayonza district. Your participation is completely voluntary, and all of the information you provide will be kept private.

I promise that the discussion will not exceed the time of one hour and that you will be able to start at any time you are available and can leave at any time you want.

IDENTIFICATION OF RESPONDENT

Code of the respondents**……**

1. Sector …….. Cell…….. Village …….

2. Age of respondent: a) 19-25 b) 26-35 ☐ c) 36-45 ☐

d) Between 46-55 ☐ e) 56 and above ☐

3. Sex: M ☐ F ☐

4. Education level of respondent: a) Graduate from university ☐ b) Complete high school ☐

c) Not completed high school ☐ d) complete primary school ☐

e) Not complete primary ☐ f) No education ☐

5. Land size: a) 1- 500m2 ☐ b) 501-2500m2 ☐ c) 2501-5000m2 ☐

d) 5001 m2 and above ☐ specify your land ☐

Section A: Information on the use of Mobile apps

1. Do you have any idea about mobile apps used in agriculture? Yes ☐ No ☐
2. Do you use any mobile apps? Yes ☐ No ☐
3. What type of mobile apps do you use? SNS ☐ Mopa ☐ Esoko ☐

☐

Others Please specify……

4. When did you start using the mobile apps used in your agriculture production today?
5. How long have you been using these agricultural mobile apps for food provision and Accessibility?
6. For what types of crops do you use SNS, MOPA and Esoko?

Beans ☐ Maize ☐ vegetable ☐ other crops ☐

If others, please specify ……

Section B: Knowledge of mobile apps users

1. What knowledge and skills do you have on using the mobile apps u do use?
2. How do you acquire this knowledge and skill of using mobile apps in your agriculture activities?
3. Would you describe different ways in which you use mobile apps in your agricultural activities to increase food availability and accessibility in this area?

Search market of the production ☐

Apply seeds ☐

Apply fertilisers ☐

Apply seeds and fertilisers ☐

Others which ☐

4. What knowledge and skills do you have on using available mobile apps that you use in your agricultural activities?
5. Is the knowledge and skills you have enough for you to reach expected results from the use of available agricultural mob apps for increasing food availability and accessibility in this area? ……

……

Section C: Impact of using mobile apps

1. With using SNS, Do you observe (realise) any change in local agricultural food production from when you started using the mobile apps? If yes / no or still the same, you can provide me with the past situation and the current one

Increased why? ☐ ☐

Decreased why? ☐ ☐

Still the same ☐

2. With using ESOKO, Do you observe (realise) any change from when you started using the mobile apps? If yes / no or still the same, you can provide me with the past situation and current one

Increased why ☐

Decreased why? ☐

Still the same ☐

3. With using MOPA, Do you observe (realise) any change from when you started using the mobile apps? If yes / no or still the same, you can provide me with the past situation and current one

Increased why? ☐

Decreased why? ☐

Still the same ☐

4. What role did the use of mobile apps play in this food production change?

……

……

5. Would you describe how household consumption has changed since you started using mobile apps in agricultural food production?
6. What contribution did the use of mobile apps bring to these changes?

……

……

7. What are the strengths of using each used mobile app in agriculture for food availability and accessibility?
8. What are the weaknesses of using each used mobile app in agriculture for food availability and accessibility?

SECTION E: ICOME, PRICE & MARKET

1. Are physical markets available near here a) Yes ☐ No ☐
2. . How long do people take to get to the market?
3. A) what agricultural foodstuffs are most available at your physical market?

b) How consistent are these foodstuffs available in this market?

4. What transport means do you use for getting to the market?

5. Describe the quantity of food production surplus taken by farmers to the market from local agriculture since they started using mobile apps.

6. What changes have been incurred in the quantities of local agricultural food production taken to the market by farmers since mobile apps started? What contribution do you attribute to these changes in agricultural food compared to when you were not using them?

7. How did the changes brought by mobile apps agricultural food change the price of food in the market?

8. Is the price affordable for the residents of this area to access local agricultural food at the market?

Section E: Perception of the use of mobile apps

1. Do you find the use of mobile apps be helpful in your agriculture production? Yes ☐ No ☐

2. What is your experience in using mobile apps in your farming activities?
……
……

3. What did you like about the use of the apps?

……
……

4. How are these mobile apps helping you to access food in your household? …..

……
……

5. From the experience of using mobile apps, are you willing to continue using the mobile apps you are using?

Yes, ☐ Why? ☐

No, ☐ why? ☐

6. What challenges do you face in using these mobile apps?
……
……

Thank you

ANNEX 3: Focus group discussion guide

I am Claire Ruterana, a master's student in management of development with a specialisation in food nutrition and security at Van Hall Larenstein University of applied science in the Netherlands. I am conducting a research thesis to complete my studies on the contribution of digital technologies used in agriculture on food availability and accessibility in the Kayonza district of Rwanda: a case study of the KOTWIDIKA Murama cooperative. This will help the Kayonza District because much effort is put into the use of digital technology, especially mobile applications, in agriculture to improve solve the problem of food security among the population. Yet, it has been demonstrated that no research has been carried out to examine whether these mobile applications as giving the intended results. This study, therefore, will provide knowledge about the challenges faced by digital technology users in agriculture to find ways of assisting them in overcoming those challenges. I would like to request your support in answering the questions below concerning this research topic to help me formulate the recommendation to the Kayonza district. Your participation is completely voluntary, and all of the information you provide will be kept private. I promise that the discussion will not exceed the time of one hour and that you will be able to start at any time you are available and can leave at any time you want.

1. Describe all the agriculture mobile apps used, the crops on which these mobile apps are used, and how they are used to increase food availability and food accessibility in your KOTWIDIKA Cooperative.
2. . Describe the knowledge and skill farmers in KOTWIDIKA Murama Cooperative on the use of the available mobile apps? How do they get this knowledge and skills? Are those knowledge and skills enough?

3. Discuss the availability of telecommunication (facilities/ networks) for the use of mobile apps

4. What changes do you realise in agricultural food production from the use of mobile apps?

5. Define these changes in agricultural food products availability and accessibility before and after the use the mobile apps in agriculture.

6 . What strengths and weaknesses do you find in these mobile apps used in agriculture for food availability and accessibility in Kayonza?

7. Describe the challenges KOTWIDIKA Murama Cooperative farmers face in using mobile agricultural apps for food availability and food accessibility?

ANNEX 4:The key informant's interview guide

I am Claire Ruterana, a master's student in management of development with a specialisation in food nutrition and security at Van Hall Larenstein University of applied science in the Netherlands. I am conducting a research thesis to complete my studies on the contribution of digital technologies used in agriculture on food availability and accessibility in the Kayonza district of Rwanda: a case study of the KOTWIDIKA Murama cooperative. This will help the Kayonza District because much effort is put into the use of digital technology, especially mobile applications, in agriculture to improve solve the problem of food security among the population. Yet, it has been demonstrated that no research has been carried out to examine whether these mobile applications as giving the intended results. This study, therefore, will provide knowledge about the challenges faced by digital technology users in agriculture to find ways of assisting them in overcoming those challenges. I would like to request your support in answering the questions below concerning this research topic to help me formulate the recommendation to the Kayonza district. Your participation is completely voluntary, and all of the information you provide will be kept private.

I promise that the discussion will not exceed the time of one hour and that you will be able to start at any time you are available and can leave at any time you want.

1. Please explain why digital technology in terms of mobile apps is introduced in agriculture?
2. Do farmers in KOTWIDIKA Murama Cooperative have enough knowledge on the use of the available mobile apps? Discuss how the farmers get this knowledge and skills of using these apps? Are this knowledge and skill enough to give intended results?

4. To what crops are the agricultural mobile apps used? Why?

Maize, how and why?	
Beans how and why?	
Vegetable how and why?	
Others specify	

5. Describe the situation of food availability and food accessibility among kayonza residents before using digital technology in agriculture.

6. When have mobile apps started being used in Kayonza?

7. a) Is there any change brought by the use of mobile apps to the availability and accessibility of agricultural food in the Kayonza district?

b) Describe these changes brought by mobile apps in agricultural food compared to when they are not used

(i) In the household consumption

(ii) On the market

7. What are the strengths of using the available mobile apps in agriculture for improving food availability and accessibility in Kayonza?
8. What are the weaknesses of using those apps?

9 . Do you see the benefits of using these mobile apps? If yes, which? Is there any challenge you see in using the mobile apps? Explain?

10. Considering the objectives of my research there explained above, is there any other information I did not ask, and you would like to share with me?

Thank you

ANNEX 5:Checklist for photo elicitation

The following are ways in which pictures will be taken:

1. Screenshot of using the application of mobile apps from farmers for different purposes
2. Stocks of agricultural food produced locally

3. Farmers group in the field working with mobile apps
4. Food different segments of local food in Kayonza market

ANNEX 6:The comparison between the production of different years and seasons

Year	SEASON	Maize	BEANS

		Area cultivated(ha)	Yield (kg/ha)	Production (MT)	Area cultivated(ha)	Yield (kg/ha)	Production (MT)
2008	A	567	978	554	6999	545	3814
	B	193	600	115	9871	879	8676
2009	A	1490	1110	1653	12694	459	5826
	B	978	1255	1227	4661	725	3379
2010	A	2325	2000	4650	9078	850	7716
	B	1329	1287	1710	4302	725	3118
2011	A	2259	1730	3908	7984	583	4654
	B	1677	2149	3603	5217	873	4554
2012	A	2865	2150	6159	8195	683	5597
	B	2754	1864	5133	6120	370	2264
2013	A	3891	1668	6490	5329	398	2120
	B	1459	1587	2315	6436	375	2413
2014	A	2608	1526	3979	5358	361	1934
	B	1629	1145	1865	5219	296	1544
2015	A	6147	1243	7640	6452	301	1942
	B	2498	1178	2942	7196	375	2698
2016	A	4591	1239	5688	5651	294	1661
	B	1693	1215	2056	6794	317	2153
2017	A	7689	1220	9380	9430	435	4102
	B	4321	1367	5906	16139	478	7714
2018	A	8974	1457	13075	11639	493	5738
	B	4985	1747	8708	18964	567	10752
2019	A	12541	1811	22711	13674	630	8614
	B	5107	1809	9238	19431	632	12280
2020	A	9756	1918	18712	11678	665	7765
	B	4020	2254	9061	18632	730	13601
2021	A	12196	2711	33063	13871	748	10375
	B	5674	2894	16420	19832	775	15369

Source: Kayonza District's Agriculture production Records

ANNEX 7: An extract of esoko report from kayonza district

PROVINCE	District	MARKET	Dates	Beans/ MUTIKI	Beans/ KIRYUM UKWE	Beans/ SHYUS HYA	Beans/ MUSHIN GIRIRO	Beans/ IBINYA RWAND A	Beans/ KORUT A/ COLTA	Maize/M ais
PROVINCE EST	KAYONZA	Kabarondo	5/8/2021	680	700	670	680	630	900	300
PROVINCE EST	KAYONZA	Kabarondo	6/8/2021	650	670	630	640	620	900	300
PROVINCE EST	KAYONZA	Kabarondo	7/8/2021	600	630	600	600	600	800	300
PROVINCE EST	KAYONZA	Kabarondo	8/8/2021	450	450	400	450	400	750	320
PROVINCE EST	KAYONZA	Kabarondo	9/8/2021	450	450	450	450	430	650	350
PROVINCE EST	KAYONZA	Kabarondo	10/8/2021	480	500	460	460	450	650	340
PROVINCE EST	KAYONZA	Kabarondo	11/8/2021	500	500	480	480	460	650	360
PROVINCE EST	KAYONZA	Kabarondo	12/8/2021	500	500	420	450	415	650	360

ANNEX 8:The table indicating the increase in the number of farmers who use SNS, the quantities of seeds and fertilisers ordered using SNS with the increase on land at the district level between 2016 and 2021

Year	Season	Registration of farmers	Hectare registries for maize	Qty of Seeds request (kg)	Qty Dap request (kg)	Qty Urea request (kg)	Hectare registries for beans	Qty Seeds request for beans (kg)	Qty Request of dap (kg)
2016	B	1981	594.3	14857.5	59430	29715	40	1600	4000
2017	A	6899	1379.8	34495	137980	68990	89	3560	8900
	B	4973	1391.5	34787.5	139150	69575	154	6160	15400
2018	A	9679	2806.9	70172.5	280690	140345	219	8760	21900
	B	8567	2570.1	64252.5	257010	128505	311	12440	31100
2019	A	34915	11048.80	276220	110880	55440	784.73	31389.2	78473
	B	12763	3499.77	87494	349977	174988.5	494.25	19770	49425
2020	A	29950	14791.16	369779	1479116	739558	554,68	22187.2	55468
	B	23464	9947.01	248675.25	994701	497350.5	324,33	12973.2	32433
2021	A	40026	26051.74	651293.5	2605174	1302587	295.40	11816	29540
	B	27197	14439.05	360976.25	1443905	721952.5	281.04	11241.6	28104

Source: Kayonza District electronic records, 2021

ANNEX 9:The table indicating the increase in the number of farmers who use SNS, the quantities of seeds and fertilisers ordered using SNS with the increase on land at district level between 2016 and 2021

Year	Season	Registration of farmers	Hectare registries for maize production	Qty Seeds request (kg)	Qty Dap request (kg)	Qty Urea request(kg)	Hectare registries for beans	Qty Seeds request for beans (kg)	Qty Dap request (kg)
2016	B	62	43	1075	4300	2150	21	840	2100
2017	A	123	69.8	139.6	6980	279.2	39.8	1592	3980
	B	90	51	102	5100	204	43	1720	4300
2018	A	634	156.9	313.8	156.8	627.6	67.9	2716	6790
	B	212	94.4	188.8	9440	377.6	31.2	1248	3120
2019	A	2320	498.93	997.86	49893	1995.72	37.05	1482	3705
	B	519	137.59	275.18	13759	550.36	69.54	2781.6	6954
2020	A	2343	819.49	1638.98	81949	3277.96	43.06	1722.4	4306
	B	1453	458.54	917.08	45854	1834.16	9.35	374	935
2021	A	3263	1418	2836	141800	5672	7.52	300.8	752
	B	1714	647.36	1294.72	64736	2589.44	4.50	180	450

Source: Murama Sector electronic records