

Antecedents of technology adoption in agriculture in developing nations

Saul Maldonado

19410957

A research project submitted to the Gordon Institute of Business Science, University of Pretoria, in partial fulfilment of the requirements for the degree of Master of Business Administration.

29 March 2021

Abstract

Understanding the antecedents determining technology adoption in agriculture is essential to promote technology adoption to improve agricultural productivity in developing nations. The aims of this research were to understand the meaning of technology adoption for people involved in farming activities in developing nations, the antecedents determining technology adoption, their effect and how their interaction influences decision-making with regards to technology implementation in agriculture in developing nations.

This study was qualitative in nature and followed an exploratory approach. This allowed the researcher to gain and understand new insights about the antecedents determining technology adoption in agriculture in developing nations. A total of 12 synchronous online semi-structured interviews were conducted with farmers and agriculture technicians from developing nations where the reliance on the agriculture sector is high. These interviews were analysed using thematic content analysis approach which led to the development of 'The antecedents determining technology adoption in agriculture in developing nations' Framework.

This Framework refuted literature findings which highlighted the existence of four antecedents determining technology adoption in agriculture in these nations. Five predominant antecedents namely: awareness; financial assistance; applicability of technology; training and technical support; and demonstrations were identified in this study. This framework explains that the interaction of the identified antecedents is essential to foster technology adoption among farmers in developing nations and is important for stakeholders since it can provide a better understanding and guidance for the creation of integrated strategies to improve technology adoption in agriculture in developing nations.

Keywords

Technology adoption, technology implementation, agricultural productivity, economic growth, developing nations.

Declaration

I declare that this research project is my own work. It is submitted in partial fulfilment of the requirements for the degree of Master of Business Administration at the Gordon Institute of Business Science, University of Pretoria. It has not been submitted before for any degree or examination in any other University. I further declare that I have obtained the necessary authorisation and consent to carry out this research.

Saul Maldonado

29/03/2021

Contents

Abstract	ii
Keywords	iii
Declaration	iv
Contents	v
List of tables	viii
List of Figures	ix
Chapter 1: Introduction to the Research Problem	1
1.1 Introduction	1
1.2 The Research Problem.....	2
1.3 Significance of the Research.....	4
1.4 Scope of the Research	4
1.5 Purpose of the Research	4
1.6 Conclusion	5
Chapter 2: Literature Review	7
2.1 Introduction	7
2.2 Technology Acceptance Theories.....	8
2.2.1 Technology Acceptance Model (TAM).....	9
2.2.2 Unified Theory of Acceptance and Use of Technology (UTAUT).....	10
2.3 Factors determining technology adoption in agriculture in developing nations	11
2.3.1 Economic factors	12
2.3.2 Institutional Factors.....	14
2.3.3 Household factors.....	16
2.3.4 Technology characteristic factors.....	18
2.4 Technology applications in agriculture and its benefits	19
2.5 Conclusion	21
Chapter 3: Research Questions	23
3.1 Introduction	23
3.2 Research Questions	23
3.3 Conclusion	24
Chapter 4: Research Methodology	25
4.1 Introduction	25
4.2 Research methodology and design.....	25

4.3	Population	26
4.4	Sampling method and size	27
4.5	Unit of analysis.....	28
4.6	Data collection tool.....	28
4.7	Data collection.....	31
4.8	Data analysis.....	33
4.9	Quality controls	34
4.10	Research Methodology limitations	35
4.11	Conclusion	37
Chapter 5:	Results.....	38
5.1	Introduction	38
5.2	Description of the sample	38
5.3	Presentation of results	41
5.4	Results for Research Question 1	41
5.4.1	Participants' perception about technology adoption to improve agricultural productivity.....	42
5.4.2	Participants' perception about the benefits offered by technology implementation to agricultural practices	44
5.5	Results for Research Question 2	47
5.5.1	Circumstances which could influence technology adoption in agriculture in developing nations.....	48
5.5.2	Circumstances which could influence further technology adoption in agriculture in developing nations.....	50
5.6	Results for Research Question 3	53
5.6.1	Reasons of lack of experience with technology adoption in agriculture.....	54
5.6.2	Benefits provided by technology adoption in agriculture	57
5.6.3	Factors that influenced technology adoption	61
5.6.4	Challenges of current technology implementation.....	65
5.6.5	Overcoming technology adoption challenges	71
5.7	Results for Research Question 4	78
5.7.1	The interaction of the antecedents determining technology adoption in agriculture in developing nations.....	79
5.8	Conclusion	82
Chapter 6:	Discussion of Results.....	83
6.1	Introduction	83
6.2	Discussion of Results for Research Question 1	83

6.2.1	Participants' perception about technology adoption to improve agricultural productivity.....	83
6.2.2	Participants' perception about the benefits offered by technology implementation to agricultural practices	84
6.2.3	Conclusive findings from Research Question 1	86
6.3	Discussion of Results for Research Question 2	86
6.3.1	Circumstances which could influence technology adoption in agriculture in developing nations.....	87
6.3.2	Circumstances which could influence further technology adoption in agriculture in developing nations.....	89
6.3.3	Conclusive findings from Research Question 2.....	91
6.4	Discussion of Results for Research Question 3	93
6.4.1	Reasons of lack of experience with technology adoption in agriculture.....	94
6.4.2	Benefits provided by technology adoption in agriculture	96
6.4.3	Factors that influenced technology adoption	97
6.4.4	Challenges and actions taken to overcome them during technology adoption process	99
6.4.5	Conclusive findings from Research Question 3.....	101
6.5	Discussion of Results for Research Question 4	102
6.5.1	Conclusive findings from Research Question 4.....	102
6.6	Conclusion	103
Chapter 7:	Conclusion and recommendations.....	104
7.1	Introduction	104
7.2	Research Findings.....	104
7.2.1	Technology adoption meaning in agriculture in developing nations	105
7.2.2	The antecedents determining technology adoption in agriculture in developing nations.....	105
7.2.3	Interaction of the antecedents determining technology adoption in agriculture in developing nations.....	108
7.3	Implications and recommendations.....	110
7.4	Research limitations.....	111
7.5	Suggestions for future research	112
7.6	Conclusion	113
8.	Reference list.....	114
9.	Appendix list.....	124

List of tables

Table 1: Consistency Matrix	29
Table 2: Description of Interviewees	39
Table 3: Perception of technology adoption to improve agricultural productivity	42
Table 4: Perception of the benefits of technology implementation in agriculture....	44
Table 5: Type of experience with technology implementation in agriculture.....	47
Table 6: Reasons of lack of technology implementation in agriculture	54
Table 7: Benefits perceived with current technology implementation in agriculture	57
Table 8: Influencing factors of current technology implementation	62
Table 9: Categorisation of challenges faced with current technology implementation	65
Table 10: Actions taken to overcome challenges faced with current technology implementation.....	72
Table 11: Actions taken grouped by type of challenge faced by specialists in the field	74
Table 12: Actions taken grouped by type of challenges faced by farmers.....	76
Table 13: Circumstances determining technology adoption in agriculture in developing nations.....	78
Table 14: Comparison between theoretical and real antecedents within the context of this study determining technology adoption in agriculture in developing nations	92
Table 15: Effect of the antecedents on technology adoption in agriculture in developing nations.....	106

List of Figures

Figure 1: Hypothetical framework of the theoretical antecedents determining technology adoption in agriculture in developing nations	22
Figure 2: Hypothetical framework of the real antecedents within the context of this study determining technology adoption in agriculture in developing nations.....	93
Figure 3: Reasons of lack of experience with technology implementation and their relationship to the identified antecedents determining technology adoption in agriculture in developing nations.....	96
Figure 4. Influencing factors of current implementation and relationship to identified antecedents determining technology adoption in agriculture in developing nations97
Figure 5. Effect of the antecedents determining technology adoption in agriculture in developing nations on overcoming challenges faced through technology implementation.....	99
Figure 6: Interaction of the antecedents determining technology adoption in agriculture in developing nations.....	103
Figure 7: ‘The antecedents determining technology adoption in agriculture in developing nations’ Framework.....	109

Chapter 1: Introduction to the Research Problem

1.1 Introduction

Most economies in developing nations are mainly controlled by outputs from agriculture, fishing and other farming activities (Gui-Diby & Renard, 2015; Linh, Long, Chi, Tam, & Lebailly, 2019). Bekun (2015), supports this inference stating that the agrarian and rural nature in most developing nations has turned agriculture into one of the main contributors for their economies. This sector remains as the largest provider of inputs, food, employment opportunities and even foreign earnings from exports in developing nations (Okoro, 2011; Linh et al., 2019). Moreover, people in rural areas in developing nations rely on agriculture for their livelihoods (Fink, Jack, & Masiye, 2018). Therefore, a need to prioritise the development of the sector has arisen, since a relationship between agriculture and economic growth in these nations has been identified (Oluwatoyese & Applanaidu, 2014; Santangelo, 2018).

Throughout the years, the identified contribution of the agriculture sector to the economy of developing nations has been categorised into four perspective areas: provision of products, contribution of inputs, market participation and accrual from foreign exchange (Bekun, 2015). Henderson, Squires, Storeygard, and Weil (2018), stated that a big proportion of food in the modern world is supplied by domestic farming in developing nations, where a large fraction of labour force is required for these activities. Furthermore, the agriculture sector has been considered as an important determinant for the economy of developing nations during periods of crisis (FAO, 2009). Agriculture is considered as an essential activity which can lead to economic growth, poverty alleviation and prosperity in developing nations (Bekun, 2015; Chandra, McNamara, & Dargusch, 2018; Rönnbäck & Theodoridis, 2019). Several studies have evidenced high contributions of the sector to the economy of developing nations (Bekun, 2015; Henderson et al., 2018). In fact, least developing countries have benefited from agriculture activities with a contribution of over 25% of their Gross Domestic Product (Bekun, 2015).

However, the contribution of the sector to the economies of developing nations has declined due to several factors (Bekun, 2015). One of them is the limited capacity to exploit abundant natural resources for productive use (Iamsiraroj & Ulubaşoğlu,

2015). This has transformed agriculture into mainly a source of subsistence, and benefits and economic gains from these activities have been reduced significantly in these nations (Ben Slimane, Huchet-Bourdon, & Zitouna, 2016). One of the main contributors of the decrease on the contribution to the sector are low levels of productivity (Ben Slimane et al., 2016; Fuglie, 2018), which have been mainly caused by the existence of inappropriate human and physical capital and technological “know-how” (Iamsiraroj & Ulubaşođlu, 2015).

1.2 The Research Problem

A lack of technological knowledge has been identified in the agriculture sector in most developing nations (Iamsiraroj & Ulubaşođlu, 2015). Gondchawar and Kawitkar (2016), supported this fact stating that traditional agriculture practices still dominate the sector, causing a decrease on the productive use of natural resources (Mwangi & Kariuki, 2015). Olujenyo (2008) and Bekun (2015), attributed this problem to the high predominance of small holder farmers in the sector in most of these nations. This is supported by an increase on the numbers of farmers in developing nations due to a rise of subsistence farming (Raithatha, 2020). The combination of the lack of technological knowledge and the dominance of traditional farming practices have affected levels of productivity in the sector, reducing in a significant way its contribution to these economies (Bekun, 2015).

Low levels of productivity have caused outputs from agriculture to be used only as a source of subsistence, affecting commercialisation in countries where the reliance of the economy on this sector is high (Bekun, 2015). The application of traditional agriculture practices often results in low potential yields, low generation of outputs and limited earnings from farming (Mwangi & Kariuki, 2015; Olanipekun, Olasehinde-Williams, & Alao, 2019). Thus, a need to improve agricultural productivity has emerged based on the current conditions of the sector (Mottaleb, 2018). Although land use for farming has increased across developing nations, positive results in agricultural productivity have not been achieved due to low levels of technology adoption (Raithatha, 2020).

The agriculture sector is strongly tied to economic growth in developing nations (Oluwatoyese & Applanaidu, 2014; Mwangi & Kariuki, 2015). Thus, the improvement

of agricultural productivity and the development of the sector with the promotion of innovative technology can enhance livelihoods and open a path to economic prosperity in these nations (Bekun, 2015; Bustos, Caprettini, & Ponticelli, 2016; BenYishay & Mobarak, 2019). The implementation of modern science and technology can provide the sector with the right means to improve agricultural productivity (Gondchawar & Kawitkar, 2016). By doing this, the sector can be benefited with improvements in food production, price reductions, improved access to markets, and an increase on farming income (Ben Slimane et al., 2016).

Technology can offer integrated solutions to improve productivity at every stage of the agriculture value chain (Gondchawar & Kawitkar, 2016). Furthermore, technology adoption helps farmer to control a vast number of factors to increase the generation of outputs that cannot be controlled with the application of traditional practices (Jain, Arora, & Raju, 2009). However, it seems that technology in the agriculture sector in some developing nations has not yet been fully accessible (Deichmann, Goyal, & Mishra, 2016). There is a wide range of technologies that have not reached this sector and farmers have faced many restrictions that have not allowed them to acquire new and better production technologies (Deichmann et al., 2016; Larson, Sekhri, & Sidhu, 2016; BenYishay & Mobarak, 2019).

Having extensively reviewed the literature on technology adoption, four antecedents that determine technology adoption in agriculture in developing nations were identified. These four antecedents are: economic, institutional, household, and technology characteristic factors (Deichmann et al., 2016; Larson et al., 2016; Mwangi & Kariuki, 2015). Each of these antecedents have been presented in isolation and studies about technology adoption in these nations seemed to focus on the individual effect of them. Only an interaction analysis between technology characteristic factors and household factors was identified in a study conducted by Mwangi and Kariuki (2015).

As described in this section, the agriculture sector in some developing nations has not been able to maximise the benefits from productive use of natural resources (Iamsiraroj & Ulubaşoğlu, 2015). The application of traditional agricultural practices due to low technology adoption levels have limited earnings from farming activities and decreased agricultural productivity (Raithatha, 2020). Consequences from low

technology adoption levels have turned the sector into mainly a source for subsistence and decreased the contribution of agriculture to the economy of the nations where the reliance on these activities is significantly high (Bekun, 2015).

1.3 Significance of the Research

The research problem described in this study is significant to both academia and organisations working on the development of the agriculture sector. As stated previously, extensive literature review helped to define four antecedents determining technology adoption in agriculture in developing nations. These antecedents have been mainly analysed in isolation in prior studies (Mwangi & Kariuki, 2015; Rehman, Jingdong, Khatoon, Hussain, & Iqbal, 2017). Moreover, Rehman et al. (2017), defined economic factors such as affordability and profitability of innovative applications as major antecedents determining technology adoption. Besides focusing on the effect of the identified antecedents, this research focused on the identification of real antecedents according to the perception of people involved in farming activities in developing nations and emphasised on how the interaction of these antecedents affects decision-making with regards to technology adoption in the sector. Furthermore, this study may also lead to additional research as it may uncover antecedents that have not been previously identified.

1.4 Scope of the Research

As developing countries rely on agriculture as a main contributor for economic growth (Ben Slimane et al., 2016), the scope of this study was restricted to understanding the antecedents determining technology adoption in agriculture based on perceptions and opinions from people involved in farming activities in developing nations where the reliance of agriculture is high.

1.5 Purpose of the Research

The purpose of this research was to determine and gain a deep understanding of the antecedents determining technology adoption in agriculture in developing nations according to perceptions of people involved in farming activities, as well as the effect of their interaction on decision-making with regards to technology adoption.

Understanding these antecedents is essential for planning and developing technology accessibility programmes to address low levels of productivity in the sector (Mwangi & Kariuki, 2015). Therefore, this study is expected to contribute to previously established theories and assist entities involved with the implementation of technology in agriculture with a better understanding about the topic of interest.

This research aimed to:

1. Understand the meaning of technology adoption for people involved in farming activities in developing nations.
2. Identify and understand what are considered as the antecedents determining technology adoption according to people involved in farming activities in developing nations.
3. Understand the effect of the identified antecedents on technology adoption in agriculture in developing nations.
4. Understand how the interaction of the antecedents influence decision-making with regards to technology adoption in agriculture in developing nations.

To facilitate understanding of the determinants that drive technology adoption as well as the data collection process, a hypothetical model of technology adoption was developed. This model derived from the findings of the literature review described in Chapter 2 and is presented at the end of this section. The model was not presented to interviewees; however, it was used as a base to drive the interviews and look for new insights that have not been described in previous studies about this topic. These new insights and additional findings from discussions presented in chapter 6 contributed to the development of a more inclusive model that aimed to more clearly describe the interaction of each of the identified antecedents determining technology adoption and its effect on decision-making with regards to technology adoption.

1.6 Conclusion

Technology can provide innovative and creative solutions to the issues of low productivity faced by the agriculture sector in developing nations (Gondchawar & Kawitkar, 2016). Addressing these issues to promote agricultural development with the implementation of technology is important to enhance economic benefits from

farming activities (Mwangi & Kariuki, 2015). In fact, the development of the sector in developing nations is considered to be a main contributor of the Sustainable Development Goals (SDG's) established by the United Nations to promote sustainable poverty reduction and economic growth (FAO, 2018). Therefore, the analysis of the different perceptions and opinions about technology adoption of people involved in farming activities in developing nations is important to enhance agricultural development.

The following sections of this document include a literature review section, which focuses on the theoretical antecedents identified that determine technology adoption in the sector and a theoretical model developed by the researcher to facilitate understanding. This section is followed by the research questions with which this study aimed to understand the research problem. Next, the description of the research methodology adopted in this study is described, which will lead to the presentation and discussion of results. And finally, a conclusions and recommendations section, which will provide the main findings of the research, implications for entities interested in the topic, limitations of the research, and suggestions for future research.

Chapter 2: Literature Review

2.1 Introduction

Technology adoption can enable the easier accomplishment of tasks (Lavison, 2013), it facilitates the gathering of knowledge and information, leading to desirable levels of outputs from the production of goods and services (Mwangi & Kariuki, 2015). New technologies have transformed a wide range of aspects of life as well as required strategical changes to remain competitive in markets that have been disrupted by technology implementation (Deichmann et al., 2016). Globalisation has contributed to the worldwide spread of technology (Deichmann et al., 2016). This has been often related to economic growth since it offers international trade opportunities that incorporate the diffusion of knowledge and technology, contributing to the generation of better human capital (Blanchard & Olney, 2017).

Technology has worked as an economic improvement tool across multiple sectors (Deichmann et al., 2016). Its implementation aims to provide solutions to a wide range of business sectors around the world and the agriculture sector has not been an exception to this (Mwangi & Kariuki, 2015). However, a lack of knowledge about technology implementation has been identified in people involved in farming activities in most developing nations, which has limited the potential benefits of technology for the development of the sector (Iamsiraroj & Ulubaşoğlu, 2015). According to Che and Zhang (2018), technology adoption depends on the absorptive capacity of a country, which is determined in a significant way by human capital. Therefore, developing nations with deficient absorptive capacity may lag behind on technological advances and may not take advantage of technology transfers (Che & Zhang, 2018).

There is a need to establish a sense of urgency to improve the agriculture sector in developing nations (Bekun, 2015; Gondchawar & Kawitkar, 2016). According to statistics from The World Bank (2008), agriculture was the main source of income of 2.5 billion people in the world (Bekun, 2015). An increase in these numbers has been expected due to the rise of subsistence agriculture activities and the amount of land used for farming activities in developing nations (Raithatha, 2020). Therefore, agriculture development with technology implementation has been considered as an

important tool to enhance the benefits perceived from these activities, and understanding the determinants of technology adoption is essential to promote this development (Mwangi & Kariuki, 2015).

Four antecedents determining technology adoption in the agriculture sector in developing nations have been identified: economic, institutional, household, and technology characteristic factors (Deichmann et al., 2016; Larson et al., 2016; Mwangi & Kariuki, 2015). Whilst technology adoption is considered as important to accelerate change and transform agriculture systems (Bekun, 2015; Gondchawar & Kawitkar, 2016; FAO, 2018), little research has been carried out to determine the effect of the interaction of these identified factors to determine technology adoption. In most studies these factors have been analysed in isolation and explained the individual effect of each of them on technology adoption. Others, for instance, have associated economic factors such as affordability and profitability of the implementation as the most important drivers of technology adoption in agriculture in developing nations (Rehman et al., 2017).

In order to better understand the antecedents determining technology adoption and the effect of their interaction, an extensive literature review was conducted to address the following areas: technology acceptance theories; factors determining technology adoption in agriculture in developing nations; and technology applications in agriculture and its benefits.

2.2 Technology Acceptance Theories

Understanding the reasons of acceptance or rejection from users to any type of new technologies has become essential in the areas of Information Technology (IT), Information Systems (IS) and social science (Momani & Jamous, 2017; Alkhwaldi & Kamala, 2017; Taherdoost, 2018). During the last decades, a wide number of studies to analyse technology acceptance and its usage have been conducted (Blut, Wang, & Schoefer, 2016; Dwivedi, Rana, Jeyaraj, Clement, & Williams, 2019). These studies have focused on how users understand and accept new technologies, and the variables associated to a specific technology that determine individual's decision-making processes with regards to technology implementation (Momani & Jamous, 2017). This section will focus on two specific models: Technology Acceptance Model

(TAM) and the Unified Theory of Acceptance and Use of Technology (UTAUT). Two theoretical models that have been widely used in research to understand factors of acceptance and predict user's response to new technologies (Taherdoost, 2018).

2.2.1 Technology Acceptance Model (TAM)

The Technology Acceptance Model (TAM) explains users' motivation with regards to technology acceptance with three factors: perceived usefulness, perceived ease of use, and attitude towards use (Taherdoost, 2018). According to this model, perceived usefulness and perceived ease of use are considered as the main significant determinants of technology acceptance (Alkhwaldi & Kamala, 2017). Perceived usefulness is defined as the potential users' likelihood that the use of a specific technology will improve and facilitate users' actions. Whereas, perceived ease of use refers to the degree to which the potential user expects the application of a specific technology to be effortless (Blut & Wang, 2020). Furthermore, the model considers the effect of external factors on perceived usefulness and perceived ease of use as predictors of users' attitude towards using a technology (Salloum, Alhamad, Al-Emran, Monem, & Shaalan, 2019).

Technology Acceptance Model (TAM) has been used in many research papers and become quite significant in the literature related to technology acceptance (Salloum et al., 2019). However, its application still has some limitations such as not including subjective norm factors (Alkhwaldi & Kamala, 2017), which are defined as the persons' perception about what other people think about performing a behaviour or not (Momani & Jamous, 2017). By not considering the effect of social influence on technology acceptance its effectiveness to understand behavioural intention and actual use of a specific technology beyond the workplace context has been questioned by many researchers (Taherdoost, 2018). Studies have shown that the limitations of the model are well acknowledged and that the integration with additional models and variables should be considered to really understand technology acceptance (Alkhwaldi & Kamala, 2017).

2.2.2 Unified Theory of Acceptance and Use of Technology (UTAUT)

The Unified Theory of Acceptance and Use of Technology (UTAUT) explains technology acceptance with four key components: performance expectancy, effort expectancy, social influence, and facilitating conditions (Kiwanuka, 2015). The model considers performance and effort expectancy as technology attributes. Whereas social influence and facilitating conditions are considered as contextual factors (Dwivedi et al., 2019).

Technology attributes are evaluated by the user in terms of expectancy. Based on this premise, an individual will evaluate technology adoption with the expected improvement on gains in performance and effort (Blut et al., 2016). Performance gains are evaluated by individuals by the degree to which technology implementation is perceived to enhance job performance (Kiwanuka, 2015). Whereas effort gains refers to the degree of ease added by technology implementation to the completion of tasks (Kiwanuka, 2015), which according to Lavison (2013), is the purpose of any technology implementation.

This model presents contextual factors as perceptions held by individuals with regards to the context of a specific technology (Dwivedi et al., 2019). Social influence refers to the degree of importance to which an individual perceives the influence of others to accept new technology systems (Kiwanuka, 2015). Whereas facilitating conditions are defined as the degree to which an individual perceives that organisational and technical infrastructures exist to support the use of the system (Kiwanuka, 2015).

All the components that explain technology acceptance in this model are moderated by gender, age, voluntariness of use, and experience. These are considered as variables that lead to behavioural intention and use behaviour of a specific technology (Blut et al., 2016). These moderators affect technology usage determining the relationship between behavioural intention and use of behaviour, which are considered as dependent variables of the model, and the key components, considered as the independent variables (Kiwanuka, 2015).

This model is considered as one of the most effective integrated models to analyse technology acceptance (Chao, 2019). Mostly because it has derived from the adaptation of previous theories related to technology adoption, which allows the model to explain a significant variation in behavioural intention and behaviour of usage (Dwivedi et al., 2019). Furthermore, the flexibility of this model allows to understand the human factors associated with technology implementation in a wide range of fields (Kiwanuka, 2015). However, certain limitations can be attributed to this model. Prior studies have not considered moderators because a lack of variation in the moderator for adoption. For instance, adoption of a new technology may be mandated by an organisation, which implies that voluntariness of use may not moderate the implementation (Dwivedi et al., 2019).

Another missing consideration of the model is the individual characteristics. These could influence behavioural intention and behaviour of use. Attitude towards the implementation, technical knowledge, technologic self-efficacy, and personal innovativeness can moderate technology acceptance (Dwivedi et al., 2019). Thus, when studying factors determining technology adoption, the researcher should consider additional moderators that can influence acceptance of a new and innovative technology (Carter & Schaupp, 2008; Venkatesh, Thong, Chan, Hu, & Brown, 2011; Chong, 2013).

2.3 Factors determining technology adoption in agriculture in developing nations

According to Gondchawar and Kawitkar (2016), agriculture has played a vital role for the economies of developing nations. Bekun (2015), supported this statement suggesting that this sector has been the largest contributor to most of these economies and had an important role on driving economic growth and development. A number of studies have determined that this contribution has been reduced significantly due to low levels of productivity in the sector (Mwangi & Kariuki, 2015; Ben Slimane et al., 2016). There are many natural causes that have contributed to this issue such as droughts, excess rain, and the quality of soils, which lead to minimum yields (Mwangi & Kariuki, 2015). However, one of the most important contributors of low productivity levels has been the lack of technological knowledge (Iamsiraroj & Ulubaşoğlu, 2015), which has led farmers to remain using traditional

practices and methods that result in low economic outputs and poor benefits (Deichmann et al., 2016; Raithatha, 2020).

Agricultural productivity may vary around the world. There is a big difference in agricultural productivity between developed and developing countries, which has been caused by technology adoption levels (Magruder, 2018). In addition, identified factors that have contributed to this variation in developing nations are financial access, infrastructure, current agriculture practices and management (Deichmann et al., 2016). Therefore, the implicit assumption of identical levels of agricultural productivity across different economies may seem unrealistic (Awokuse, 2015). The agriculture sector in developing nations has faced barriers that have limited technology adoption, which have discouraged people involved in these activities to consider its implementation (Larson et al., 2016). Mwangi and Kariuki (2015), Deichmann et al. (2016) and Larson et al. (2016), identified four antecedents of technology adoption in the agriculture sector in developing nations, which will be explained in detail in this section.

There is no doubt of the potential of developing nations to address the issue of agricultural productivity with the efficient and effective use of its abundant natural resources (Bekun, 2015; Rodrik, 2018). The better use of inputs, application of new technologies, and diversification of production into new crops can provide the sector with the necessary means to enhance productivity levels (Rodrik, 2018). Therefore, understanding the antecedents that determine technology acceptance in the sector is essential to promote economic growth in these nations (Mwangi & Kariuki, 2015).

2.3.1 Economic factors

Several studies have considered economic factors as main antecedents determining technology adoption (Lavison, 2013; Mwangi & Kariuki, 2015; Larson et al., 2016). Mwangi and Kariuki (2015), stated that technology implementation is dependent of farming sizes, implying that big farmers are more likely to adopt technologies because of the availability of resources. Alternatively, some studies have determined that effective adoption costs are less significant for larger farmers in developing nations (Larson et al., 2016). However, it has been proved that technology adoption is not dependent on the farming systems' size. There is a wide range of technologies

that can be directed to farmers regardless of the proportion of land of their farming systems (Deichmann et al., 2016).

A question then arises on what are considered as important economic factors that determine technology acceptance in agriculture in developing nations. Mwangi and Kariuki (2015), suggested that technology acceptance can be determined by net gains perceived from implementation. Lavison (2013), supported this by stating that positive net gains can serve as motivational factors for implementation. Furthermore, two major economic determinants of successful technology implementation identified in prior studies have been affordability and profitability of new technologies (Rehman et al., 2017). One of the causes of low technology adoption levels in developing nations has been the perception of high installation costs and upfront investments of technology implementation (Mwangi & Kariuki, 2015). An initial attractive factor for technology implementation is higher product prices. However, when prevailing installation costs are considered to be higher than the net gains, farmers tend to reject technology applications (Kijima, Otsuka, & Sserunkuuma, 2011).

Another important economic factor to take into consideration is the lack of financial access and financial inclusion policies that limit credit facilities for technology implementation (Mwangi & Kariuki, 2015). In most developing nations credit markets are either non-existing or dysfunctional, which have obliged farmers to look for opportunities to generate off-farm income as a substitute for borrowed capital (Diirro, 2013). Some argue that this can promote technology adoption because it can provide farmers with liquid capital for purchasing productivity enhancing inputs, however, pursuit of off-farm income can undermine technology adoption because of a reduction on the amount of labour dedicated to farming activities (Mwangi & Kariuki, 2015). Therefore, financial inclusion policies in developing nations should be broaden to reach those who have been excluded from them (Allen, Demirguc-Kunt, Klapper, & Martinez Peria, 2016). In nations where informal financial systems are predominant, access to finance should be encouraged, providing unbanked people with opportunities to save money and circulate it through financial systems that can facilitate access to credit (Tchamyoun, Erreygers, & Cassimon, 2019).

In addition to the lack of credit facilities, farmers in developing nations have faced lack of access to insurance markets (Deichmann et al., 2016). Insurance like any

other financial institutions or services is essential for the development of the agriculture sector since it promotes risk sharing, increased savings and higher investments (Assa, Sharifi, & Lyons, 2021). According to Karlan, Osei, Osei-Akoto, and Udry (2014), investment decisions of farmers in developing nations are conditioned by the financial environment in which they are immersed in. For that reason, credit market constraints and deficient insurance services can limit investment in activities with high expected profits. Furthermore, investments in the agriculture sector are regarded as highly sensitive to market risks since some of them may only produce long-term results (Assa et al., 2021). Therefore, proper insurance policies and access to finance for people in the agriculture sector can lead to larger agricultural investments (Karlan et al., 2014), which can improve technology adoption levels to address the issue of agricultural productivity and promote economic growth in developing nations (Mwangi & Kariuki, 2015; Deichmann et al., 2016).

Economic factors are considered as important antecedents that determine technology adoption. The lack of financial access in developing nations have provided farmers with high levels of risk-aversion in terms of investments of new productivity enhancement technologies (Mwangi & Kariuki, 2015). Should these factors not be addressed, farmers can be discouraged from accepting technology and efforts to reduce subsistence farming to improve agriculture outputs may not progress (Mwangi & Kariuki, 2015; Larson et al., 2016; Raithatha, 2020).

2.3.2 Institutional Factors

Individual's exposure to peers has been determined to have a positive impact on technology adoption (Takahashi, Mano, & Otsuka, 2019). Rehman et al. (2017), stated that peer effects help to promote technology adoption through information and knowledge sharing. Learning from peers has been considered as an important factor to overcome information gaps about technology implementation (BenYishay & Mobarak, 2019). Furthermore, Oster and Thornton (2009), suggested that peer effects lead to three positive outcomes that promote technology adoption: individuals behave like their peers, individuals learn about the benefits of technology from their peers, and individuals learn how to use new technologies from their peers. Mwangi and Kariuki, (2015), stressed the importance of individuals belonging to social groups due to a higher openness to learn about the existence and effective use of

technologies within farmers' association and communities. Peer effects and social groups can lead to economies of scale and engagement with social learning, by which farmers can exchange information, share technologies that can lower implementation costs and become more open to adoption (Mwangi & Kariuki, 2015; Rehman et al., 2017).

However, peer effects and social groups can lead to increased competition of land and the appearance of "free-riding behaviours", which can reverse technology adoption (Foster & Rosenzweig, 1995; Rehman et al., 2017). To this extent, Foster and Rosenzweig (1995), stated that findings from a study of adoption of Green Revolution technologies in India indicated that learning externalities within social networks increased the profitability of adoption. Nevertheless, individual adoption rates did not increase because of opportunistic behaviours of individuals taking advantage of their neighbour's costly experimentation with the new technologies. Bandiera and Rasul (2002), explained this inverse relationship between learning in social groups and individual adoption levels with an inverted U-shape adoption curve, in which they implied that network effects are positive at low rates of adoption.

Another institutional factor that determines technology adoption in agriculture in developing nations is awareness (Mwangi & Kariuki, 2015). According to Bardhan and Mookherjee (2011), in order to increase technology adoption levels, farmers should be aware of its existence, must believe that technology is beneficial for them and must know how to use it effectively (Deichmann et al., 2016). Having timely access to information can influence farmers' decision-making with regards to implementation (Liu, Bruins, & Heberling, 2018). Bonabana-Wabbi (2002), suggested that access to information reduces uncertainty about technology performance, changing farmers' perception about it from a subjective to an objective basis. However, access to information does not necessarily mean that adoption levels will improve (Mwangi & Kariuki, 2015). For instance, information sharing about limited experiences with technology can lead to dis-adoption, since more information will induce negative attitudes towards implementation (Bonabana-Wabbi, 2002).

Therefore, good information sources and use of technical information are important for the promotion of technology adoption in the sector (Liu et al., 2018). Information channels, mainly public extension agents play an important role in reducing

information gaps about technology and its benefits to promote adoption (Deichmann et al., 2016). These channels should provide reliable, consistent, and accurate information about the existence of technology to solve identified needs in the sector, promote its benefits and teach how to effectively use them (Mwangi & Kariuki, 2015).

These extension agents are considered as an additional institutional factor that determines technology adoption (Liu et al., 2018). They should act as a connection link between the developers of new technologies and the final users (Mwangi & Kariuki, 2015). Proximity to these agents can influence technology adoption, their reliance in providing timely and effective information can be essential to achieve higher technology adoption levels (Liu et al., 2018). In fact, support and technical assistance from extension agents can undermine the negative effect of lack of years of formal education from farmers in the sector (Bonabana-Wabbi, 2002), and contribute to the generation of better human capital to facilitate technology adoption levels (Mwangi & Kariuki, 2015; Che & Zhang, 2018).

2.3.3 Household factors

It is assumed that human capital and individual characteristics of the farmer can influence their decision with regards to technology adoption (Mwangi & Kariuki, 2015). Many studies analysing technology adoption have measured household factors with characteristics from farmer's human and social capital, such as education levels, age, household size, and gender (Keelan, Thorne, Flanagan, Newman, & Mullins, 2014; Hunecke, Engler, Jara-Rojas, & Poortvliet, 2017). Furthermore, individual characteristics, human, and social capital can include variables that lead to behavioural intention and use behaviour of a specific technology (Kiwauka, 2015).

According to Mwangi and Kariuki (2015), education levels have a positive influence on farmers' decision-making processes with regards to technology implementation. Higher education levels provide farmers with the ability of being more receptive to information, enabling them to obtain, process and use relevant information about a specific technology more efficiently (Mignouna, Manyong, Rusike, Mutabazi & Senkondo, 2011; Lavison, 2013; Mwangi & Kariuki, 2015). Waller, W. Hoy, Henderson, Stinner, and Welty (1998), stated that higher education levels influence

farmers' attitudes and thoughts to have a more open and rational approach, enabling them to effectively analyse benefits from new technologies. This facilitates the introduction of new innovative technologies, which can result higher levels of adoption in the sector (Adebiyi & Okunlola, 2013).

Another important household factor which can moderate technology adoption is age (Mwangi & Kariuki, 2015). In one study about the adoption of organic fertilizers, Lavisson (2013), inferred that age has a positive impact on adoption because older farmers may have more experience in the sector and may be aware of the needs that can be solved with innovative applications. Mignouna et al. (2011), supported this inference stating that older farmers are assumed to have gained knowledge and experience over time and can better evaluate information about technology implementation. However evidence of a negative impact of age on technology adoption has been determined (Barrera, Norton, Alwang, & Mauceri, 2005; Alexander & Mellor, 2005). Older farmers present higher levels of risk aversion and are not too interested in long-term investments in their farms. Whereas younger farmers are typically less risk-averse and are more willing to try new technologies (Mwangi & Kariuki, 2015).

Sociocultural values also play an important role in determining technology adoption. (Mwangi & Kariuki, 2015). In most developing nations men are considered as primary decision makers and head of the household. Thus, they tend to have more access and control over vital production resources than women (Omonona, Oni, & Uwagboe, 2006; Mignouna et al., 2011). For instance, in some of these nations, women are restricted and excluded from financial services such as credit facilities (Mwangi & Kariuki, 2015). Although it has been proved that technology adoption depends primarily on access to resources rather than gender (Doss & Morris, 1999), some researchers have determined that men can be more attracted to technology than women (Goswami & Dutta, 2016). To this extent, Lavisson (2013) and Obisesan (2014) considered that men acting like primary decision makers in farming households can positively impact technology adoption in the sector in developing nations.

In addition to household factors that can determine technology adoption, household size has been considered to have an effect on technology acceptance (Hunecke et

al., 2017). Studies have shown that larger households may imply higher chances of adoption (Mwangi & Kariuki, 2015; Larson et al., 2016). Household size is considered as a measure of labour availability (Mwangi & Kariuki, 2015). Thus, farmers with higher household size may have the capacity to release labour units required during the introduction of new technologies (Bonabana-Wabbi, 2002; Mignouna et al., 2011). In contrast, small household owners are more likely to focus on the negative aspects of technology implementation due to labour constraints to take control, manage and learn from the introduction of new technologies (Hunecke et al., 2017).

There is a wide range of technologies that can provide innovative solutions to farmers in developing nations regardless of their household size. Technology promotion should be consistent with the conditions of farmers' household environments such as proportion of land, labour and natural conditions (Deichmann et al., 2016).

2.3.4 Technology characteristic factors

According to Mwangi and Kariuki (2015), technology attributes and characteristics are preconditions of technology adoption. Mignouna et al. (2011), stated that technology characteristics play an important role in determining technology adoption. They inferred that technology implementation that is consistent with farmers' needs and compatible to their environment have higher chances of adoption. Farmers are more receptive and open to technology applications that are perceived as compatible with the conditions of their farms and beneficial to addressing their needs (Mwangi & Kariuki, 2015). For instance, the agriculture sector in most developing nations is vulnerable to climate change impacts such as droughts, precipitation, increase in temperatures, and humidity, which can cause scarcity of resources (Arslan, McCarthy, Lipper, Asfaw, Cattaneo & Kokwe, 2015). Therefore, Senyolo, Long, Blok, and Omta (2018), suggested that implementation directed to the efficient resource management can be suitable to address the effect of these impacts and promote climate change adaptation strategies.

In addition to technology attributes and characteristics, farmers' decision-making with regards to technology adoption can be influenced by the flexibility of implementation in terms of pilot testing (Mwangi & Kariuki, 2015; Larson et al., 2016). Strategic experimentation can lower farmers' risk-aversion, which is undermined when

performance of the pilot-implementation result in satisfactory outcomes (Mwangi & Kariuki, 2015). For instance, in one study of the adoption of water saving devices, Larson et al. (2016), suggested that for farmers who are uncertain about investment pay offs, technology promotion can be done with pilot testing strategies to measure performance and benefits prior to implementation. These strategies allow farmers to evaluate performance of a specific technology and can lead to permanent adoption in case of positive evaluations. Otherwise, losses in productivity are limited to the area of pilot-implementation. Farmers' perception about performance of an implementation is crucial for its adoption. It is therefore important that for any new introduction of innovative technology, farmers are involved in its evaluation to find whether an application is suitable to their circumstances (Mwangi & Kariuki, 2015).

2.4 Technology applications in agriculture and its benefits

Population growth and consequences from climate change have put agriculture production under pressure and demanded a shift towards smart agriculture practices (Gacar, Aktas, & Ozdogan, 2017; Elijah, Abd Rahman, Orikumhi, Leow, & Hindia, 2018). Modern inputs and improved agriculture practices can improve agricultural productivity, which has been recognised as an important driver of transformation and economic growth in developing countries (Emerick, de Janvry, Sadoulet, & Dar, 2016; Rehman et al., 2017). Gondchawar and Kawitkar (2016), stated that technology systems can control a wide range of aspects related to productivity in the agriculture sector. Juma (2015), supported this explaining that innovative systems can contribute to improve production, packaging, storage, and distributions processes, adding value to the entire productive agricultural chain.

The agriculture sector has benefited from agricultural developments such as Global Positioning Systems (GPS), Geographic Information Systems (GIS), and other mobile technologies that have provided improvements on precision agriculture implementation (López-Riquelme, Pavón-Pulido, Navarro-Hellín, Soto, & Torres, 2016; Gacar et al., 2017). Precision agriculture implementation allows farmers to accurately monitor crop conditions, reducing human error and improving efficient use of resources (Rehman et al., 2017). In addition to controlling and monitoring of crops, the development of integrated pest management devices have provided farmers with

higher yields and caused less damage to the environment and human health (Midingoyi, Kassie, Muriithi, Diiro, & Ekesi, 2019).

Developments in recent years in communication technologies, internet connectedness, data analysis and Internet of Things (IoT) have led to a revolution in the agriculture sector (Gacar et al., 2017). Internet connectedness and data analysis in the agriculture sector plays a major role for the productivity enhancement process (Elijah et al., 2018), since it can be applied for diagnostics and production controls, as well as enabling easier access to information for producers and final consumers (Muangprathub, Boonnam, Kajornkasirat, Lekbangpong, Wanichsombat & Nillaor, 2019). Nowadays, the implementation of digital tools provides communication means to people involved in the agriculture sector and enhances the interaction of farmers with extension agents and official information channels promoting technology adoption (BenYishay & Mobarak, 2019).

Advanced technologies can bring benefits to the majority of people in the agriculture sector (Muangprathub et al., 2019). IoT and data analysis tools such as wireless monitoring sensors, monitoring mobile applications, cloud computing and robotic technologies can improve effective and efficient use of resources, reduce labour efforts and inputs costs, and provide farmers with accurate information about production parameters to take control of productivity (Rehman et al., 2017; Gacar et al., 2017). Gondchawar and Kawitkar (2016), stated that the integration of these systems can improve yields, facilitate efforts reducing man-labour and lead to desirable levels of productivity.

Technology has disrupted the agriculture sector and the transition of traditional practices to smart practices is a requirement to improve agricultural productivity (Gacar et al., 2017). Agriculture is considered as the basis of human life since it is the main source of food grains and other raw materials for human consumption (Henderson et al., 2018). Therefore, growth for the sector with technology implementation is necessary for the development of nations where the contribution to the economy from this sector is high (Bekun, 2015; Gondchawar & Kawitkar, 2016).

2.5 Conclusion

Technology adoption can provide solutions to farmers to improve benefits from agriculture activities and promote economic growth in the sector (Deichmann et al., 2016). The relevance of the economic contribution of this sector to the economies of developing nations should encourage practices to promote technology adoption among farmers and ensure access to innovative systems that improve agricultural outputs and benefits from these practices. The increase of farming activities from farmers who only rely on traditional practices has turned agricultural outputs to serve only as a source of subsistence (Raithatha, 2020). Therefore, a need to promote sustainable agriculture with new technologies to enhance the livelihood of farmers has emerged worldwide (FAO, 2018). Furthermore, sustainable agriculture is considered as one of the Sustainable Development Goals by the United Nations, which focuses on the reduction of poverty and hunger through the improvement of agricultural productivity (Dhahri & Omri, 2020).

Through the literature review, key actors playing an important role for the development of the agriculture sector, and theoretical antecedents determining technology adoption were identified. The individual effect of each of these antecedents on decision making processes with regards to technology adoption were explained in detail. From where it was found that economic, institutional, household and technology characteristic factors have posed circumstances that have limited and discouraged farmers from trying new and innovative agricultural solutions with technology (Deichmann et al., 2016; Mwangi & Kariuki, 2015; Larson et al., 2016).

Findings from the literature review allowed the researcher to develop a hypothetical framework, which is presented in Figure 1. This model explains in a graphic way the effect of the theoretical antecedents determining technology adoption in agriculture in developing nations.

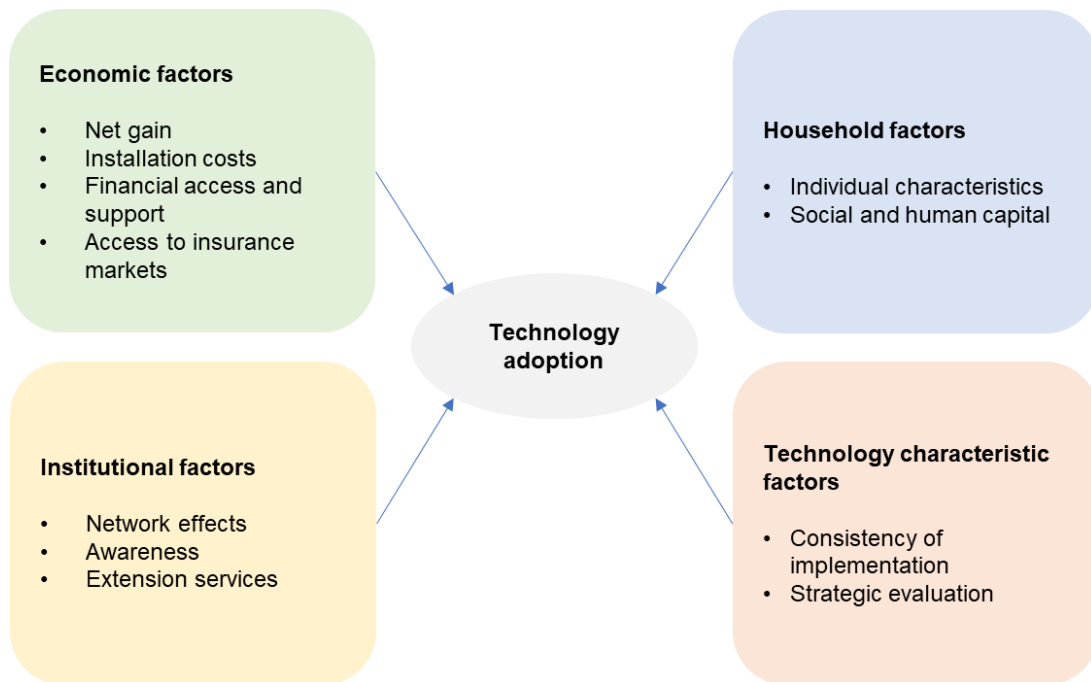


Figure 1: Hypothetical framework of the theoretical antecedents determining technology adoption in agriculture in developing nations

Understanding the antecedents determining technology adoption in agriculture in developing nations can provide useful insights to improve the development of the sector. This hypothetical model describes the influence of each of the identified antecedents on technology adoption. However, literature from where this model derived focused only on the individual effect of each antecedent. Prior studies have identified and analysed each of these antecedents in isolation. Some focused on identifying the main antecedent and defined that addressing the most influential antecedent determining technology adoption can drive improvements in agricultural productivity (Rehman et al., 2017). Findings from this study are therefore important because they can identify new antecedents that have not been taken into consideration in prior studies. Furthermore, findings from the data collection method will enable the researcher to establish the effect of the interaction of the identified antecedents on decision making with regards to technology implementation. Rather than analysing the isolated effect of each antecedent, this study will attempt to understand whether these identified antecedents work in conjunction to influence decision making according to perceptions of people involved in the agriculture sector.

Chapter 3: Research Questions

3.1 Introduction

The literature review in Chapter 2 provided insights about the antecedents that drive technology adoption in agriculture in developing nations and led to the generation of four research questions that are intended to be answered by conducting this study. This chapter will describe in detail each of these research questions with which the researcher aims to understand the antecedents determining technology adoption in the sector based on participants' perception.

3.2 Research Questions

Research Question 1: What does technology adoption in agriculture mean for people involved in the sector in developing nations?

Research Question 1 aims to identify and understand the perception of people involved in agriculture activities in developing nations about technology implementation. Theory suggest that technology implementation in agriculture can promote growth in the sector and increase levels of productivity (Bekun, 2015). Thus, it is essential to understand the perception of people involved in these activities about the benefits technology can provide to the sector according to their opinion.

Research Question 2: What are considered as the antecedents determining technology adoption in agriculture in developing nations?

Research Question 2 will help to identify and understand what are considered as the antecedents that determine technology adoption in agriculture in developing nations from the point of view of the participants of the study. Furthermore, this will seek to confirm whether the four main factors: economic, institutional, household and technology characteristics, identified in theory are considered by participants as the antecedents of technology adoption or not. Additional insights, if found, about drivers that have not been considered on theory will also be provided for consideration on future studies related to this topic.

Research Question 3: How do the identified antecedents affect technology adoption in agriculture in developing nations?

This Research Question aims to determine and understand the effect of the identified antecedents on technology adoption in agriculture in developing nations. Based on participants' perception this research question will provide insights to understand about the implications of each of these identified antecedents and what should be done to promote technology adoption in the sector.

Research Question 4: How do these antecedents interact to influence decision making with regards to technology implementation in agriculture practices?

The influence of the interaction between the identified antecedents that drive technology adoption in the agriculture sector in developing nations on decision making with regards to technology adoption is intended to be explained with Research Question 4. This question will lead to understanding whether the identified antecedents work together to influence this decision or not.

3.3 Conclusion

The Research Questions described in this chapter aimed to provide the researcher with the ability to understand the problem described in Chapter 1. The next chapter will provide detailed insights about the research methodology and design that were followed during the conduction of this study to address and answer these Research Questions.

Chapter 4: Research Methodology

4.1 Introduction

The purpose of this chapter is to explain the research methodology followed in this study. The literature Review presented in Chapter 2 guided the research questions that were intended to be answered by this study. This chapter presents in detail the methodology followed to answer these research questions by discussing the following sections: the research design, population, sampling method and size, unit of analysis, data collection tool, data collection process, data analysis, data biases and trustworthiness, and limitations of the research.

4.2 Research methodology and design

Following the purpose of this research, which is based on perceptions of people involved in farming activities about technology adoption in agriculture in developing nations, a qualitative mono-method design was adopted. According to Saunders, Lewis, and Thornhill (2016), an interpretivism philosophy allows the researcher to gain deeper and richer understandings about social worlds and contexts. Thus, this philosophy was considered suitable to follow. With an emphasis on understanding the research context, an inductive approach was adopted. This allowed the researcher to understand the meanings of humans attached to events with alternative explanations from participants in this study (Saunders & Lewis, 2018). Moreover, these alternative explanations from participants were collected using a single data collection method, which were semi-structured interviews.

Qualitative studies allow the researcher to explore an issue and identify variables that cannot be easily measured (Creswell, 2007). Moreover, an exploratory approach can help to find specific insights about a particular phenomenon and are well suited with qualitative collection methods such as semi-structured interviews (Saunders & Lewis, 2018). Therefore, this study was conducted using an exploratory approach which helped to understand the antecedents determining technology adoption in agriculture in developing nations. An interpretivism philosophy was adopted for this study, which was focused on understanding a particular phenomenon focusing on participants' lived experiences. Thus, the research strategy followed in this study was

phenomenology. This helped the researcher to collect information about these particular experiences and their interpretations which helped to generate meanings and gain insights about the phenomenon of interest (Creswell, 2007; Saunders et al., 2016), which was the low levels of productivity in the agriculture sector due to low levels of technology adoption.

Synchronous online semi-structured interviews were used as the data collection method. This method works for participants who are geographically dispersed (Saunders & Lewis, 2018), which was the case for this study. Interviews were developed using the video conferencing platform Zoom™, and information was collected following a cross-sectional time horizon. This involves the study of a specific phenomenon at a particular time (Saunders et al., 2016). Therefore, this study focused on participants' perception about technology adoption in the specific point in time when the data collection process was held. Any changes of perception with time or daily perspectives about the topic were not considered as a subject of interest in this study.

4.3 Population

Many studies focus on the size of farming systems to determine and understand major antecedents of technology adoption in the agriculture sector. For instance, (Larson et al., 2016), suggest that differentiation of small and big farmers is important to understand the main drivers of technology adoption. However, technology is not dependent on farming size (Mwangi & Kariuki, 2015). There is a wide range of technologic and innovative solutions that can be provided to the sector regardless of the proportion of land of farming systems (Deichmann et al., 2016).

The contribution of agriculture to the economies of some developing nations has significantly decreased because of lack of technology adoption (Iamsiraroj & Ulubaşoğlu, 2015). This has resulted in low levels of productivity in the sector (Raithatha, 2020), which have turned agriculture into mainly a source of subsistence (Bekun, 2015). Agriculture was considered to be a pillar for some of these nations, which had a strong reliance on the sector to achieve economic growth (Bekun, 2015). Therefore, the population that was considered in this study was people involved in agriculture activities of El Salvador and Botswana, two developing nations where the

reliance on agriculture is high (Lekobane & Seleka, 2017; Blanco-Gómez, Jimeno-Sáez, Senent-Aparicio, & Pérez-Sánchez, 2019).

4.4 Sampling method and size

The sampling technique that was adopted in this study was non-probability sampling. Using this technique allowed the researcher to select sampling units based on personal judgement and convenience (Babin, Quinlan, Zikmund, Carr, & Griffin, 2019). The sampling technique adopted in this study included purposive and volunteer sampling. Purposive sampling required the researcher to use his own personal judgement to select sampling units that better enabled him to answer the research questions (Saunders et al., 2016). Whereas, volunteer sampling was carried out using a snowball sampling technique, by which cases in the population were asked to identify further participants for this study (Saunders et al., 2016).

As this study was qualitative and followed a phenomenology strategy, the sample was small in size (Saunders & Lewis, 2018). All participants had similar characteristics, which allowed the implementation of a homogeneous type of sampling (Saunders et al., 2016). This sample consisted of 12 participants who had been or were currently involved in agriculture activities. Data saturation was reached with 12 interviews due to the homogeneous nature of the sample (Boddy, 2016). This is the point in which additional data collected provide few or no additional insights valuable for the study (Saunders et al., 2016). Most studies reviewed related to the topic of interest of this study were quantitative in nature and therefore, could not provide a guide for determining an appropriate sample size for this qualitative research. However, Creswell (2013), stated that in qualitative research following a phenomenology strategy, studying three to 10 subjects is recommended. Thus, a sample of 12 participants was considered suitable for the purpose of this research. This sample was comprised of three agriculture technicians who had experience in the aquaculture sector, four farmers who were working on agriculture institutions and five farmers fully dedicated to this type of activities. Further details about the sample will be provided in section 5.2.

4.5 Unit of analysis

Insights provided by participants of this study who were directly involved with agriculture activities allowed the identification and understanding of the antecedents that determine technology adoption in the sector. Furthermore, their perception allowed the researcher to understand how the identified antecedents and the interaction between them affected the participants' decision regarding technology adoption in their practices. Therefore, during the data analysis stage of the research, the individual opinions and perceptions of each participant were determined as the final unit of analysis for this study.

4.6 Data collection tool

When undertaking an exploratory study it is advantageous for the researcher to conduct semi-structured interviews (Saunders et al., 2016). In addition, exploring a phenomenon typically requires interviewing as a data collection method (Creswell, 2013). This provides the researcher with the opportunity to explore answers which require the interviewee to explain or build on their responses (Saunders et al., 2016). Furthermore, because an interpretivism philosophy was adopted in this study, semi-structured interviews allowed the understanding of meanings attached by participants to the phenomena of interest (Saunders et al., 2016). Therefore, 12 online synchronous semi-structured interviews were conducted with participants of this study.

The completion time of the semi-structured interviews varied according to the level of detail provided by each interviewee on each of the interview questions. These times varied from 25 minutes to 1 hour and 37 minutes. On average, completion time of one interview was 55 minutes. Each of these interviews were conducted at a convenient time for the participant. As interviews were conducted through an online video conferencing platform, the researcher asked participants to select a convenient location for conducting the interview, with the purpose of avoiding any kind of interruptions.

Participants were invited to take part in this study via email and text messages, which included detailed information about the purpose of the research and explanation of

the data collection method that the researcher intended to use. Furthermore, each participant was provided with an official consent form which the participant filled with his/her name and the date of the scheduled interview. This consent form also explained the purpose of the research and how data was intended to be collected, it also contained the researcher and supervisor’s contact information in case of any doubts about their participation in the study. This helped the researcher to establish credibility with participants and to reduce uncertainties from their side about sharing information (Saunders et al., 2016). The consent form template that was delivered to participants is presented in Appendix 1.

Research questions were designed based on the literature review presented in Chapter 2. To answer these research questions, the researcher developed 11 interview questions which were asked to each participant to understand the antecedents determining technology adoption and their interaction to influence decision making with regards to implementation in the sector. The order of the interview questions varied according to the flow of the conversation with participants, and in some cases additional questions to explore the research questions were required based on the nature of events described by participants (Saunders et al., 2016). To ensure consistency between the interview and research questions, the interview guideline, presented in Appendix 2, was mapped in a consistency matrix presented in Table 1. This consistency matrix provided guidance on how each of the research questions was intended to be answered with the questions developed in the semi-structured interviews.

Table 1: Consistency Matrix

Research Question	Interview Question
1. What does technology adoption in agriculture mean for people involved in the sector developing nations?	1. What is your perception about technology adoption to improve agricultural productivity? 2. What is your understanding about the benefits offered by technology implementation in agricultural practices?

<p>2. What are considered as the antecedents determining technology adoption in agriculture in developing nations?</p>	<p>3. What have your experiences been with technology implementation in your agricultural practices?</p> <p>a. If participant has not had any experience with technology implementation:</p> <p>I. Under what circumstances would you consider technology adoption?</p> <p>b. If participant has had experiences with technology implementation:</p> <p>I. Under what circumstances would you consider further technology adoption?</p>
<p>3. How do the identified antecedents affect technology adoption in agriculture in developing nations?</p>	<p>a. For participants who have not had any experience with technology implementation:</p> <p>I. What are the reasons you have not adopted technology in your agricultural practices?</p> <p>b. For participants who have had experiences with technology implementation:</p> <p>I. What are the benefits that you have experienced with technology implementation?</p> <p>II. What influenced your decision to adopt technology in your agricultural practices?</p> <p>III. What are the challenges experienced with the implementation of technology in your agricultural practices?</p>

	IV. How did you overcome these challenges?
4. How do these antecedents interact to influence decision making with regards to technology implementation in agriculture practices?	4. How do you consider these circumstances are pulled together to influence decision making regarding technology implementation in agricultural practices?

4.7 Data collection

Data was collected through synchronous online semi-structured interviews with 12 participants involved in agriculture activities. This data collection method was selected to provide interviewees with the opportunity to share insights that may not have been thought about before, which enabled the collection of rich and detailed data (Saunders et al., 2016). To gain useful insights based on the focus of this research, the interviews were conducted following the interview guideline presented in Appendix 2. Interview themes that were included in this data collection method derived from a combination of theory, common sense and experience (Saunders et al., 2016).

Acquiring knowledge and interviewing skills were required for the researcher to develop the interviews in a proper way. To do this, the researcher acquired the necessary source of knowledge with investigations and learnings from the topic of interest prior to the development of the interviews. This enabled the delivery of interviews that followed a proper sense of direction in terms of the purpose of this research (Saunders et al., 2016). Furthermore, prior to the development of the interviews, the researcher performed pilot-test interviews which allowed the acquisition of the required competences to conduct quality interviews (Saunders et al., 2016).

Setting a logic flow of information, the interviews were conducted in three stages. First, the interviewer and interviewee were formally introduced. In this stage the consent form was reviewed by both parties and the participant's approval to record the interview for further analysis of information was requested. The purpose of the research was again explained to the participant, which allowed the understanding

about the context of the research and the purpose of the data collection method. Following with the interview process, demographic information of the participant was requested such as age, country, and gender to facilitate identification of participants during the data analysis process. The last stage consisted of the development of the 11 interview questions and discussion with the participants. These interview questions were open-ended and were expected to be responded based on the participants' personal experiences in the agriculture sector. After finalising the interview, participants were thanked for their time and contribution to this study.

The focus of the interviews was on exploring perceptions about technology adoption in the agriculture sector. Therefore, participants were encouraged to openly comment and answer each of the interview questions. Insights provided by participants were carefully listened to and captured with detailed handwritten notes. This allowed the researcher to understand what was told by participants and test this comprehension with the development of probing questions in some cases (Saunders et al., 2016). The two last interviews provided remarkably similar insights and their completion times were shorter because few additional insights were found. Thus, it was determined that data saturation point was reached after finalising the 12th interview.

All participants approved the recordings of the interviews for further analysis. To facilitate data analysis, the researcher created different digital folders for each participant, in which the interview guide, consent form and the interview recordings were saved. Interviews were conducted with participants in El Salvador and Botswana, Spanish and English-speaking countries, respectively. All the recordings were word processed and transcribed by the researcher using audio transcription digital applications. The transcripts generated by these applications were further analysed and corrected by the researcher listening to the recordings and comparing the text of the each of the transcriptions. Furthermore, transcripts of the interviews conducted in Spanish were also translated by the researcher. Each of these transcriptions were saved in the respective folders of each participant to facilitate analysis.

4.8 Data analysis

Inputs for data analysis were the recordings, transcription, and handwritten notes of each of the interviews. Because of the interpretivism philosophy of this study, the analysis of data required the researcher to make sense of the subjective insights provided by the participants on the interviews (Saunders et al., 2016). Qualitative data collection methods provides large volumes of non-standardised and complex information (Saunders et al., 2016). To this extent, the researcher found large quantities of handwritten notes and electronic files that were needed to be explored, synthesised and transformed to address the research questions (Saunders et al., 2016).

Analysis of data in this study was conducted following the Phases of Thematic Analysis suggested by Braun and Clarke (2006). This analysis approach is a method used for identifying, analysing and reporting patterns within data that work to organise and describe data in richer detail (Braun & Clarke, 2006). Advantages of using this analysis approach were flexibility, ease to learn, accessibility to researchers with little or no experience with qualitative research, usefulness of summarising large volumes of data and the capacity that provides to the researcher to highlight similarities and differences across the data set (Braun & Clarke, 2006).

This analysis method begins with familiarisation with the data. To do this the researcher transcribed all the interview recordings and took notes about initial ideas found during the process (Braun & Clarke, 2006). Emphasis was made on participants' expressions when answering the interview questions as non-verbal communication is essential to fully understand their perceptions about the topic of interest (Saunders et al., 2016). On average, completion time for transcribing one interview was six hours and the average translation time per interview conducted in Spanish was four hours. The obtention of accurate data was achieved with a data cleaning process of the transcripts (Saunders et al., 2016).

After the data was accurately transcribed, codes were generated for different units of data to summarise its meaning and facilitate analysis (Saunders et al., 2016). These codes were grouped and collated together with the purpose of gathering all relevant data to each potential theme identified on the interviews (Braun & Clarke,

2006). Themes were defined through the identification of important constructs that were continuously referred to by the participants. These constructs were considered to deliver a useful meaning to address the research questions (Saunders & Lewis, 2018). The list of codes and code groups used for analysis purposes in this study are presented in Appendix 3.

The analysis completion for each interview following the analysis method proposed took approximately four hours, which led to a total analysis time of approximately 50 hours. The data was analysed using qualitative analysis software such as “Atlas. ti” and manually with a Microsoft Excel template created by the researcher. The analysis process was delivered based on frequency of occurrence of certain categories of data (Saunders et al., 2016). Furthermore, the analysis of data was a recursive process, which required the researcher to move back and forth between generating data for analysis and coding it before the generation of the analysis report and conclusions (Friese, 2019), which are presented in chapters 5 and 6 respectively.

4.9 Quality controls

Establishing validity, reliability and minimising bias are considered as key drivers of the scientific rigour of the research (Myres, 2020). Reliability refers to the extent to which data collection methods and analysis procedures will produce consistent findings. Whereas validity refers to the extent to which data collection methods accurately measure what they were intended to measure (Saunders & Lewis, 2018).

As Saunders and Lewis (2018) stated, qualitative research may be considered as subjective by nature and can be affected by different types of bias that can affect the reliability of the research. To ensure reliability of the data collection method, questions on the interview guideline presented in Appendix 2 were standardised for all participants of the study. This guideline contained themes derived from literature and experience gathered by the researcher before conducting the interviews.

Interviewer and participant bias can affect reliability of the research and the researcher took into consideration several factors to minimise these types of bias before conducting the interviews (Saunders et al., 2016). To minimise interviewer

bias, the researcher acquired knowledge doing a thorough investigation about the topic of interest and problems faced by the sample. This was essential to gain participants' trust and reduce interviewer bias by establishing personal credibility (Saunders et al., 2016). To minimise participant bias, the sample was purposively selected. Taking into consideration that the nature of participants should be a strict factor of sample selection (Saunders et al., 2016), participants selected for this study were people involved in agriculture activities from developing nations where the theoretical research problem was identified.

To ensure validity of the research, interview themes were shared with participants before conducting the interviews. This allowed them to prepare information the researcher was interested in collecting (Saunders et al., 2016). Moreover, the provision of the consent form prior to conducting the interviews allowed the researcher to clarify the expected insights from participants during the interviews (Saunders et al., 2016).

Another factor taken into consideration to ensure validity of the research was the arrangement of convenient times and places for conducting the interviews. As the data collection method was synchronous online semi-structured interviews, the participant could not control the location of the participant. However, the participant was requested to attend the interview in a place where external factors could not cause any type of distraction. Furthermore, the researcher made sure that participants selected had a stable internet connection to attend the interview to avoid any type of issues with data collection.

The rigour of this research was ensured by controlling the questioning approach, making sure that insights acquired from participants matched the purpose of the study. The researcher took care of his appearance during the interviews, which helped to gain participant's confidence and provision of valid information (Saunders et al., 2016).

4.10 Research Methodology limitations

The purpose of semi-structured interviews is to explore participants' responses in detail (Saunders & Lewis, 2018). By using online video conference platforms such

as Zoom™, participants' reactions or body language expressions cannot be fully reviewed which could lead to misinterpretations about findings from the data collection method.

Furthermore, using online means as a data collection method requires participants to have technical skills, access to internet, and reading and writing proficiency (Creswell, 2013). This could limit the sample size due to the unequal access to education in rural communities in developing nations (Gulati, 2008), which may also include a lack of experience using online video conference platforms of people in the agriculture sector in developing nations, including the participants of this study.

In qualitative research, the researcher is a key instrument for data collection (Creswell, 2013). Although considerations were taken to minimise interviewer bias, low levels of experience conducting interviews of the researcher could have affected interpretation of some insights from the data collection method. In addition, interviewee bias could have also impacted research findings. Establishing a convenient location for interviewing participants is an important preparation step for conducting interviews (Saunders & Lewis, 2018). Since this location was not established by the researcher due to the nature of the data collection method, which were synchronous online semi-structured interviews (Saunders & Lewis, 2018), external factors from participants' location could cause distractions which could affect their responses during the interview.

Volunteer sampling using a snowball sampling technique was applied to reach some participants in this study. This technique begins with a convenience sample of an initial subject, who volunteers for a snowball sample identifying other participants to whom the researcher has no personal access (Marcus, Weigelt, Hergert, Gurt, & Gelléri, 2017). Although the researcher ensured that the sample remained relevant for this study, snowball sampling results in a homogeneous sample (Saunders & Lewis, 2018), which can generate bias since similar characteristics of participants can lead to low variation levels in terms of point of views and opinions about the topic of interest of the study (Marcus et al., 2017).

4.11 Conclusion

This chapter discussed the research methodology and design followed in this study, the data collection and analysis processes as well as quality controls and limitations of the chosen methodology. This methodology allowed the researcher to explore useful insights derived from participants' perceptions and understand them to successfully answer the Research Questions presented in Chapter 3. Results from the data collection method according to each of these Research Questions will be presented and discussed in the following chapter.

Chapter 5: Results

5.1 Introduction

The purpose of this chapter is to present the results of the study based on the research questions described in chapter 3. This chapter contains the analysis of data collected through the synchronous online semi-structured interviews, which were conducted using video conference platforms. To facilitate analysis of data, a consistency matrix presented in Table 1 was created to relate the research questions with the interview questions that were asked to participants. With this consistency matrix, the researcher ensured that all the research questions were covered during the interviews with the insights collected from the participants of the study.

5.2 Description of the sample

Participants of this study were selected using a non-probability sampling technique. Some interviewees were selected based on the researcher's personal judgement and convenience, while others were contacted using snowball sampling. Participants taken into consideration for this study were people who have been or are currently involved in farming activities in developing nations. The total size of the sample was 12 participants, who were entirely connected through the researcher's own professional network. Within the sample, the researcher found participants who have had experience with technology implementation in agriculture and people who have not had any. Thus, the sampling process was properly aligned with the purpose of this study. A brief description of the type of participants that were taken into consideration for this study is presented in Table 2.

Table 2: Description of Interviewees

Interviewee	Country	Occupation	Additional information
Respondent 1	El Salvador	Agriculture Technician	Respondent 1 is an agriculture technician working in the aquaculture sector in El Salvador. He has worked leading technology implementation for the improvement of the sector such as monitoring devices to control production parameters and improve productivity for farmers in rural communities in the country.
Respondent 2	Botswana	Farmer	Respondent 2 is a full-time farmer who commercialises farming products to supermarkets and local shops in Botswana. Most of the products he grows in his farms are comprised by fruits, vegetables, and livestock.
Respondent 3	Botswana	Farmer	Respondent 3 is a full-time farmer dedicated to the commercialisation of products derived from livestock in rural communities in Botswana.
Respondent 4	El Salvador	Farmer	Respondent 4 is a full-time farmer dedicated to the production of vegetables and consumables derived from livestock in a rural community in El Salvador. He has been working in the agriculture sector since a young age and most of the products grown in his farms are used for own consumption.
Respondent 5	El Salvador	Agriculture Technician	Respondent 5 is an agriculture technician working in the aquaculture sector in El Salvador. She has worked on technology implementation projects to increase productivity in the sector in rural communities of the country.
Respondent 6	El Salvador	Farmer	Respondent 6 is a farmer working at an agricultural institution to promote the sector in El Salvador. He has led technology implementation projects in rural communities in the country to promote development in the sector. He also dedicates to the production of vegetables in his own farms.
Respondent 7	El Salvador	Agriculture Technician	Respondent 7 is an agriculture technician working in the aquaculture sector in El Salvador. He has worked on technology implementation projects to increase productivity in the sector in rural communities of the country.

Respondent 8	El Salvador	Farmer	Respondent 8 is a farmer and agriculture engineer working at the Ministry of Agriculture in El Salvador. He has led monitoring and production control applications with innovative devices such as drones to improve agricultural productivity in rural communities in the country.
Respondent 9	El Salvador	Farmer	Respondent 9 is a farmer who works in the production of vegetables in El Salvador. He is also a business owner who provides monitoring and production control services with drone applications to private farming companies in the country.
Respondent 10	El Salvador	Farmer	Respondent 10 is a farmer working at the Ministry of Agriculture in El Salvador. He has had experiences with technology applications such as monitoring and production control devices to improve agricultural productivity in the sector.
Respondent 11	El Salvador	Farmer	Respondent 11 is a farmer working at the Ministry of Agriculture in El Salvador. He has had experiences with technology applications such as digital trade and commercialisation platforms to improve economic gains in the sector.
Respondent 12	El Salvador	Farmer	Respondent 12 is a full-time farmer working in the production of vegetables and grains for local consumption in a rural community of El Salvador.

The biggest proportion of the sample was comprised by farmers who only worked taking care of their farms. Some of the participants also had a role in agricultural institutions, such as farmers' associations and the Ministry of Agriculture. The smallest proportion of the sample was comprised by agriculture technicians, who were specialist in the development of the sector and their main role is to provide technical assistance to farming communities in their respective countries. Moreover, these agriculture technicians were also specialist in the aquaculture sector, another farming sector which can also be improved with technology adoption.

5.3 Presentation of results

This section presents the analysis results of each of the research questions of this study. As per guided on the consistency matrix, interview questions were designed and grouped following the purpose of this research and to answer each of the research questions.

5.4 Results for Research Question 1

Research Question 1: What does technology adoption in agriculture mean for people involved in the sector in developing nations?

Research Question 1 aimed to understand what people involved in agricultural activities thought about technology implementation in the sector. Two interview questions were created to answer this first research question. The first one was intended to get the participants' opinion about technology adoption to improve agricultural productivity. Insights from this question allowed the researcher to define the level of understanding of each participant about the improvement of agricultural productivity with technology implementation in the sector. The second interview question focused on the benefits of technology implementation in agriculture practices. With this question the researcher was able to determine the level of awareness of the benefits that technology can provide to the sector and the participants' understanding about this.

5.4.1 Participants' perception about technology adoption to improve agricultural productivity

Each participant was able to provide useful insights about their understanding of technology implementation to improve productivity in the agriculture sector based on the conditions of the environment they were immersed in. Some of these answers were concise to the fact that technology does improve agricultural productivity. However, some participants also provided insights about the requirements of successful technology adoption to improve the agriculture sector in developing nations.

Participants' opinions about technology adoption to improve agricultural productivity were grouped into a list of constructs presented in Table 3.

Table 3: Perception of technology adoption to improve agricultural productivity

No.	Construct
1	Technology implementation will be useful as long as the sector has the proper knowledge about it
2	Technology implementation helps to use resources more efficiently
3	Technology implementation leads to better production volumes
4	Technology implementation helps with a reduction of production times
5	Technology implementation leads to better productivity levels and improve farmers' life quality
6	Technology implementation leads to cost reduction
7	Technology implementation improves production control
8	Technology implementation improves trade activities in the sector

Analysing insights from the first interview question, all the participants had an idea of how technology implementation can improve agricultural productivity. Most of the participants agreed that technology implementation would lead to better benefits for the sector only if the people involved have a proper level of knowledge about the implementation. The opinions of participants who stated the importance of

knowledge in technology implementation were similar. To this extent, Respondent 5 stated, “I am in favour of technology being adopted, as long as we are taught good management, the proper handling required by each type of application”. Respondent 1 shared this same thought stating that “technology could increase productivity as long as you have the right monitoring, proper controls, and the right knowledge and expertise for the implementation”. Respondent 8 went even further assigning the responsibility of providing this knowledge to the sector to government entities stating that “Within the framework of new digital agriculture, the Ministry of Agriculture, in this case on the government side, to sensitise and make accessible this training and information must be set as a priority”.

It is important to clarify that these opinions came from agriculture technicians and participants working on agricultural institutions who might know about this because of their experience and roles in these institutions. However, there was a farmer’s opinion that surprisingly matched to what specialist have mentioned about technology implementation in the sector. To this extent, Respondent 12 mentioned:

“Implementing technology in agriculture requires knowledge of what you are going to do. Knowledge on how you are going to prepare the land, how are you going to prepare a planter to place your crops because you cannot place them anywhere”.

Where he referred to a previous preparation of the conditions of the farm according to the requirements of a specific implementation.

The other two more shared constructs among participants in the sample with regards to improving agricultural productivity with technology were related to a more efficient usage of resources for production and the generation of higher production volumes. Respondent 9 pointed out this fact, supporting his opinion with statements such as “With drones you get a lot more tons of product, much more plants per meter compared to doing manual work”, referring to a drone implementation he had carried out in his farm. Respondent 7, an agricultural technician specialised in the aquaculture sector shared this thought by stating “For every 500m they produce on average 14 quintals of tilapia and using aeration we were able to produce 28 quintals”, referring to the benefits on productivity generated by an implementation of aeration systems in ponds for producing fish.

5.4.2 Participants' perception about the benefits offered by technology implementation to agricultural practices

The second question of the interview aimed to analyse the participants' understanding of the benefits of technology implementation in the agriculture sector. This helped the researcher to understand the level of awareness about the benefits offered by technology besides improving agricultural productivity. To fully understand the participants' perception with regards to the benefits of technology implementation in agriculture, each of them were explored in detail. Participants were asked to list what they perceived to be the benefits of technology based on their current situation and actual experience in the sector. From the answers of the participants, a list of 18 benefits presented in Table 4 was created.

Table 4: Perception of the benefits of technology implementation in agriculture

No.	Benefits of technology implementation in agriculture
1	Efficiency improvement
2	Higher production volumes
3	Improves production controls
4	Improves farmer's income
5	Improves farmer's quality of life
6	Improves farmer's health
7	Makes work easier
8	Makes work more precise
9	Improves commercialisation
10	Job generation
11	Diversification of production
12	Improves adaptation to non-controllable factors
13	Improves production quality
14	Promotes education
15	Promotes growth in the sector
16	Promotes taking care of the environment
17	Reduces labour costs
18	Social prosperity

Participants provided a wide range of benefits from which it can be inferred that efficiency improvement was considered as the most predominant benefit provided by technology to the sector for the sample of this research. According to the participants' perception, efficiency improvement is tied to the utilisation of less resources to achieve higher levels of production. It is interesting to point out that participants of this study had a certain level of awareness about this benefit regardless of whether they had experiences with technology implementation or not. For instance, Respondent 2, a participant who has adopted machinery to work in his farms stated, "something that would have taken us three to four days, we can do it in less than three hours with the machineries we are working with". Respondent 4, who has not had any experiences with technology implementation supported this by stating "technology can help making work easier, and we could even have good results during winter, when resources are very limited in this area".

It is worth mentioning that the two more predominant benefits explained by participants were related to the constructs perceived about the impact of technology implementation in the sector on agricultural productivity. However, some of the benefits that participants listed were considered as consequences of improving agricultural productivity. Some participants mentioned that a technology implementation aimed to improve productivity could also improve the farmer's quality of life. For example, Respondent 3, a farmer who was considering the implementation of drones in his farms stated, "I would not be forced to be there full time, I would be able to control everything aerially and even if I am not physically there, I will be able to carry on with my daily activities". Respondent 5 also related the improvement of a farmer's quality of life with an improvement in his/her financial situation, the generation of more jobs, and motivation to receive education to be able to carry out technology implementation, by stating:

"Generally, our shrimpers are located in rural areas right, so this can give it a plus and the improvement of the quality of life of the inhabitants because they would already have higher incomes in the sector, there would be more sources of employment, perhaps many more young people would be motivated to not only study to a high school level but continuing... Continue to train academically because these types of farms don't just need an agronomist or a biologist. They need business

administrators, they need people who can manage projects. There should be other kinds of professions that also add up to the sector”.

Furthermore, some participants also related the improvement of the farmer’s quality of life with an improvement in the farmer’s health with the implementation of technology. Describing current agricultural practices that are harmful for the farmer, Respondent 4 commented:

“Note that these agrochemicals, I call them because I mean, they are fertilizers but... I see sometimes the labels that come there, and some here in the country have been banned and some products are still coming out there. I'm talking about glyphosate, which has to be regulated but apparently is still there. There it's also the “Burst” it's called, it's like to burn grass, that's also coming out there on the market and it's being used in an abundant way. And that is... the effect it causes over time is chronic diseases in the kidneys, kidney failure.”

Where the importance of using technologic equipment to do these activities was highlighted because of the risk to which farmers in the community where he lives were being exposed by applying this type of fertilizers to their crops. To this extent, this same person described the process of applying fertilizers manually with backpack pumps as:

“They are backpack pumps that you have to carry them to fumigate and the person who is fumigating disappears in the middle of the crops. It is impossible to see him because of the smoke and the particles that the pumps spread across the crops and the poor farmer cannot see anything because of that huge smoke cloud of the thing that is being applied to the crops.”

Participants were aware that technology implementation can provide them with better quality of life in terms of health. Respondent 8 supported this fact by stating “People do not want to take health risks by being in contact with agrochemicals, they do not want to carry backpack pumps anymore”, referring to the necessity of implementing drones to take control of the application of fertilizers in farms.

Another important finding from the second interview question was that some participants were aware of the importance of monitoring production parameters and

controls to improve agricultural productivity. Participants who listed this as one of the benefits from technology implementation highlighted its importance to achieve better results improving the productive use of their resources. For instance, Respondent 9, a participant who has adopted drones to examine his crops using satellite images stated, “Performance improves, it is improved obviously because technology identifies things we cannot identify doing manual work”. Respondent 3, who was considering the implementation of the same systems supported this by stating “I will be able to have more control of my production, I will be able to monitor in an easier way what is going on with my crops”. This implies that some participants have identified a sense of urgency for improving their production parameters to achieve a better productive use of the resources in their farms.

5.5 Results for Research Question 2

Research Question 2: What are considered as the antecedents determining technology adoption in agriculture in developing nations?

Research Question 2 aimed to identify and understand the antecedents determining technology in agriculture in developing nations according to the participants’ perception. To do this the researcher first asked the participants whether they have had experiences with technology implementation or not. This allowed the researcher to divide the sample of participants based on experience with technology implementation. Results of this division of the sample are presented in Table 5.

Table 5: Type of experience with technology implementation in agriculture

Type of experience with technology implementation	Number of participants
Digital commerce platforms	1
Automatic irrigation systems	2
None	2
Intensive systems to control parameters of production	3
Pest control devices and satellite monitoring	4
Total	12

Findings from the way the sample was divided indicated that most participants have had diverse experiences with technology in farming activities. Only two participants had not been involved with any type of technology implementation in their farms. The purpose of this division was to identify and understand the antecedents determining technology adoption from the point of view of both, participants who have not yet adopted technology and those who have. Thus, different interview questions were designed for both scenarios. On one hand, participants who have not adopted technology in their practices were asked about the different circumstances by which they would consider starting a technology implementation. On the other hand, participants who have adopted technology in their agriculture practices were asked about the circumstances by which they would consider further or additional technology implementation. Circumstances identified during the interview according to participants' perception were considered as the antecedents determining technology adoption since these are decisive factors taken into consideration with regards to technology implementation.

5.5.1 Circumstances which could influence technology adoption in agriculture in developing nations

The interview question directed to participants who have not adopted technology in their practices aimed to identify and understand the circumstances which according to their perception, could influence their decision of adopting technology in their farming activities. Participants were asked to list and explain the circumstances which can facilitate technology adoption for them. This list of circumstances was grouped into four different categories: awareness, training and technical support, financial assistance, and demonstrations.

Most of the circumstances provided by the participants were related, which helped to group them into these four categories. In terms of awareness, both participants (Respondent 3 and Respondent 4) agreed that being aware about specific types of technologies and its benefits based on the current conditions of their farms would be an influencing factor to adopt implementation. Supporting this fact, Respondent 3 who was considering the implementation of drone systems to have better production controls stated:

“We need knowledge, awareness should come from technology promotion made by governments and entities working with the sector. If it were not because I did some research on my own, because I heard that other farmers in neighbouring countries are using these systems, I would have not considered that this is something I should have in my farm too”.

Knowledge gathered from awareness and promotion campaigns carried by the government or entities working with the agriculture sector was considered as non-existent to both farmers. For instance, Respondent 4, who has also not adopted technology in his practices stated that agriculture institutions have not reached the communities where they live to promote technology implementation and demonstrate its benefits to improve agricultural productivity.

Following with training and technical support, both participants stated that this should be provided by the entities responsible for the development of the sector, such as government entities or farmers' associations. They also highlighted the importance of being able to effectively use the implementation to achieve the full benefits of it. To this extent, Respondent 4 stated:

“One of the main things we need... I would say is... perhaps knowledge to be able to implement. Another circumstance is also being trained to effectively work the seeds, because if I have the tools but I don't know what I'm going to do with that technology, nothing will happen.”

Another circumstance that according to both participants would influence the decision of adopting technology was related to economic factors. Referring to how essential the provision of financial assistance and the reduction of production costs are to make a decision about adopting technology implementation in agriculture practices, Respondent 4 stated:

“Imagine, the price of a quintal of corn varies between ten or twelve dollars right now, and to produce a quintal of corn if you do the investment calculations, it costs around eight, seven to eight dollars. And in the year, I receive a profit of two dollars, that's where... there's like a, like it's not giving enough to think about implementing technology.”

Respondent 4 also highlighted the importance of witnessing demonstrations of the benefits of technology implementation before proceeding with the adoption. In the case of having all the facilities to implement a specific type of technology, this participant considered getting to know the benefits prior to implementation as important by stating:

“Perhaps a test before, to see if the technology can be for example suitable for crops here or to adapt to the climate, to our climate here. I think it would have to be done as a test, a pre-test before implementing it.”

5.5.2 Circumstances which could influence further technology adoption in agriculture in developing nations

The interview question directed to participants who have adopted technology in their practices aimed to identify and understand the circumstances which according to their perception, could influence their decision of acquiring newer or additional technology implementation in their farming activities. These participants were asked to identify and explain these circumstances, which were grouped into 5 different categories: awareness, applicability, financial assistance, demonstrations, and training and technical support.

The same as for participants who have not had experiences with technology adoption, awareness was one of the most predominant circumstances identified which could influence further or additional technology adoption for participants who have had experiences with technology implementation. To this extent, Respondent 6 highlighted the importance of being aware of the benefits new technology can provide to improve production and the quality of life of the farmer. Respondent 9 supported this by stating “The first step is to identify a need, then awareness about how to solve this need. In this case, if technology offers the best opportunity to solve this need, the necessary means to adopt it could be acquired by the farmer”. This was supported by Respondent 8, a participant who has worked with technology implementation with the ministry of agriculture. Referring to the requirements of launching a new implementation, this participant stated:

“So, first before releasing a new technology we have to understand it, and I think that very few countries are given the task of raising awareness of new technology and to understand how can really be applied or tropicalized in the country.”

Participants also considered applicability of a new technology as an important circumstance of further technology adoption. According to their opinion, applicability refers to how a new technology adapts to the conditions of their farms. For example, Respondent 8 stated:

“I know many places for example Brazil, uh... that they use mechanical harvesters for coffee, in the case of El Salvador, we cannot because of the slopes in the fields, using this is inoperative. And I would pretend that because Brazil harvests so many millions of hectares a day, I will also be able to harvest all that on a day in El Salvador, that’s impossible... Obviously you need to understand your productive capacity, and think... Ok, I cannot produce volume, but I can produce quality.”

Respondent 9 provided an example of his current application with drones, where he stated, “I have drones because of the size of my farms, it was easier for me to fly drones to apply fertilizers and monitor crops than doing it manually”. He applied this to a situation where farmers would be considering getting these systems as additional technology, and highlighted the importance of understanding the conditions of the farms by stating:

“Because a farmer who only has five hectares... what sense could it make for him to buy a drone? It will be very expensive and economic gains will probably come in a very long-term, if there are any... This is why, it would be better for them to acquire the service instead of the real product. It is not advisable to invest in something that will not be recovered because of the conditions of your farms.”

Respondent 2 also related climate change, which according to his opinion affects the agriculture sector, to the fact of considering further technology adoption. This person pointed out that the climate changing conditions will require farmers to improve and acquire more technology implementation to better adapt and not be affected by the consequences of the climate change in the sector. Respondent 1, an agriculture

technician specialised in the aquaculture sector supported this providing an example of the consequences of climate change to the sector. He stated:

“I see that also lately from 2013, there was an increase in the appearance of diseases within this crop that also became a brake on the progress that was achieved. Many technicians claim it is a result of climate change. In fact, in our midst, it has increased perhaps as in one Celsius degree the... temperature of the waters and also environmental temperature”.

The third most predominant circumstance by which participants would consider further technology adoption was financial assistance. Referring to drone systems, Respondent 9 stated, “they are expensive and because there is a lot of risk of damaging the drone, there are no entities who want to provide insurance or credit facilities to adopt this implementation”, implying that the lack of credit facilities could limit further technology adoption or can inhibit a farmer to even think about getting started with this type of implementation. Respondent 6 supported this by stating “financial support should be provided by government entities, banks or suppliers of this equipment to make it easier for us to access them”. Respondent 9 added to this explaining the lack of support from financial institutions to the sector. He stated, “I was lucky to have a good relationship with some of the biggest sugar cane producers in the country. They have provided me with the financial inputs to carry this implementation, as I provide service to them and also apply it in my own farms”. Participants highlighted the importance of having credit facilities from financial institutions or financial support from the entities responsible of the development of the sector to consider further technology implementation.

The other two circumstances mentioned by the participants were demonstrations and technical support. According to their opinion, these circumstances were tied to each other. For instance, Respondent 6 stated, “technical assistance and support to transfer knowledge, to explain how a system must be utilised to gain higher benefits, will improve technology acceptance”, referring to a relationship between demonstrations and technical support to promote technology in the sector. Two agriculture technicians supported this relationship between circumstances; however, they pointed that technical assistance is needed to follow-up and measure progress of technology implementation. Both agreed that this technical assistance should not

be granted for free to the sector. Based on previous experiences, Respondent 7 stated:

“Farmers have received equipment and free technical assistance for free. However, because of their mindset that does not allow them to save money, they can’t provide sustainability to the implementation. If the machinery needs maintenance, they will say they don’t have money to do it. Same happens with technical assistance, if something needs to be corrected on the machinery, they will say they don’t have money to get a specialist and check it. There is no sense of empowerment of the implementation because it was granted for free. I think farmers should be able to borrow money at low interest rates rather than receiving implementation for free because some don’t appreciate things if it hasn’t come out of their pocket”.

Respondent 5 supported this, but also referred to how the integration of these two circumstances could influence farmer’s motivation levels to consider further technology adoption by stating:

“Providing free access to these implementation does not provide any incentive to the farmer. There is no sustainability and all technical assistance efforts result in failure. There should be a trade-off with farmers and institutions, providing them with credit facilities for investment and access to technical assistance. This will generate a sense of motivation in the farmer to sustain the implementation and they will get the benefits from it”.

5.6 Results for Research Question 3

Research Question 3: How do the identified antecedents affect technology adoption in agriculture in developing nations?

Research Question 3 aimed to understand the effect of the identified antecedents on technology adoption in agriculture in developing nations. To do this, the researcher used the sample division created to answer Research Question 2. This division allowed the researcher to understand how the identified antecedents affect technology adoption from the point of view of both, participants who have adopted technology and those who have not. For participants who have not had experiences with implementation, the effect of the antecedents on technology adoption was

determined understanding the reasons why the participant has not been involved with any type of implementation.

For participants who have had experiences with technology implementation, the effect of the identified antecedents of technology adoption was determined analysing different insights from implementation. First, exploring and analysing the benefits of a specific technology implementation, second, understanding what influenced the participants' decision to adopt this technology, third, understanding the challenges experienced with technology implementation, and last, exploring and analysing how the different challenges faced through technology implementation were overcome.

5.6.1 Reasons of lack of experience with technology adoption in agriculture

The interview question of this section that was directed to participants who have not adopted any type of technology implementation aimed to understand the effect of the identified antecedents determining technology adoption by identifying and understanding the reasons they have not adopted technology in their practices. To this extent, the participants were asked to list and explain in detail what they perceived as the main reasons why no technology implementation had been carried out in their farms. This list of reasons is presented in Table 6.

Table 6: Reasons of lack of technology implementation in agriculture

No.	Reasons of lack of technology implementation
1	Lack of knowledge about implementation that can improve the sector
2	Infrastructure of the country and the sector
3	Availability of financial resources
4	Connectivity
5	Technology is not accessible
6	Technological advances in the country

Participants who have not had experiences with technology implementation (Respondent 3 and Respondent 4) agreed and shared that lack of knowledge, infrastructure of the country and the agriculture sector, and availability of financial

resources were considered as reasons of lack of technology adoption in their farming activities. In terms of the lack of knowledge about implementation that can improve the sector, Respondent 3 mentioned:

“We are still in Africa; we are still developing. There is not much knowledge about this, we don’t have much accessibility to resources that can allow us to do what we wish. The main thing is knowledge, we don’t have much expertise.”

Respondent 4 associated this lack of knowledge about implementation to improve the sector to the lack of support from government entities, lack of technical assistance, support, and training by stating:

“Note that the Ministry of Agriculture plays an important role, but here in the area since I have... I already have enough years to live around here, they have visited only a few times only to do a half interview of the crop, and from there... they have not returned. They have not trained us; they have not told us which products to use or in what ways to work best to get the best quality of maize. Or let’s say, not even training us to be able to implement agriculture in a different way here in the zone. It is something that is, only generates an expense of personnel to be able to come and implement the training of a true expert.”

Both participants also listed the poor infrastructure of the country and the agriculture sector as one of the main reasons they have not implemented any technology in their practices. With regards to this issue, Respondent 3 stated:

“Uh, the reason right now is because it wasn't accessible where I live, where I am currently operating. It is only now when they they've put electric transformers or these mobile provider services. Now we can be able to have Internet at the farm. It's been a challenging factor from the past. I think the infrastructure wasn't available in the past, but now it's getting there as the years go by.”

Where he referred to the low accessibility of technology in his country because of the poor levels of infrastructure and development.

Another important factor to mention is that both participants considered availability of financial resources as a reason of not having experience with technology implementation. To this extent, Respondent 4 mentioned:

“I would say that one of the reasons is because the economy. Sometimes there is no... to implement technology you have to have ah... you need to have... can I tell you money?... Or something, a capital gain to be able to implement technologies. But like us in these areas here, all north of San Vicente, all, most of them, here are a lot of farmers in the country and we do not implement nothing else.”

Where he referred to the inability to generate any type of financial gains with their current agriculture practices. Furthermore, he supported this fact and associated it to the lack of support from the government, and entities that commercialize agriculture products by stating that:

“This is probably because perhaps all the transnationals that bring product to the country, sell us nothing else than this way to work, to cultivate and we have not implemented another way.”

Respondent 3 also mentioned that connectivity is an important reason why he has not adopted technology in his practices. He related this fact with the poor infrastructure of the area where he operates and highlighted the importance of having acceptable connectivity levels to be able to receive technical assistance by stating “we need to have good internet first, then we can be trained by any means of technology we might seem to need”. Furthermore, he also mentioned that the poor infrastructure levels affect technology accessibility, and this caused the lack of knowledge and awareness about technology implementation in the sector.

Respondent 4 considered that technology progress in his country is not enough to provide the agriculture sector with sophisticated equipment and tools to improve agricultural practices. He provided a biased opinion about technology advances based on the conditions of the area where he lives about technology advances in the sector by stating:

“The only thing implemented here are backpack pumps and engine pumps. They are called motor pumps here, but that is the most technological thing that is being used.”

There are rare cases of people who from time to time, well, here in the community only one person has a tractor, and we are many farmers in here...”

5.6.2 Benefits provided by technology adoption in agriculture

The first interview question of this section that was directed to participants who have had experience with technology implementation aimed to identify and understand the benefits provided from the application of technology in their farming practices. To do this, participants were asked to list and explain in detail the benefits this implementation has provided them in their practices. A wide list of benefits from implementation was provided, which were grouped into seven different categories by the researcher to facilitate analysis. The verbatim description and the categories under each of the benefits could be associated according to the researcher’s judgment are presented in Table 7.

Table 7: Benefits perceived with current technology implementation in agriculture

Category	Benefits
Better commercialisation	Change from subsistence to commercialisation
	High production for commercialisation
	Improvement of commercialisation
	Increase in earnings by commercialisation
Cost reduction	Inputs cost reduction
	Labour costs reduction
	Reduction in production times
	Saves money
Easier adaptation to non-controllable factors	Accurate control of production parameters
	Improvement in production control for adaptation to non-controllable factors
	Improvement in production controls and monitoring
	Makes control and monitoring easier
Economic growth	Improvement of the sector

	Job generation
	Promotes economic, social, and environmental sustainability
Higher production quality	Improves quality of crops
	Production with higher quality
Higher production volumes	Diversification and increase of production
	Higher number of products
	Higher number of units produced
	Increase in production volumes
	Increase of productivity
	Increase in production
	Innovation to increase productivity
	More production in shorter time
Improvement of farmer's quality of life	Improvement of farmer's financial situation
	Improves farmer's quality of life
	Increase in income
	Makes operations easier
	Promotes education
	Provides farmer with more confidence to operate
	Reduces man labour
	Social prosperity
	Takes care of farmer's health

A list of 34 benefits was provided by participants who have had experience with technology implementation. The categorisation of benefits facilitated analysis and each of these categories were discussed in detail.

Most participants agreed that technology implementation has provided them with higher production volumes and lower costs. To some of these participants, these benefits have allowed them to improve their quality-of-life conditions and to move from a subsistence agriculture to agriculture as a business. Referring to changing the

focus of agricultural activities from subsistence to commercialisation, Respondent 8 stated:

“If we can't make that change in terms of people's mindsets, to be able to guide them to be more productive or more profitable, we will continue in these called subsistence or developing countries because we have favourable Central American climatic conditions for many special crops, especially fresh fruit, vegetables”.

Respondent 6, who has experienced higher production volumes with technology implementation supported this inference, by stating:

“This allows one to diversify crop production on a plot applying a new technology. For example, the irrigation systems that I have implemented have allowed me to get more production and not only of corn or beans... Let's say, I've already been able to harvest cucumber, uh... tomato, and zucchini. Then... well, I also have a plot that I used to grow only corn, now I also grow papaya there”.

In terms of costs reduction, a big proportion of the participants agreed that technology implementation helps farmers to save money by reducing labour and inputs costs, and production times. To this extent, Respondent 10 stated, “technology helps to reduce costs, and this can provide farmers with opportunities for saving money. These savings can be strategically used for getting additional equipment to simplify work in the sector”. Respondent 8, referring to the reduction on input costs supported this fact stating:

“I used to make 15 applications of agrochemicals in my crops manually. Now with technology, I have been able to reduce the number of applications to 4 or 5. I have saved a lot of money with this, which at the end reduces the cost of the quintal of produced output”.

Half of the participants who have had experiences with technology implementation indicated that technology can improve farmer's quality of life. Supporting this, Respondent 6 stated:

“I think we need to move from traditional agriculture practices to more sophisticated ones with technology implementation. The use of more sophisticated equipment and machineries will help us to facilitate operations for us”.

Moreover, Respondent 5 added to this mentioning that technology adoption not only improves the living conditions of the owner of the technology, but also of those who work in his/her farms, opening a path to achieve social prosperity in the communities they are immersed in.

Another important finding from the analysis was that some participants indicated that having higher production volumes led to improved commercialisation of products. Respondent 5, who supported this mentioned that having higher production volumes has allowed the improvement of commercialisation by improving distribution channels, allowing the farmer to supply more products to more customers.

Respondent 1, supported that higher productivity volumes result in benefits for the entire supply chain of the agriculture product by stating:

“For example, when you say, you produce more you use more inputs, right? In order to achieve these other realities and also reach higher volumes, that means that you also produce more and there is also a direct effect for people who are directly say, in cultivation, for the people that harvest, for the people who commercialize and finally for people let's say, that consume the product. So, yes, there's one, like... like a route that gets a little bigger with technologic implementation”.

Some participants also considered that technology implementation in their practices has led to the easy adaptation to non-controllable factors such as change in climate conditions. All the participants who highlighted this benefit agreed that technology provided them with the right means to control and monitor production parameters in an easier and more accurate way. To this extent, Respondent 6 stated, “the changing climate conditions can affect the soil properties and damage in a significant way the crops. Technology can help you to monitor these parameters and control the level of nutrients of your crops to keep up with production even with these natural conditions affecting the soil”. Furthermore, Respondent 9 added to this point stating that

“controlling in an easier way production parameters can improve the product quality because technology can identify problems the human eye cannot see”.

Economic growth in the sector was also considered by some participants to be achieved with the implementation of technology. Respondent 10, who referred to this, stated:

“Technology can create social, economic, and environmental sustainability. Technology can improve farmer’s economic conditions, quality of life, and it is beneficial for the environment. This in the end leads to economic growth”.

Respondent 5 and Respondent 9 agreed that one of the reasons why technology implementation leads to economic growth is because it generates more job opportunities in the sector and provides farmers with the economic capacity to hire more competitive labour to take control of these innovative applications.

The last category of identified benefits from technology implementation was the improvement on production quality. Two participants mentioned that technology implementation has allowed them to have higher volume of quality products. Respondent 2 added to this fact, by stating:

“I consider myself as a small farmer. I produce tomatoes, beetroot, onions, butternut, and other products. Technology adoption has allowed me to commercialise with supermarkets because besides my volumes of product have improved, I can also produce quality products that fulfil the required quality standards in these supermarkets”.

5.6.3 Factors that influenced technology adoption

The second interview question that was directed to participants who have had experience with technology implementation aimed to identify and understand the factors taken into consideration by them to adopt technology implementation in their practices. To this extent, participants were asked to list and explain what influenced them to make this decision. Influencing factors described by participants who have had experience with technology implementation were grouped into nine different categories. These are presented in Table 8.

Table 8: Influencing factors of current technology implementation

No.	Influencing factor
1	Sense of urgency to improve economic situation
2	Awareness and promotion campaigns
3	Benefits demonstration
4	Access to technical assistance
5	Trials
6	Ambition
7	Sense to improve farmer's life conditions
8	Benchmark
9	Market competitiveness

Most participants agreed that a sense of urgency to improve their economic situation was an influencing factor that determined their decision to implement technology in their farming practices. As described earlier, participants were aware of the benefits of technology in the sector and most of them knew about the improvement on economic gains that can be achieved with technology implementation. Respondent 8, who has implemented aerial monitoring systems with drone implementation stated:

“Previously in monitoring, people were doing it walking or in vehicles and moved to give a general tour of all the pipes. This took approximately two weeks, and it was expensive. This incurred into the cost of the technician, the resource of the fuel, the vehicle, the depreciation, the travels passed by that technician, etc.”

Respondent 9, who has had experiences with the same type of implementation using drone systems for monitoring and fertilizer application supported this fact stating:

“I have a few people working on my farms, I paid them before to take control of this things manually. With this implementation I have been able to improve their quality of work, they earn more now because the implementation has given me the capacity to improve my production and sell more. People who were cutting the infected cane with the “machete” before are the ones now flying the drones and taking control of the pests. So, they have learned how to do this and become more competitive in terms of technology. Also, I now have the capacity to hire more people to take care

of the farm, so in the end this provides a lot of good economic benefits. It improves production and commercialization, and this is why I decided to do it."

The influential factors were similar for most of the participants regardless of the type of technology they have implemented. For instance, Respondent 12, a farmer who has adopted irrigation systems in his farms stated:

"This helped us to produce a little more because the time we dedicated to water the crops manually was used for planning and developing more production in our space. Also, it helped to use efficiently the resources, in this case water. If you pour too much water, you can damage your crops. Then, when you use the technology such as an irrigation system, which is programmed once in the morning and once in the afternoon, then that helps you protect your vegetables, it is something that helps you reduce costs in every way, that you occupy fewer people to work for you and that generates profits."

Agriculture technicians who have been involved on technology implementation in the sector supported this and pointed out the importance of changing the farmers' mindset about technology in the sector. For instance, Respondent 7, a technician specialised in the aquaculture sector stated:

"They are already on another mental level, sincerely. This... I think that even though we can all have the same brain structure, not everyone has the same ability to develop properly. There are people who are smarter. One of them to give you an example, is the biggest producer of tilapia and he started out as a salesman of cream and cheese in his bike and now he's the biggest producer of tilapia. He even sells concentrate and, then when I think that depending on the mental ability that people must visualize the benefits that they can have, uh... I think it depends a lot on that, doesn't it? How people are visualized in how they're going to fix or how their situation is going to improve."

Another factor taken into consideration was the importance of awareness campaigns. To this extent, Respondent 8 suggested that entities focused on the development of the sector should accept the costs of learning and raising awareness to promote technology adoption in the sector. He highlighted the importance of

raising awareness to break the people's paradigm that technology is only a cost and not an investment that will provide better results for the agriculture sector.

Demonstrations were also considered as an important influencing factor of technology adoption. Describing a particular experience working with an organisation dedicated to promoting development in the agriculture sector, Respondent 6 highlighted the impact of the demonstration of the benefits of technology implementation by stating:

"When seeing the benefits of the implementation we were working on and being involved in demonstrations, I decided to personally adopt these systems in my farms".

Four participants considered the influence of technical assistance as important with regards to technology adoption. To this extent, Respondent 11 highlighted that technical assistance can be provided remotely taking advantage of the high internet penetration levels in his country. He stated that "software applications can have high acceptance levels because of the significant proportion of people who are connected, it is only a matter of having a good awareness strategy that provides guidance to people on how to do things". Respondent 1 supported this fact and added that awareness and promotion campaigns should be tied to technical assistance. He specifically provided an example of how the combination of these factors has helped the promotion of technology adoption in the aquaculture sector, stating:

"From 2012 there was a program here at the institutional level that set a standard the, uh... this institution norm and let's say it promoted those who grow crops. And it was created a program where they were helped to improve a little in equipment and technology and were given technical assistance. So, let's say that's what allowed people to adopt pumping systems..."

Other factors considered by participants as influential with regards to technology adoption were the development of trials or pilot tests of an implementation, ambition to grow in terms of production, a sense to improve farmers' quality of life, benchmarking other farmers or countries, and the necessity to grow levels of competitiveness in the market.

5.6.4 Challenges of current technology implementation

The third interview question of this section that was directed to participants who have had experiences with technology implementation aimed to identify and understand the challenges faced throughout the implementation process. To do this, the researcher asked participants to list and explain in detail issues encountered during the implementation process. Based on the insights shared by participants, these challenges were grouped into different categories to facilitate analysis. The list of challenges and its respective categories are presented in Table 9.

Table 9: Categorisation of challenges faced with current technology implementation

Category	Challenge
Attitude	Lack of a vision to change status quo
	Attituded towards change
	Uncertainty of results
	Resistance to change working routines
Economic	Economic resources for implementation
	Risk adversity for investment
	Long-term return on investment
	Availability of economic resources
	Lack of saving practices
Environmental	Climate change conditions
Social	Customer fear of consuming products created with technology applications
	Safety in rural communities limits levels of technical assistance
Technical	Lack of technical knowledge
	Lack of skills to operate the equipment
	Maintenance of the equipment (Specialised people to do it and availability of spare parts)
	Lack of "Know-how"
	Finding the right people to provide maintenance to equipment
	Lack of comprehension of the full benefits of implementation

A list of 18 different challenges was provided which were grouped into five different categories: Attitude, economic, environmental, social, and technical challenges. According to the results from the category of challenges analysis, technical challenges were the most predominant during experiences with technology implementation. To this extent, six of the participants described the issue of having a lack of technical knowledge on how to properly operate the equipment or device of the implementation as the main challenge for the implementation. Two other participants described the main challenge encountered was finding the right people to provide maintenance to the equipment implemented. The last participant described the main issue during the implementation was a lack of comprehension of the full benefits of the implementation.

Respondent 12 considered lack of technical knowledge as the main challenge of the implementation by stating:

“The biggest problem is that sometimes the irrigation system was not well programmed, and it damaged our entire production. Because we couldn't get the right schedule for every irrigation to the plant, or the right amount of every nutrient for the plant for example fertilizer, foliage liquids, root liquids. It generated a big problem because we couldn't program well the system and things were not accurately set for our crops. Because of this, the crop became malnourished, then it started to die. But that happened because we weren't careful when programming the irrigation system, we didn't put everything right. Then, that caused you a problem and you've lost all your production”.

Referring to external factors that can affect technology implementation and the lack of technical preparation in the sector, Respondent 6 stated:

“Well, the other thing is also the lack of technical preparation of our producers, right? Once we faced a pest attack, an attack of bacteria or viruses. Because producers in my farms didn't know how to act to this factor that was affecting our implementation and saw the corn plants didn't grow, they got disillusioned and abandoned production... this affected my production and I think for small farmers this is more catastrophic”.

Respondent 5, an agriculture technician highlighted the impact of not understanding correctly how to operate technology systems by stating:

“A little perhaps on a personal level, it is the question that we even as technicians are learning from this system because basically, we had never worked with intensive systems. The only experience we have had is with one gentleman in his farm. He has been the most successful in terms of productivity, which is at 50 units per meter. But we as technicians when we've tried, the most we work is about 15 shrimp per meter. So, even for us as technicians the truth is that it is a challenge”.

With regards to the maintenance of the new equipment for the implementation, Respondent 9, a participant who has implemented monitoring and pest control with drones stated:

“For now, there are not too many people or specialist who can provide maintenance to these drones. If something happens to the drone and I need to send it to repair, it will take 7 to 10 days to be fixed because I need it to send it to another country and that would be very significant for my productivity”.

The last consideration for technical challenges was the full comprehension of the benefits of the implementation. Respondent 11, who has worked with software applications in the sector stated:

“Technology acceptance will never be good if people don't understand the problem that this application is trying to solve. If people have incomplete information and understanding about the benefits from technology, acceptance levels will remain low in our country and the ones who adopt it will not use it the way it is meant to be used”.

Economic challenges were considered as the second most predominant type of challenges identified during technology implementation. These challenges were related to availability of economic resources, risk adversity for investment, long-term returns on investment and lack of saving practices. Four participants described availability of economic resources as the main challenge during technology implementation. To this extent, Respondent 6 described:

“If it weren’t for the support of the NGO, we would have had economic problems to start thinking about technology implementation in this farm. Without it we wouldn’t have had the change to acquire them and improve our conditions in here”.

Supporting this statement, Respondent 9 mentioned:

“Another challenge in the application of technology is the cost, this technology is expensive. I mean, it’s extremely expensive, a drone is expensive, the batteries are expensive, so in the end, uh... it’s a huge challenge to seek funding for this type of equipment, it’s not cheap equipment. Also, you add to this that it is an expensive equipment which can be quickly damaged if not used with precaution. I don’t see anyone wanting to fund it. The banks can do it but there are a lot of conditions in this type of funding that at the end it does not become attractive for the person who is willing to implement”.

Risk adversity for investment was determined as the second main economic challenge for technology implementation in the sector. Two agriculture technicians described experiences where they led technology implementation in which they found high levels of risk-aversion among farmers in the sector in developing nations. Explaining factors that have inhibited technology implementation in the aquaculture sector, Respondent 5 stated:

“Let’s say, there are still some farmers that are still using traditional systems because their economic levels and perhaps failures more than anything with this problem of the increase in temperatures that causes the most mortality of crops in the real systems. This does not allow them many times not even to be able to buy a pumping system, which could help a lot in their ponds to lower salinities, to lower temperatures, to put higher quality water with oxygen. So, because of the same real social issue and most of the investments that are made are really high, farmers have developed a closed mindset in terms of risk adversity for investment. This high mortality rate of crops affects production in a way that farmers are not available to even cover costs”.

Long-term return on investment was also considered as an economic challenge faced during the implementation of irrigation systems. With regards to time spent

until realising financial benefits from technology implementation, Respondent 12 explained:

"When we started doing this experiment because it took a lot to be able to do it because everything was done through the Ministry of Agriculture. They approved all the machinery, but we had to contribute a lot. We had to do a lot of work, we all worked for a certain time without receiving any type of economic gains. I mean, because we were testing the implementation and we needed those resources to survive, to eat... but we knew that the benefits later were going to be good for us. But in those challenges, there are many people who don't prefer to work together, they say: "why aren't we going to earn while I am testing this?". Nobody wanted to take this risk".

The last consideration with regards to economic challenges was identified by Respondent 7. He mentioned that while leading some implementation he could perceive a lack of willingness to save money of people involved in the agriculture sector in developing nations. He explained the implications of this challenge by stating:

"Well, I think the first thing the people's mental scheme. They don't... They don't keep money to invest. That is, people generally produce, get a profit, which is fully used for own consumption. They do not think, because recently I was doing an investigation of what methodologies they've implemented and from those methodologies that they implement, eh... see which ones cause problems for them. So, when I asked them: "Why don't you have an aeration system? They just say: Oh! It's just that it's very expensive. Well, I ask then: "For how long you have been producing tilapia?". They say: "20 years". And in 20 years why haven't they saved a little money to buy these aeration systems? They just say: "Ah then, we spend it all."... So no, they don't have that savings mindset to re-invest in property. So that's pretty hard, and the people who have made it were people who did save a little for their own benefit".

Social challenges were considered as the third most predominant type of challenges during technology implementation. Two participants considered to have faced this type of challenges during the implementation. Respondent 2 explained an

experience with commercialisation of products created with technology implementation by stating:

“You'll find in Botswana people are generally only used to eating watermelons between February or March. But, for us who are able now through technology to have water throughout the year using the irrigation systems to water the plants has enabled us to produce watermelons earlier. By September, by now or even by the last month some of these are already in the market. Now... those people won't even buy these watermelons because they believe they are not in the right season and are not watermelons from February”.

Another important social challenge described by participants is how technology accessibility in rural communities can be affected by safety issues. Respondent 8, who has applied monitoring applications with drones and led these types of implementation in rural communities mentioned:

“Safety is one of the most sensitive issues, because there are very dangerous places. Being able to get into communities that are ruled by gangs... Elsewhere, they can be terrorist groups, in Africa obviously there is the issue of those, of separatist groups and the whole thing, then there is an issue, perhaps the issue of social safety. You can't go anywhere anytime you want because you don't... or you have to coordinate with someone or security, the same security of the state in order to enter. Let's say the first problem I have, it's safety.”.

Attitude towards technology implementation was also considered to be predominant in the sector. Two agriculture technicians who have led technology implementation identified within farmers of communities where they worked wrong attitudes towards change and a lack of vision to change the farmer's living conditions. To this extent, Respondent 7 stated:

“It also exists, eh... a culture of "waiting for help to be put in your hand". They don't do anything to change their situation. That's a culture deeply rooted in our country. People want to be given everything for free. So, breaking with that mindset of "I'm waiting for what the government is going to give to help us" culture is a very difficult thing because they always ask: "what are they going to bring us?"”.

Respondent 5, the other agriculture technician who pointed out attitude challenges during implementation stated that there is a big barrier to improve technology adoption with people being sceptical to change in the sector. Respondent 9, a farmer who has adopted technology in his farming activities supported the fact described by the two agriculture technicians. He highlighted that attitude challenges are predominant in the sector because of the uncertainty of results, which could lead to wrong attitudes of farmers towards technology adoption.

The last predominant challenge considered by participants were environmental challenges. To this extent, Respondent 8 explained the implications of changing climate conditions to monitoring applications with drone systems by stating:

“Second limitation I have faced, uh... weather conditions, conditions are changing very fast, eh... there are times when I have an excellent condition to be able to do the application of drones, but weather is changing, I could stay and say with certainty "from 8 am I start applying and I will end at 10:00-10:30 am because I have a good climate". However, sometimes is not possible... suddenly I start at 8:00, stop at 8:20, at 9:00 I can do it again, then that climatic part to make efficient applications, is very variable. And I can get there with a goal of 100 hectares daily but if the weather condition doesn't allow me, that's a very big challenge.”

5.6.5 Overcoming technology adoption challenges

The fourth interview question of this section that was directed to participants who have had experiences with technology implementation aimed to understand how challenges faced through technology implementation processes were overcome. To do this, the researcher asked participants about the required actions that were taken to address each of the challenges they listed on the previous section. This list of challenges and its respective actions to overcome them is presented in Table 10.

Table 10: Actions taken to overcome challenges faced with current technology implementation

Challenges	Required action to overcome challenge
Lack of "Know-how"	Technical assistance and field schools
Resistance to change	Technical assistance and demonstrations
Finding the right people to provide maintenance to equipment	Continuous search of qualified people to work in maintenance of the machineries
Customer fear of consuming products created with technology applications	Awareness and promotion of healthy living in the country used as an advantage to commercialise products before natural seasons
Lack of skills to operate the equipment	Promote constant learning even for technicians and learn from other countries, farmers, institutions
Risk adversity for investment	<ul style="list-style-type: none"> • Awareness • Promotion of farmers' associations to collect required funds for implementation
Lack of technological knowledge	<ul style="list-style-type: none"> • Technical assistance • Learning about implementation
Economic resources for implementation	<ul style="list-style-type: none"> • Support from the employer (Agriculture organisation) • Support from private companies • Farmers' association to facilitate financial assistance
Lack of saving practices	Credit facilities by financial and governmental institutions
Lack of a vision to change status quo	Trainings and demonstrations
Safety in rural communities limits levels of technical assistance	Identification of safe areas to operate
Climate change conditions	Change application schedules

Maintenance of the equipment (Specialised people to do it and availability of spare parts)	Maintenance process learning and self- operated
Uncertainty of results	Technical assistance and support
Resistance to change working routines	Education, motivation to improve conditions of the farmer and developing a mindset open to change
Availability of economic resources	Joined farmers' association
Lack of comprehension of the full benefits of implementation	<ul style="list-style-type: none"> • Technical assistance • Support and online communication and interaction with specialists
Long-term return on investment	Adapted to the implementation process (testing as an initial stage)

Two different perspectives about the actions taken to overcome challenges faced during technology implementation were gathered during the analysis. On one hand, the list of actions taken provided by agriculture technicians came from a perspective of providing a solution to the farmers while leading implementation processes. On the other hand, farmers' perspective about these actions were related to the processes by which challenges faced were solved. Therefore, to facilitate analysis, these countermeasures were grouped by type of challenge and participant. The analysis based on the agriculture technicians' point of view is presented in Table 11.

Table 11: Actions taken grouped by type of challenge faced by specialists in the field

Participant Type	Type of challenge	Required action to overcome challenge
Agriculture Technician	Attitude	<ul style="list-style-type: none"> • Awareness • Technical assistance
	Economic	<ul style="list-style-type: none"> • Promotion of farmers' associations to collect funds easier • Support from financial institutions
	Technical	<ul style="list-style-type: none"> • Education and learning • Technical assistance

According to agriculture technicians, technical assistance was essential to overcome some technical and attitude challenges faced by farmers during technology implementation. In terms of improving technical knowledge and skills, Respondent 1 stated:

“There was a methodology called field schools. What we did there is practically field visits in which we provided assistance to a group of farmers and taught them about specific topics that are essential for the development of crops. We came to have a field school with an average of 25 producers and the particularity of that experience is that we worked directly in their ponds for them to understand how to treat and take care of their product during its growth cycle”.

Respondent 7 highlighted the importance of different types of technical assistance that should be provided to improve farmers' skills to make successful implementation:

“There are different types of technical assistance, right? Because for example marketing affects them, we should have experts in the area who are looking the best marketing strategies for them and everything with expert people in the field. Because they are producers, they are not marketers. Once you have already assembled a system well, economically they should be strengthened. Then, they will be able to maintain the system, but there would have to be technicians, they need to pay for this technical assistance...”

Respondent 1 also stated that technical assistance helped to change farmer's attitude towards changing their work routines. He explained an experience with a farmer who was not using the right inputs to feed his shrimp crops and highlighted the importance of showing farmers the benefits of correctly using the implementation by stating:

"There was a gentleman who had two ponds and little ones. As of an average of 1 hectare, I noticed that he fed shrimps with corn grains as if they were chickens and I explained to him that probably that was not the best alternative to do it. I explained the benefits of using concentrate already specific to shrimp because there are concentrates already specific for it, then he tells me, "but I have years of working like this and my crop is fine"... We made an experiment, in one pond we worked with his feeding system and in the other one we used the concentrate. Then we sowed it with equal planting densities, at the same time and waited for further results. At the end, the difference in production was significant, in the pond he used traditional food to feed the shrimps, he only produced six quintals or 600 pounds. In the other, where we used concentrate, we got 1300 pounds. So, once he noticed that the production volume changed, he was able to realise that he had missed the change of generating more".

Technicians also mentioned the importance of awareness to help overcome attitude challenges faced by farmers. Respondent 7 described how important it is for farmers to be aware of the benefits that technology can provide them to create a vision directed to change their quality of life. He explained one case of a person who was motivated by these campaigns, by stating:

"There are people working in the area for 30 years or 40 years and they remain in the same poverty, they remain in the same poverty. And there's a private producer, uh... who realized about the importance of technology with these awareness campaigns, who has less time working in the sector and now is the biggest producer. But why? Because this gentleman says that when he needed to tighten his belt and eat less, he kept money to invest again... well, now he has about 70 hectares, so you have an idea, he's the biggest producer. But he says that when you have to tighten your belt, you have to tighten your belt to re-invest".

In terms of economic challenges, technicians mentioned the importance of support from financial and government institutions to improve development in the sector. However, they highlighted the important role of farmers' associations to acquire this support. Referring to the easier collection of funds for implementation with groups of farmers and associations, Respondent 5 mentioned:

"A project has now been reached with the Ministry of economy, which is "Productive Coordinators". The purpose of this project was to support shrimp farmers' associations with projects for the adoption of new technologies. They allocated \$125,000, from where farmers' associations had to finance the 10% of the implementation. So, there is always like that part, that they have to put a certain amount to be able to execute the project".

Findings from the farmers' point of view on how challenges faced were overcome are presented in Table 12.

Table 12: Actions taken grouped by type of challenges faced by farmers

Participant Type	Type of challenge	Required action to overcome challenge
Farmer	Attitude	<ul style="list-style-type: none"> • Technical assistance
	Economic	<ul style="list-style-type: none"> • Adaptation • Institutional support • Promotion of farmers' associations to collect funds easier • Support from private companies
	Environmental	<ul style="list-style-type: none"> • Change application schedules
	Social	<ul style="list-style-type: none"> • Awareness • Education and learning • Identification of safe areas to operate
	Technical	<ul style="list-style-type: none"> • Continuous search of qualified people to work in maintenance of the machinery • Maintenance process learning and self-operated • Technical assistance

Farmers also mentioned the importance of technical assistance to overcome technical and attitude challenges. With regards to this, Respondent 12, who faced low productivity because of incorrect operation of the technology implemented stated:

“Well to use it properly we had to hire an engineer, a specialist who explained to us how to organize and how to program an irrigation system. So, mmm... The engineer taught us how to program it every time the irrigation system had to be used. It is not that easy because the system has several tanks in different areas, it is a pump that extracts all insecticides, fertilizers, everything goes separately. It is a single system that handles all of this. But it carries it is programmed for different areas... So, this engineer had to explain to us how everything worked to properly use the system...”

Technical assistance was also considered a contributor for solving attitude challenges. For instance, Respondent 9, who pointed out that uncertainty of results was one of the main challenges before starting with an implementation, highlighted the importance of technical assistance from specialists to overcome this. He mentioned that this support throughout the first successful round of the implementation motivated him to acquire more equipment, which has provided him with more benefits.

As stated by agriculture technicians, the promotion of farmers' association to facilitate financial support helped some farmers to overcome economic challenges. Respondent 6 supported this statement explaining that individual financial support for technology implementation in his farms could only be achieved with private companies and institutions, highlighting the importance of having credit or financing facilities from government institutions to promote the development of the sector. This financial support from government and financial institutions was considered as essential to promote technology adoption in agriculture in developing nations. To this extent, Respondent 9 stated:

“If we want to improve the sector with this implementation, if we want to reach every corner in the agriculture sector, we need support from financial institutions. We need to be able to take credits and insurance for getting new and sophisticated equipment to boost productivity in the sector”.

Social challenges faced by farmers were related to fear of consuming products that have been created using technology implementation and safety in rural communities. Two participants affected by this considered education, awareness, and the identification of safe areas to operate as contributor to overcome these issues. With regards to safety in rural communities, Respondent 8, a participant who works with drone systems for monitoring crops mentioned that technology adoption levels could be affected because of the low safety levels in most of the rural areas. He also mentioned that climate change conditions have required them to change schedules of application to overnight schedules, which could pose safety and security risks.

5.7 Results for Research Question 4

Research Question 4: How do these antecedents interact to influence decision making with regards to technology implementation in agriculture practices?

Research Question 4 aimed to understand the interaction between the identified antecedents to influence the participants' decision to implement technology in their practices. Results from Research Question 2 allowed the identification and understanding of the circumstances by which farmers would consider starting with technology implementation in their farming practices or acquire additional applications. The list of circumstances which could influence technology adoption described by participants are summarised in Table 13.

Table 13: Circumstances determining technology adoption in agriculture in developing nations

No.	Circumstances
1	Awareness
2	Financial Assistance
3	Applicability
4	Training and Technical support
5	Demonstrations

According to most participants awareness was the most predominant antecedent determining technology adoption. Most agreed that awareness about the benefits of

a specific technology is essential for implementation. Moreover, the provision of awareness campaigns by governments or entities working in the development of the sector was considered as essential to identify current needs and how to solve them with technology implementation.

Financial assistance was also considered as an important antecedent determining technology adoption according to most participants. They agreed that financial support from the government or banking institutions should be provided to promote technology adoption in the sector. Furthermore, this was referred as financial support in the form of grants, accessibility to credit, insurance, and low interest rate loans.

Participants also considered applicability of technology applications to be an antecedent determining technology adoption. To this extent participants stated that to consider technology implementation in their practices there should be a need which can be solved with a specific technology that adapts to their farm conditions.

In addition, participants agreed that training, technical support, and demonstrations are also antecedents of technology adoption. Most of them stated that technology adoption levels in the sector can improve with technical support. Where, the transfer of knowledge with technical assistance and demonstrations on how to use properly the implementation was considered as an important factor that can influence farmers to adopt technology in their practices.

5.7.1 The interaction of the antecedents determining technology adoption in agriculture in developing nations

The last interview question aimed to understand how the circumstances that determine technology adoption should be addressed to consider technology implementation. To do this, the researcher asked participants to explain whether all the circumstances mentioned should be fulfilled to consider implementation of a certain type of technology or not.

Most of the participants mentioned that all the circumstances required to consider technology implementation in their practices must be fulfilled. To this extent, Respondent 12, who considered that applicability of a technology implementation,

financial assistance, demonstrations, and awareness could influence his decision on acquiring additional applications in his farming practices stated:

“You need to meet all four circumstances... because to acquire new technology you need financial resources, you need to see if that will work for you, if that implementation adapts to your farm conditions. Then, you have to prepare the area where you are going to make the implementation, the conditions of my farm should be adapted to this new implementation. So, when you are going to acquire new technology, it requires financial resources, dedication, requires work and having good knowledge to be able to manage it, so that that technology you will use is going to provide you with more benefits than losses.”

Respondent 2, who indicated that awareness and applicability of technology can drive his decision of acquiring additional technology implementation in his practices supported this by stating:

“I think that they are inclusive, they go hand in hand. Because if the market demands more, I cannot produce more under this climate conditions. So, and... if the market demands more, I need the best technologies, and again to survive, I need things that will adapt well to the climate conditions. So, these two factors are factors that work hand in hand, if I need more, it needs to be under the best conditions.”

Respondent 11 highlighted the importance of joining farmers' associations to get financial assistance and training and technical support. He considered these circumstances as determinants of technology adoption in his practices and supported the fact that they should all be addressed to consider further technology implementation by stating:

“I think they go hand in hand. For example, these two of which we were talking about, farmers' associations and technical support, I think they go hand in hand. In fact, let's say, one is almost a requirement of the other. For example, if the Ministry is going to make a technology transfer it does directly to the association and almost it is becoming a requirement for farmers to join these associations to have better access to technology. In fact, the Ministry has created an office called the "division of

agricultural associations" and is precisely responsible for giving support to all those associated farmers. So, I think both circumstances need to stay together."

Respondent 6 also agreed that all circumstances identified should be addressed to improve technology adoption levels in agriculture in developing nations. He considered that applicability of a technology implementation, financial assistance and awareness should be provided to influence his decision with regards to adopt a specific type of technology application in his practices. Supporting this fact, he stated:

"We're not going to acquire for example, we're talking about drones, right? To do a soil analysis in a small space, this is useful for big spaces... And as I said, the other thing is that we are prepared to be able to manipulate that kind of technology. Let us remember that there is implicit knowledge of the education system. And as I said at the beginning, every new technology requires a pretty strong investment"

Only three participants indicated that not all the circumstances must be fulfilled. For them, addressing the main identified circumstance should suffice the decision-making process of adopting technology in their practices. To this extent, Respondent 4 commented:

"I think only one is enough, and then the others will all follow suit. Because if one has the main basis, which is the knowledge of the technology that is thought to be implemented, one already says: "If this... technology make things better than what I did before why not implement it?" It's like switching the mindset for a moment and thinking differently. So, I think that relates to the rest. When I have the knowledge... as I plan to implement this new technology, I will have to make an effort to be able to obtain this tool, for example saving some money to acquire the technology and technical assistance to explain me how to correctly operate the implementation. Knowledge is the main factor that will serve me to be able to implement that technology"

Supporting this, Respondent 10 stated:

"Let's not necessarily say rigorously with all these three circumstances, I think that if there is no education, but the awareness campaigns generated that curiosity, good things can be achieved... for example, I feel in agriculture, demonstration is the most

important thing, because in the end you have to be very clear with people... everyone is going towards the same view, which is economic. Unfortunately, we don't see how technology will improve the environment, we are not interested, if it's a technology that will increase our revenues... that's what we want".

Only Respondent 8 commented that the fulfilment of circumstances depends on the farmer's needs. He mentioned that awareness and adaptability could be main drivers of technology adoption in the sector. However, according to his perception, the fulfilment of these circumstances could vary according to the farming systems' size. He stated that large household farmers could only require awareness of the benefits of technology adoption to make a decision because having bigger farms and areas to operate could facilitate adaptability of the implementation. In contrast, he mentioned that small household farmers could need both awareness of the benefits of an implementation and adaptability to their farm conditions. Referring to adaptability, he explained that any change on the farm conditions will be more significant for small farmers with the following analogy:

"Obviously for a person who administers 100 hectares of corn, some things are not so sensitive for him. Example, there are worms in a small proportion of the 100 hectares, for this person this is permissible. But tell a farmer who has only ½ hectare that his corn has worms, he will go, and he will take them out even with his hands."

5.8 Conclusion

This chapter presented the results of the synchronous online semi-structured interviews which were conducted with 12 participants in this study. The detailed insights from the 11 interview questions developed that attempt to answer the proposed Research Questions presented in Chapter 3 were discussed in this section. Based on findings from literature review, new insights emerged from participants' perception about the topic of interest. These findings will be discussed in detail in Chapter 6, where a proposed and redesigned hypothetical framework to understand the antecedents determining technology adoption in agriculture in developing nations based on these perceptions and opinions of people directly involved in the sector will be presented.

Chapter 6: Discussion of Results

6.1 Introduction

Findings from the results of the data collection method presented in Chapter 5 are discussed in further detail in this chapter. These insights are compared and contrasted with the findings from the literature review presented in Chapter 2 to address and provide answers to the Research Questions defined in Chapter 3. Findings to be discussed in this section contribute to a better understanding of the antecedents determining technology adoption based on perceptions of people involved in the agriculture sector in developing nations. Furthermore, a new version of the hypothetical framework to understand these antecedents presented in Chapter 2 is proposed, which was developed with the additional findings from the data collection method.

6.2 Discussion of Results for Research Question 1

Research Question 1: What does technology adoption in agriculture mean for people involved in the sector in developing nations?

Research Question 1 aimed to understand participants' perception about technology adoption to improve agricultural productivity as well as the benefits offered by technology in the sector. The focus of this research question was to determine whether participants were aware of the theoretical benefits technology implementation can provide to the sector, which were identified on the literature or not.

6.2.1 Participants' perception about technology adoption to improve agricultural productivity

Participants in this study were asked to explain their perception about technology adoption to improve agricultural productivity. Table 3 presented a list of constructs that derived from their opinion about this topic. All the participants were able to provide useful insights about their perception on how technology can improve

agricultural productivity based on the farming conditions they have been immersed in.

Findings from literature suggested that technology implementation can improve levels of productivity in the agriculture sector (Bekun, 2015). In addition, Deichmann et al. (2016), suggested that in order to achieve higher levels of productivity, farmers should be aware of the existence of technologies and how to use them effectively. These insights were consistent with participants' perception about technology adoption to improve agricultural productivity since most of them highlighted the importance of knowledge about the correct use of the implementation to achieve the benefits offered by any technology implementation.

In addition, participants stated that technology adoption can improve productivity by allowing farmers to use resources in a more efficient way and have a better control of production, which leads to higher production volumes, and reduction of production times. This is in line with findings from literature. For instance, Rehman et al., (2017); Gacar et al., (2017), suggested that technology applications can allow farmers to use resources in a more efficient way and have better production controls, which can reduce input and labour costs leading to higher levels of productivity.

6.2.2 Participants' perception about the benefits offered by technology implementation to agricultural practices

Besides understanding participants' perceptions about technology adoption to improve agricultural productivity, identifying and understanding other benefits that technology can provide to the sector was taken into consideration to answer Research Question 1. Therefore, participants were also asked to list and explain other benefits that according to their perception can be provided to the sector with technology implementation. These findings were summarised and presented in Table 4.

All participants were able to provide benefits that according to their perception can be achieved with technology implementation regardless of their experience in the topic. The three most predominant benefits that participants shared were related to the improvement of agricultural productivity. For instance, participants stated that

within the wide range of benefits provided by technology implementation farmers can improve efficiencies, achieve higher production volumes, and improve production controls. These benefits were already discussed in section 6.2.1, however, other benefits listed by participants could be interpreted as consequences from improvements in agricultural productivity such as improvement of farmers' quality of life and health.

In terms of improvement of farmers' quality of life, participants mentioned that technologies aiming to improve agricultural productivity can result in higher commercialisation levels, which may improve their financial situation. Furthermore, they added that technology can make work easier as man labour requirements are reduced with innovative application systems. Bekun (2015), supported this by stating that the lack of technology implementation in the sector has contributed to the low levels of productivity evidenced in developing nations, causing agriculture to serve mainly as a source of subsistence due to low levels of commercialisation. Gondchawar and Kawitkar (2016), stated that the implementation of integrated technology systems can reduce labour requirements and facilitate efforts to achieve desirable levels of productivity. Thus, findings from participants' perception were supported by the literature.

Participants also stated that technology implementation can improve farmers' health and safety conditions since manual work can pose harmful risks to them. For instance, participants described that exposure to agrochemicals applying fertilizers manually can have strong implications on their health. These findings were consistent with findings from literature, since Midingoyi et al. (2019), stated that technology implementation can deliver positive outcomes for both the environment and farmers' health. They described that innovative pest management devices can facilitate pest control and monitoring in crops and reduce the harmful effects of insecticides on human health.

According to the participants' opinions, effective monitoring and production controls were important benefits that technology can provide to the sector. Some of them highlighted that improvement on production parameters may lead to better productive use of their resources and improve benefits obtained from farming practices. Again, this was supported in the literature with the description of the

benefits that precision agriculture can provide to farmers. Rehman et al. (2017), stated that precise monitoring and control can lead to better use of resources by reducing human error.

6.2.3 Conclusive findings from Research Question 1

Research findings determined that participants were aware of the benefits provided by technology implementation to the agriculture sector identified in the literature. Participants provided their opinions about technology adoption in the agriculture sector and all were consistent with the theoretical finding that innovative farming practices can lead to higher levels of productivity (Bekun, 2015). Furthermore, participants indicated what are perceived as benefits from technology implementation regardless of their experience with these systems, which indicated the existence of positive perceptions about technology adoption. Further analysis will help to determine what are considered as the antecedents determining this adoption, the effect of each of them in decision-making with regards to implementation and the interaction between these antecedents to determine technology adoption in the sector.

6.3 Discussion of Results for Research Question 2

Research Question 2: What are considered as the antecedents determining technology adoption in agriculture in developing nations?

Research Question 2 aimed to identify and understand what was perceived by participants as the antecedents determining technology adoption in agriculture in developing nations. Furthermore, this Research Question aimed to confirm that the four antecedents identified in literature: economic; institutional; household; and, technology characteristic factors (Deichmann et al., 2016; Larson et al., 2016; Mwangi & Kariuki, 2015), were in fact considered by participants as the antecedents determining technology adoption in the sector. In chapter 5, the circumstances which could influence technology adoption according to participants' perception were considered as the antecedents determining technology adoption since they were referred to as decisive factors with regards to technology implementation.

6.3.1 Circumstances which could influence technology adoption in agriculture in developing nations

Participants who did not have any type of experience with technology adoption were required to list and explain the circumstances which could influence their decision with regards to technology adoption in their practices. Findings refuted the literature in terms of the existence of four antecedents determining technology adoption. According to these participants' perception, only institutional, economic, and technology characteristic factors were identified as antecedents which could influence their decision with regards to technology implementation in their practices.

The most predominant circumstance considered by participants who did not have experience with technology implementation was awareness. According to them, being aware of specific types of technology and its benefits based on the current conditions of their farms may influence their decision to adopt innovative systems and technologies. This supports findings from the literature review, since awareness is considered as an influential institutional factor that determines technology adoption in agriculture in developing nations (Mwangi & Kariuki, 2015). Furthermore, participants' opinions were consistent with findings in literature proposed by Bardhan and Mookherjee (2011), who stated that in order to increase technology adoption levels in developing nations, farmers should be aware of its existence, must believe that technology is beneficial for them and must know how to use it effectively (Deichmann et al., 2016).

Participants inferred that awareness may provide them with the required levels of knowledge through the exchange of information about technology implementation, which could influence their decision about whether to adopt a specific type of technology or not. This inference is supported in literature since it was found that timely access to information can influence farmers' decision-making with regards to implementation (Liu et al., 2018). Moreover, Bonabana-Wabbi (2002), stated that access to information reduces uncertainty and changes farmers' perception about technology to a more objective basis. This objective perception according to participants is achieved through knowledge gathering about the different technologies to improve the sector.

Participants stated that this awareness should be provided by government entities and institutions involved in the development of the sector. They also highlighted the importance of the support from these entities. According to their perception, this support has been non-existent in the communities where they live and work. Literature supported this finding from the data collection method. Deichmann et al. (2016), stated that public extension agents should reduce information gaps about technology implementation and its benefits to promote its adoption. Furthermore, extension agents' roles were considered to provide reliable, consistent and accurate information about the existence of technologies that can solve identified needs in the sector (Mwangi & Kariuki, 2015).

Liu et al. (2018), stated that extension agents that provide information and support to the sector are considered as another institutional factor that determines technology adoption. This was supported with the findings of the data collection method, since participants highlighted the importance of training and technical support provided by these entities to correctly operate new technology systems. Participants considered that the provision of technical support and training about benefits from implementation and how to effectively use technology are important factors that could determine technology adoption. Mwangi and Kariuki (2015), suggested that proximity to these agents can influence technology adoption as they act as a connection between developers of new technologies and final users. Bonabana-Wabbi (2002), stated that technical support can undermine education levels of farmers and contribute to the generation of better human capital to facilitate technology adoption levels (Mwangi & Kariuki, 2015; Che & Zhang, 2018).

Another important circumstance highlighted by participants which, according to them, could determine technology adoption was financial assistance. Lack of financial access and credit facilities were considered as essential factors to decide about implementing technology in their practices. Literature supported that economic factors are considered as determinant antecedents of technology adoption (Lavison, 2013; Mwangi & Kariuki, 2015; Larson et al., 2016). Tchamyu et al. (2019), stated that financial access for people who have been excluded from these services should be provided and encouraged within nations and communities where informal financial systems are predominant. Participants highlighted the importance of this type of assistance since it was identified that current farming practices result in high

operation costs, and there is no financial support to adopt new systems that can help them to receive higher net gains.

The last consideration by participants was related to institutional and technology characteristic factors. To this extent, participants highlighted the importance of demonstrations about the benefits of technology to influence their decision on adoption. These demonstrations were expected to be provided by the external agents described previously, thus, a relationship with institutional factors was identified with their perception. In addition, they also commented that suitability of implementation should be tested before deciding about a specific adoption. Participants considered that technologies should be consistent with their farm's conditions. These findings were supported in literature. For instance, Mignouna et al. (2011), stated that technology attributes and characteristics are precursors of technology adoption. Furthermore, technologies that are consistent to farmers' needs and compatible to the farming systems' environment are considered to have higher adoption rates because farmers are more open and receptive to them (Mwangi & Kariuki, 2015).

6.3.2 Circumstances which could influence further technology adoption in agriculture in developing nations

Participants who had experiences with technology implementation were asked to list and explain circumstances which could influence their decision about acquiring additional or further technology adoption. Their responses were grouped into five different categories: awareness, applicability, financial assistance, demonstrations, and technical support. Based on the opinion of participants who did have experience with technology implementation, the identified antecedents determining technology adoption in agriculture in developing nations were also related only to institutional, technology characteristic and economic factors.

In terms of institutional factors, participants who had experiences with technology implementation suggested that awareness may lead to further implementation. This was in line with findings from the literature, which highlighted awareness as an institutional factor that can lead to technology adoption (Mwangi & Kariuki, 2015). In addition, a process of awareness was described by participants. This process

consists of the identification of a need and further investigations of additional technology implementation to solve it. Moreover, participants highlighted the importance of understanding new application processes and the interaction with current implemented systems. Thus, access to good and reliable technical information sources are important for the promotion of technology adoption, as suggested by Liu et al. (2018).

Participants who have had experiences with technology implementation also considered technology characteristic factors could influence decisions of acquiring new or further implementation. They often referred to this as adaptability of a new implementation. According to their perceptions, new technology implementation should be consistent to the conditions of the farms and complement current systems adopted. Furthermore, participants considered that environmental conditions such as climate change may lead to further implementation as farmers need to easily adapt to production condition changes. This is supported in the literature, since consequences of climate change are considered to have a significant effect in the agriculture sector in developing nations (Arslan et al., 2015). Therefore, implementation that is suitable to adapt to these consequences should be promoted in the sector to avoid and address production problems that can arise from changes in environmental conditions (Senyolo et al., 2018).

Similar to participants who have not adopted any type of technology implementation, economic factors were considered to influence decision making with regards to further technology implementation. Participants who have had experiences with technology implementation described them as expensive and the investment requirements of implementation were considered as not feasible without support from financial institutions. Participants highlighted the importance of public access to financial and insurance services since technology implementation was considered to be a risky operation. These findings were supported in literature, Karlan et al. (2014), stated that credit and insurance market constraints can limit investment activities in high expected profit activities. Furthermore, Mwangi and Kariuki (2015) inferred that lack of financial and insurance services in the sector have provided farmers with high levels of risk-aversion, which can affect significantly the sector by reducing general well-being due to the inability to use productively natural resources with technology implementation (Deichmann et al., 2016; Assa et al., 2021).

The last factors considered which according to farmers who have had experiences with technology, can influence decision making to acquire new or further technology implementation were technical support and demonstrations. From findings in the theory, these considerations are related to institutional and technology characteristic factors (Mwangi & Kariuki, 2015; Larson et al., 2016). Participants stated that the transfer of knowledge is essential to operate technology systems in a proper way. They also highlighted that technical support should be provided from the respective entities working with the development of the sector and demonstrations should be provided in a way that allows the farmer to prove and witness the benefits from technology implementation. Participants considered that prior tests with further implementation should be carried out to determine whether new technology acquisition can provide them with more and better benefits or not. Mwangi and Kariuki (2015) and Larson et al. (2016), supported these findings by stating that strategic experimentation can lower levels of risk-aversion and undermine them when performance results of pilot implementation are considered as successful.

6.3.3 Conclusive findings from Research Question 2

The identified circumstances, which are referred to as the antecedents determining technology adoption in agriculture in developing nations according to participants' perception were: awareness, financial assistance, applicability, training and technical support, and demonstrations. Table 14 presents a comparison of the perceived antecedents determining technology adoption by participants in this study and the theoretical antecedents identified in literature.

Table 14: Comparison between theoretical and real antecedents within the context of this study determining technology adoption in agriculture in developing nations

Antecedents described by participants	Relationship with theoretical antecedents
Awareness	Institutional factors
Financial Assistance	Economic factors
Applicability	Technology characteristics factors
Training and Technical support	Institutional
Demonstrations	Institutional

Findings from the data collection method showed that three of the theoretical antecedents identified in literature were relevant according to the perception of participants in this study. None of the participants described circumstances that could influence adoption related to household factors identified the literature review presented in Chapter 2. This fact may be supported with findings from a study conducted by Deichmann et al. (2016), where it was inferred that technology adoption does not depend on the farming systems' size.

Findings from the research allowed the researcher to identify and understand the real antecedents within the context of this study which determine technology adoption in agriculture in developing nations. This allowed further development of the hypothetical framework of the antecedents determining technology adoption in agriculture in developing nations presented in Chapter 2. This new hypothetical graphic representation is depicted in Figure 2.

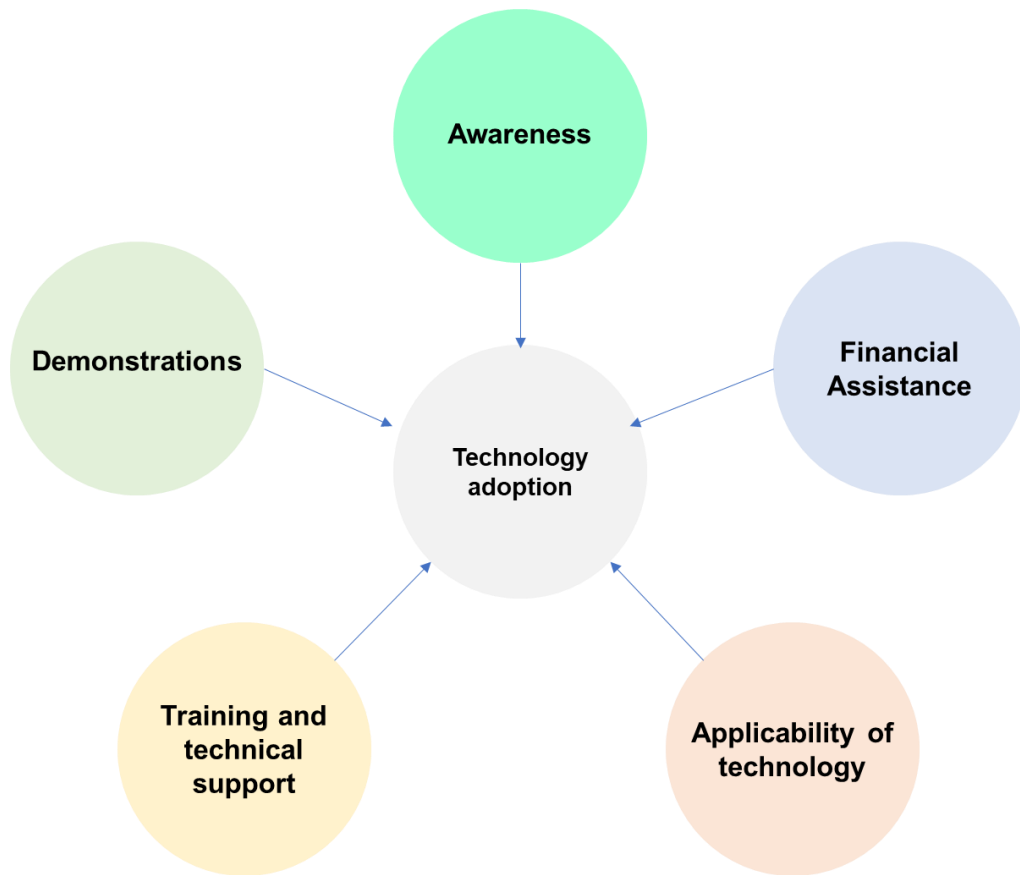


Figure 2: Hypothetical framework of the real antecedents within the context of this study determining technology adoption in agriculture in developing nations.

Each of these antecedents have been explained in detail to answer Research Question 2. However, it is still important to understand the effect and interaction of these antecedents to determine technology adoption in the agriculture sector. Further details about this will be described in the following sections.

6.4 Discussion of Results for Research Question 3

Research Question 3: How do the identified antecedents affect technology adoption in agriculture in developing nations?

Research Question 3 aimed to understand the effect of the identified antecedents on technology adoption. The data collection method supported the identification of participants who had not had experiences with technology implementation and participants who had. For the former, the effect of the identified antecedents was

determined analysing and understanding the reasons that there is a lack of technology implementation. Whereas for the latter, the effect of the antecedents was determined analysing the benefits of implementation, influencing factors for implementation, challenges experienced and how these were overcome during implementation. Each of these insights were compared and related to the antecedents identified in section 6.3 with the purpose of understanding their effect on decision-making processes with regards to technology implementation.

6.4.1 Reasons of lack of experience with technology adoption in agriculture

Participants who had no experience with technology implementation stated that low levels of awareness have affected technology implementation in their practices. For instance, participants stated that the lack of technical knowledge about implementation has not allowed them to adopt technology systems because they do not know about the benefits of technology and how to solve identified needs with innovative technology applications. They attributed this issue of knowledge to the non-existent support from government entities, which has constrained technical assistance, support, and trainings about new implementation, according to their perception. This is in line with literature findings. For instance, Iamsiraroj and Ulubaşoğlu (2015), stated that a lack of knowledge about technology implementation has been predominant in the agriculture sector in developing nations, which has limited benefits and the development of the sector.

Participants referred to the poor infrastructure levels of the country and the sector where they operate as one of the reasons why technology has not been accessible for them. Furthermore, participants stated that infrastructure levels of the sector have been constrained by technological advances in the country. This relates to the determinants of the variation of agricultural productivity around the world described in the literature review. Deichmann et al. (2016), stated that infrastructure conditions of developing nations have limited technology adoption in the agriculture sector. Moreover, Kiwanuka (2015), stated that the existence of infrastructure to support the usage of technology can facilitate technology acceptance. Thus, conditions of infrastructure described by participants may lead to the fact that conditions of infrastructure in developing nations have caused a lack of progress in terms of technology adoption in the agriculture sector. In addition, participants also attributed

low levels of connectivity to the same infrastructure issues. Where, it was described that acceptable levels of connectivity are required to access all means that provide knowledge, training, and technical assistance about technology implementation.

Participants also stated that lack of financial assistance in the sector has limited technology adoption. They explained that financial outputs from current practices do not provide them with the required monetary resources to invest in any type of technology implementation. Furthermore, they recognised that for them the only way to adopt innovative systems is through support from financial institutions, which was considered as non-existent. Literature findings supported this, Gondchawar and Kawitkar (2016), stated that traditional agriculture practices have caused a decrease on the productive use of natural resources, as well as reduced the economic contribution of the agriculture sector to the economies of developing nations (Bekun, 2015). In addition, Diiro (2013), highlighted that lack of financial assistance may lead to pursue off-farm income as a substitute for borrowed capital. However, off-farm income generation can affect technology adoption since it can reduce amounts of labour in farming activities. Therefore, financial support is essential to promote technology adoption (McNally, 2002; Goodwin, 2004; Diiro, 2013; Mwangi & Kariuki, 2015).

The reasons described by farmers who have not experienced technology implementation in their practices were related to two antecedents that determine technology adoption: awareness and financial assistance. A graphic representation of this is presented in Figure 3.

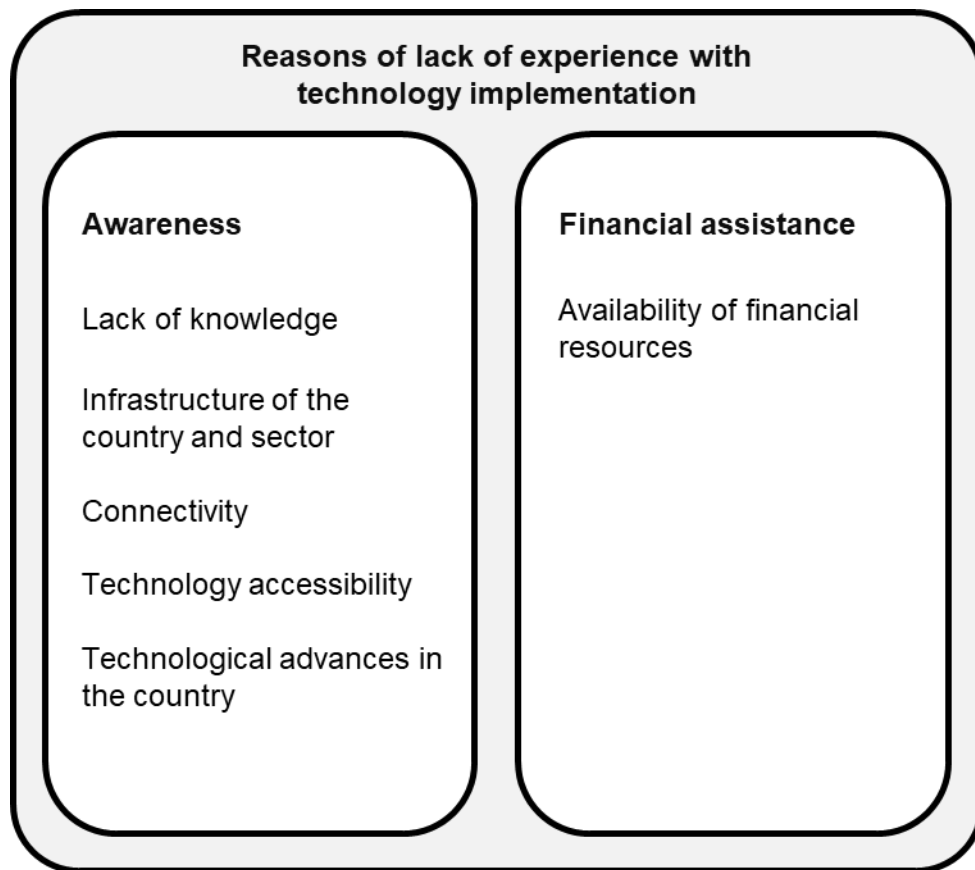


Figure 3: Reasons of lack of experience with technology implementation and their relationship to the identified antecedents determining technology adoption in agriculture in developing nations.

6.4.2 Benefits provided by technology adoption in agriculture

Participants who had experiences with technology implementation were asked to list and explain the benefits perceived with their current implementation practices. The benefits provided by participants were grouped into seven different categories: higher production volumes, costs reduction, improvements on farmer’s quality of life, better commercialisation, easier adaptation to non-controllable factors, economic growth, and higher production quality. The benefits provided were presented in Table 7 and compared with findings from literature review in Chapter 2.

As described in sections 6.2.1 and 6.2.2, participants listed and explained the benefits that, according to their perception, technology implementation can provide to the agriculture sector. All the benefits described by participants were supported by findings from the literature review presented in Chapter 2. In addition, all these

benefits described were compared to the perceived benefits by participants who have had experiences with technology implementation and an alignment between both was determined. Therefore, all the benefits perceived by participants with current technology implementation were identified and supported by the literature.

6.4.3 Factors that influenced technology adoption

The influential factors that determined adoption from farmers who have had experience with technology implementation were identified in the interviews. Participants listed and explained each of the factors taken into consideration to adopt technology in their practices. Each of these factors were categorised and presented in Table 8. For analysis purposes each of these categories were related to the antecedents previously identified. This relationship is depicted in Figure 4.

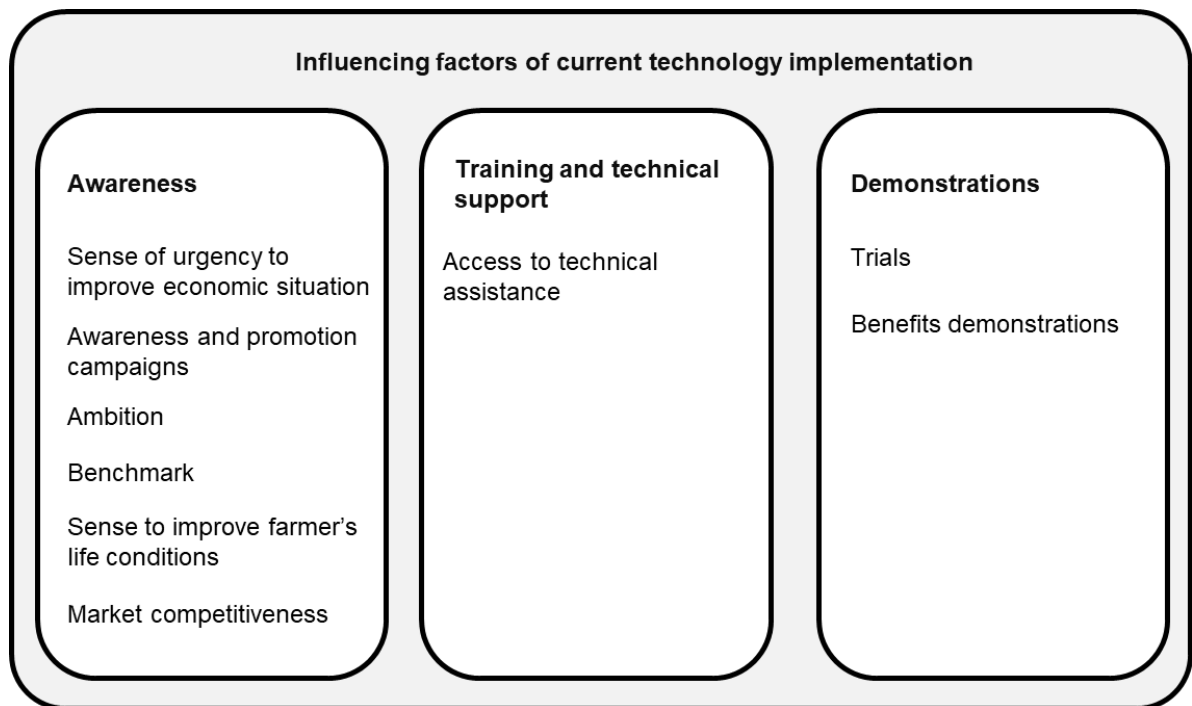


Figure 4. Influencing factors of current implementation and relationship to identified antecedents determining technology adoption in agriculture in developing nations

According to participants' opinions, a sense of urgency to improve farmer's economic situation was the most predominant influencing factor of current technology implementation. Participants stated that being aware of the benefits of technology in

the sector allowed them to recognise a need to improve economic gains from farming practices. In addition, these participants commented that technology implementation indeed improved their economic gains due to a more efficient use of resources, the utilisation of better production inputs, and product diversification. This was supported in the findings from the literature review. For instance, Rodrik (2018), stated that the better use of inputs with application of new technologies can lead to product diversification, which at the end will result into better outputs from farming practices.

The importance of awareness is essential for improving technology adoption levels in the agriculture sector in developing nations (Mwangi & Kariuki, 2015; Larson et al., 2016). Participants' opinions supported this fact. Most of them agreed that raising interest in technology with awareness and promotions campaigns is important to change farmers' mindsets of perceiving technology implementation only as a cost. Furthermore, participants added to this point by stating that awareness provided by these campaigns provided them with ambition to improve their quality of life and increase market competitiveness with improvements in commercialisation.

The importance of training and technical support was also stressed by participants. Remote access to technical assistance was highlighted as an influencing factor that determined technology implementation. This was also consistent with findings from the literature, since BenYishay and Mobarak (2019) stated that the implementation of digital tools has facilitated interaction of farmers with official information channels. Deichmann et al. (2016), supported this by stating that using a combination of voice, text, videos and internet extensions, digital tools can provide farmers remote technical assistance which can facilitate technology adoption.

Trials and demonstrations of the benefits of technology also influenced participants decision with regards to technology implementation. Participants commented that witnessing the benefits from implementation was an influential factor in implementation. Again, this was supported in the literature. According to Mwangi and Kariuki (2015), farmers' perception about performance of an implementation is essential for permanent technology adoption, highlighting the importance of involvement of farmers in evaluations of implementation to find whether a specific technology matches farmers' expectations or not.

6.4.4 Challenges and actions taken to overcome them during technology adoption process

Participants who had experience with technology implementation were asked to list and explain in detail challenges faced through the implementation process. The challenges explained by participants were categorised and presented in Table 9. Actions taken to overcome them, which are presented in Table 10, were related to each of the identified antecedents to analyse its effect on technology adoption. A graphic representation of the relation of the actions taken to overcome these challenges and the antecedents determining technology adoption is depicted in Figure 5.

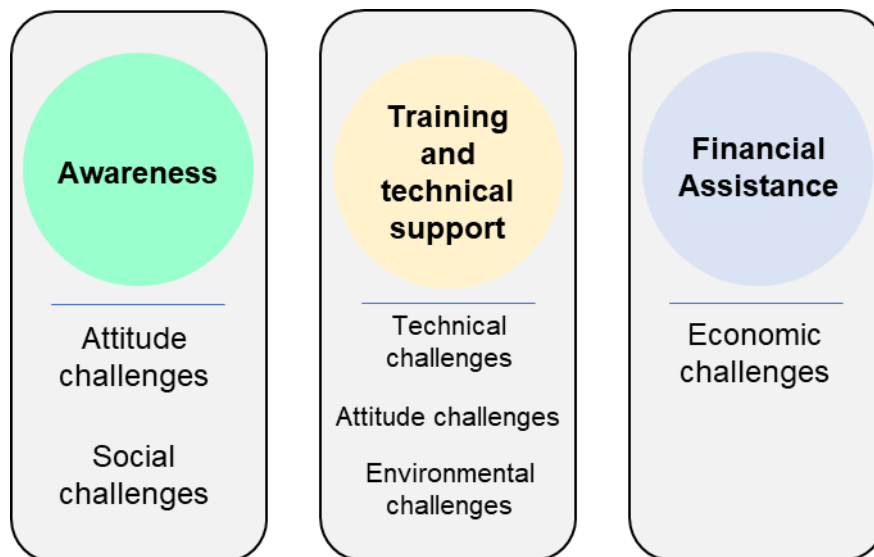


Figure 5. Effect of the antecedents determining technology adoption in agriculture in developing nations on overcoming challenges faced through technology implementation.

According to participants, increasing awareness provided solutions to attitude and social challenges faced during implementation. To this extent, participants commented that being aware of the benefits provided by technology implementation allowed to envision a change in their quality of life and motivated them to adopt technology systems in their practices. Findings from a study conducted by Lavison (2013) were consistent with participants' perception about this, since this author stated that being aware of potential net gains from technology implementation may work as a motivational factor to increase levels of technology adoption in agriculture

in developing nations. Gondchawar and Kawitkar (2016), stated that technology can provide solutions to the entire agriculture value chain. This finding was supported by participants who stated that awareness also helped to overcome social issues such as consumers' acceptance of products created with these applications.

Participants mentioned that training and technical support helped to overcome technical, attitude, and environmental challenges faced through the technology implementation process. Technical assistance delivered with field visits and trainings by public extension agents provided participants with the required levels of knowledge and technical skills to improve benefits from farming practices with technology implementation. Furthermore, technical assistance was considered to change participants' attitudes towards implementation as the uncertainty of expected results was reduced by learning how to correctly operate implemented systems. This is in line with literature findings since it was determined that attitude towards implementation can moderate technology acceptance (Dwivedi et al., 2019). Therefore, good information sources and accessibility to technical information can lead to higher adoption levels as they can create positive attitudes towards implementation (Bonabana-Wabbi, 2002; Liu et al., 2018).

Training and technical support was also considered to solve environmental challenges faced through implementation. Technical support can provide guidance to adapt to environmental conditions. For instance, fertilizer application with drone systems can be scheduled to be conducted during convenient times, mostly night-time. However, this can pose social issues to farmers. According to their perception safety levels in most rural communities in developing nations are low, thus, changing application schedules can pose safety and security risks.

Further considerations of participants led to the understanding of the effect of financial assistance to overcome economic challenges. To this extent, participants commented that joining farmers' associations facilitated financial support to overcome issues related to economic factors. This can be considered as a new finding with regards to financial support from institutions, since participants described that requesting financial support through farmers' associations or cooperatives was more effective than requesting individual financial assistance. Farmers also stated that joining these associations contributed to learning about benefits from technology

implementation as some field visits and trainings from external agents were directed to them. This promoted learning from peers, a perception that was consistent with literature findings about the importance of social groups like farmers' associations to promote technology adoption. According to Mwangi and Kariuki (2015), individual members become more receptive and open to learning about the effective use of technologies when they are part of a social group.

Participants who have not joined these associations highlighted the importance of financial support from government institutions to promote technology adoption in the sector. Some of them indicated the lack of support from these entities by stating that financial assistance was provided to them from private companies or organisations they were working with. This supported findings from literature as Diiro (2013), stated that in most developing nations, credit markets are either non-existing or dysfunctional. Mwangi and Kariuki, (2015) and Deichmann et al. (2016) also stated that financial access to people in the agriculture sector can lead to higher technology adoption levels and provide them with solutions to address the issue of low productivity levels in the sector.

6.4.5 Conclusive findings from Research Question 3

Through the analysis of results from the interview questions that aimed to provide answers to Research Question 3, the researcher determined that awareness, training and technical support, and financial assistance were identified as contributors for overcoming challenges through implementation processes by farmers who had experience with technology. Whereas for farmers who have not had experience with technology, awareness and financial assistance explained the reasons of lack of experience with technology implementation. These findings allowed to understand the effect of the identified antecedents determining technology adoption on decision making processes with regards to implementation. The following section will provide the analysis of the effect of the interaction between the antecedents determining technology adoption on decision-making with regards to implementation.

6.5 Discussion of Results for Research Question 4

Research Question 4: How do these antecedents interact to influence decision making with regards to technology implementation in agriculture practices?

In contrast to prior studies, which have only analysed the individual effect of antecedents determining technology adoption in agriculture, Research Question 4 aimed to understand how the interaction between the identified antecedents, which are summarised in Table 13, influence participants' decision to implement a specific technology in their practices. To do this, the researcher asked participants whether all the identified antecedents should be fulfilled to make a decision about implementation or not.

Findings from this interview question, presented in section 5.7.1, allowed the researcher to understand that all the identified antecedents according to participants' perceptions should be fulfilled to decide to start with new technology implementation or to acquire additional or further implementation. Most participants agreed with this, since they stated that all the identified antecedents are preconditions of technology adoption. Others argued this fact stating that should the main antecedent according to their perception be fulfilled, the others will follow suit. Only one participant considered that the fulfilment of these antecedents depends on the farmers' needs stating that some conditions of the farming systems may require the partial fulfilment of these antecedents, while others could require the total fulfilment of them.

6.5.1 Conclusive findings from Research Question 4

Based on findings from participants' perception, it is therefore suggested that the interaction of all the identified antecedents determining technology adoption in agriculture in developing nations is essential to foster technology adoption in the sector. Figure 6 depicts the findings from this analysis, which shows that the fulfilment of all antecedents determining technology adoption can transform reasons of lack of experience with technology implementation into benefits that can improve farmers' economic conditions, quality of life and provide many other benefits to promote economic growth in the sector.

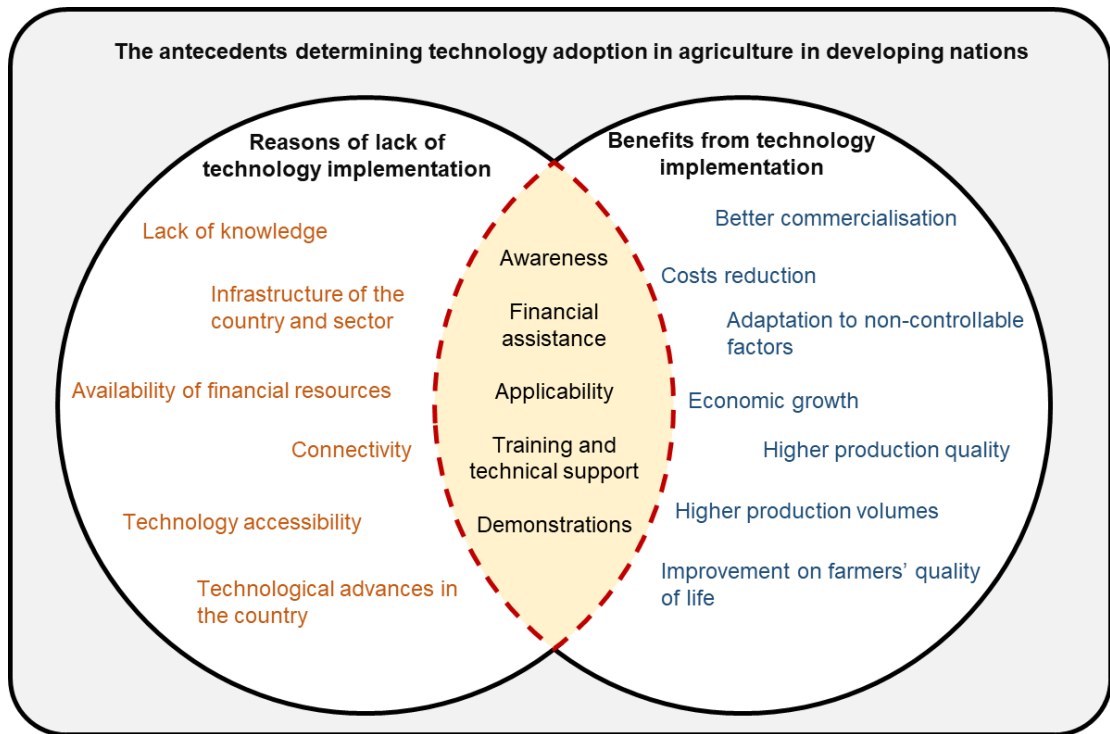


Figure 6: Interaction of the antecedents determining technology adoption in agriculture in developing nations.

6.6 Conclusion

This chapter aimed to discuss the results presented in Chapter 5 to provide answers to the Research Questions proposed for this study. These were answered comparing the data collected through the 12 online semi-structured interviews to findings from literature presented in Chapter 2. Most of the findings were supported by the literature, however, new findings and participants' perception about the about the topic of interest allowed the development of a theoretical framework, which will be discussed in detail in Chapter 7.

Chapter 7: Conclusion and recommendations

7.1 Introduction

As defined in Chapter 1, this study aimed to identify and understand the antecedents that determine technology adoption in agriculture in developing nations. Furthermore, this research aimed to understand the effect of the interaction between these antecedents on decision making with regards to technology implementation. Literature suggested that economic, institutional, household, and technology characteristic factors are the antecedents determining technology adoption in agriculture in developing nations (Deichmann et al., 2016; Larson et al., 2016; Mwangi & Kariuki, 2015). Findings from this study were compared to those from literature, which led to successfully determine the antecedents of technology adoption in agriculture in developing nations according to perceptions of people who are directly involved in farming activities.

Research findings successfully provided answers to each of the Research Question discussed in Chapter 3 and allowed the researcher to develop a framework that defines the antecedents and explain their interaction to determine technology adoption in agriculture in developing nations. Details about findings that helped to deliver conclusions on each of these Research Questions will be discussed in this chapter. In addition, this chapter will explain in detail the development of this framework, which derived from the comparison of findings from Chapter 2, with the research results, which were presented in Chapter 5 and further discussed in Chapter 6. Based on this framework, this chapter will discuss implications for relevant stakeholders. Further, limitations of this study will be discussed in detail, which will lead to suggestions for future research about the topic covered in this study.

7.2 Research Findings

Findings from research allowed the definition and understanding of how the antecedents identified based on participants' perception affect technology adoption. The following sections will discuss in detail conclusive findings from each of the Research Questions that led to the development of the framework which explains

these antecedents and their interaction to determine technology adoption in agriculture in developing nations.

7.2.1 Technology adoption meaning in agriculture in developing nations



Research Question 1 aimed to understand the meaning of technology adoption in agriculture in developing nations according to people directly involved in farming activities. To do this, the data collection method focused on understanding their perception about technology adoption to improve agricultural productivity and their understanding of the benefits that can be achieved with it.



Based on participants' perception, technology adoption can be beneficial for the agriculture sector in developing nations and lead to social prosperity and economic growth. Technology adoption can increase levels of productivity since it helps to increase production volumes, improves production controls, and helps to use resources more efficiently. Technology adoption can increase farmers' quality of life by increasing net gains from farming activities, reducing health risks with smart farming practices, job generation, and promotion of education. Furthermore, higher volumes of diversified production with better quality controls can be created with innovative technology applications, which can facilitate transition of the agriculture sector from being used only as a source of subsistence to commercial agriculture.

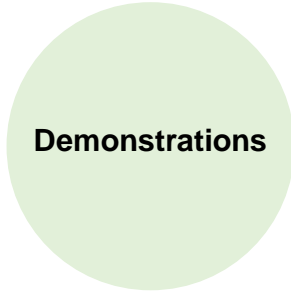
7.2.2 The antecedents determining technology adoption in agriculture in developing nations

Research Question 2 aimed to define the antecedents determining technology adoption according to participants' perceptions. Whereas Research Question 3 aimed to identify and understand the effect of these antecedents on decision-making processes with regards to technology implementation. Figure 2 presented a hypothetical framework that identified awareness, financial assistance, applicability of technology, training and technical support and demonstrations as the antecedents determining technology adoption in the agriculture sector in developing nations. The effect of each of these identified antecedents is presented in Table 15.

Table 15: Effect of the antecedents on technology adoption in agriculture in developing nations

Antecedent	Effect on decision making with regards to technology implementation
 <p>Awareness</p>	<p>Awareness was considered as necessary to increase technology adoption levels in the agriculture sector. Participants mentioned that not being aware of the different technologies that can be applied in the sector and their benefits was one of the reasons of lack of experiences with innovative applications in their practices. Participants who had experience with technology implementation considered awareness as an influencing factor that drove their decision of improving farming practices with technology. For them, knowledge gathered through promotion campaigns and benchmark strategies allowed the identification of a sense of urgency to improve agricultural outputs with technology. Furthermore, awareness allowed to overcome attitude and social challenges faced through implementation. Being aware of the benefits of adoption changed their attitude towards implementation and allowed them to create a vision directed to change their quality of life with technology implementation.</p>
 <p>Financial Assistance</p>	<p>Availability of financial resources was considered as one of the reasons of lack of experience with technology implementation. Participants considered financial access and support from the correspondent entities as an antecedent determining technology adoption since net gains perceived from traditional practices is not enough to consider investments on innovative applications. Participants who had experience with technology implementation considered financial assistance in the form of credit facilities and opportunities to borrow capital as contributors to solve economic challenges faced during</p>

	<p>current implementation processes. They also highlighted the importance of financial access to increase adoption levels in agriculture in developing nations.</p>
 <p>Applicability of technology</p>	<p>Applicability of technology was referred to as the suitability of an implementation to the farming system's conditions. For participants who had no experience with technology implementation, applicability was associated to the degree of adaptation of a specific technology to environmental and operative conditions of their farming systems. Participants who had experience with technology implementation referred to applicability as the consistency of a specific technology with the farm conditions and how compatible further implementation are with the current ones.</p>
 <p>Training and technical support</p>	<p>Access to technical assistance was considered as an influential factor that determined technology adoption. Interaction with specialist agents promoting technology adoption can work as a source of technical knowledge which can lead to the correct understanding of the benefits provided by technology adoption and right operation methods. Training and technical support was also considered to contribute to solve technical, attitude and environmental challenges faced through current implementation processes. Field visits and trainings that provide farmers with the required levels of knowledge to correctly operate technology applications can reduce uncertainty about expected results and improve technology acceptance in the sector.</p>

 <p>Demonstrations</p>	<p>Demonstrations in the form of trials and pilot implementation were considered as an influential factor that drives technology adoption. Participants commented that witnessing the benefits from technology applications can lead to higher levels of acceptance. Furthermore, participants highlighted the importance of prior tests of implementation to determine performance of application and limit losses in the case of negative results from pilot implementation.</p>
--	--

7.2.3 Interaction of the antecedents determining technology adoption in agriculture in developing nations

Research Question 4 aimed to understand the effect of the interaction of the identified antecedents on decision-making with regards to technology implementation. Findings from the data collection method determined that according to participants' perception all circumstances considered to make a decision about implementation, namely antecedents, should be addressed. Therefore, it is suggested that the interaction of the identified antecedents is essential to foster technology adoption in the agriculture sector in developing nations since they all need to be fulfilled in order to improve technology adoption levels in the sector.

Findings from the research allowed the development of a framework to explain the antecedents and how their interaction determine technology adoption in agriculture in developing nations. This framework is presented in Figure 7.

The antecedents determining technology adoption in agriculture in developing nations

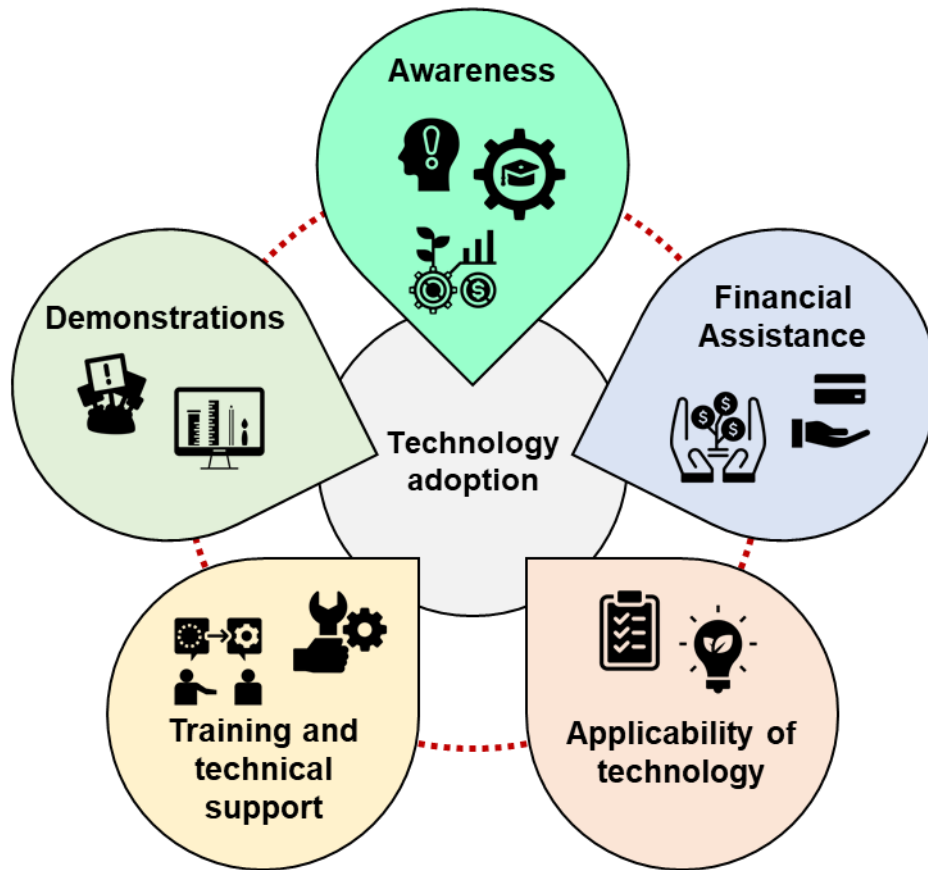


Figure 7: ‘The antecedents determining technology adoption in agriculture in developing nations’ Framework.

This framework proposes that technology adoption in the agriculture sector in developing nations is determined by the interaction of all identified antecedents, which is represented by the red dotted line. Each of the antecedents has individual effects, which have been described in previous sections, and presents factors that should be taken into consideration and addressed to improve technology adoption levels in the sector. This framework proposes that technology adoption levels can be improved with integrated strategies that address all the antecedents determining it. Insights from this framework aim to assist entities working with the development of the agriculture sector, to be better informed about actions to be taken to improve levels of productivity in the agriculture sector with the implementation of technology.

7.3 Implications and recommendations

With the Research Questions presented in Chapter 3, the researcher was able to understand the meaning of technology adoption, the antecedents determining it, the effect of each of these antecedents and how their interaction influences decision-making with regards to technology implementation in the agriculture sector in developing nations. Findings from the data collection method and the analysis of results led to the creation of the framework presented in Figure 7. This framework may provide guidance for the creation of strategies directed to improve technology adoption levels in the agriculture sector in developing nations. Governments, institutions working in the development of the agriculture sector, and technology equipment suppliers can use this framework to have a better understanding about the antecedents determining technology adoption in the sector based on the perception of people directly involved in these activities.

This framework can be utilised as a tool for the creation of integrated strategies involving the entities listed above. For instance, government entities and institutions working with the development of the sector must gather the required levels of technical knowledge about technology applications from technology equipment suppliers to be able to provide support to the agriculture sector and develop strategies that address all the identified antecedents determining technology adoption. These strategies should provide farmers with the right levels of awareness about innovative applications and their benefits (Bardhan & Mookherjee, 2011). In addition, farmers should be provided with financial assistance such as credit facilities and financial access, which can allow them to borrow capital and reduce risk-aversion levels among farmers in developing nations to promote investments in technology applications (Mwangi & Kariuki, 2015). Furthermore, strategies directed to improve technology adoption levels should promote suitable applications according to farms' conditions, technical support and training, and demonstrations about the benefits and improvements on production performance achieved with technology applications (Mwangi & Kariuki, 2015; Larson et al., 2016; Liu et al., 2018).

7.4 Research limitations

The first limitation encountered with the development of this study was the possibility of misinterpretations about the insights provided by participants. As the data collection method was online semi-structured interviews using the video conference platform Zoom™, interaction with participants was not the same as for face-to-face interviews. Because of the lack of physical interaction with participants, the researcher could have missed some attitudes and body language expressions that could have indicated importance in some themes.

Another identified limitation was the expertise of the researcher for conducting interviews. Pilot tests interviews were developed prior to the interviews with participants and the interviews were conducted following a standard interview guideline. However, low levels of experience conducting interviews from the researcher's side could have affected the interpretations and insights of the data collected (Creswell, 2013).

The sampling techniques applied by the researcher resulted in a homogeneous sample of participants with similar characteristics for this study. This can lead to minimum variations in the data collected (Marcus et al., 2017; Saunders & Lewis, 2018), which might have an effect on generalisation of conclusions (Boddy, 2016). Having low variation in the levels of opinions and perceptions about the topic of interest of this study can result in questioning whether findings from this research may be applicable to other research settings or not (Saunders et al., 2016).

The sample was selected entirely through the researcher's own professional network with contacts who travel and make on-site visits in communities dedicated to farming activities. However, traveling restrictions due to the current pandemic limited access to farming groups in some developing nations and contact was not possible with people in other countries than El Salvador and Botswana. Thus, geographical bias in the responses could affect generalisation of conclusions (Saunders et al., 2016).

7.5 Suggestions for future research

Findings from this study determined that the interaction between awareness, financial assistance, applicability of technology, training and technical support, and demonstrations determine technology adoption in agriculture in developing nations. To address the issue of low agricultural productivity due to low levels of technology adoption in these nations, the following recommendations may be valuable for future research in this field:

Since the interaction of the identified antecedents is essential to foster technology adoption in agriculture in developing nations, it would be valuable to do research on what are the required business models to address low levels of technology adoption in this sector. To this extent, future research should focus on determining integrated strategies that address all the identified antecedents to promote technology adoption as well as understanding roles and relationships between the responsible entities working on the development of the agriculture sector.

Findings from this study determined that the high upfront investments required to acquire technology in agriculture can be prohibitive to farmers in developing nations. It is therefore suggested that future research focuses on determining financial mechanisms to address financial limitations faced in the sector. To this extent, it might be valuable for future research to determine financial incentives to promote technology adoption in the sector such as credit facilities, policies, and terms as well as responsible entities which should provide this assistance to foster technology adoption in agriculture in developing nations.

This study determined that technology implementation is not dependent on the farming systems' size. However, due to farming conditions some farmers see technology only as an unnecessary cost. In addition, this study also determined that technology can provide innovative solutions to farmers regardless of their farming system conditions such as size and land space. Thus, it may be valuable for future research to focus on understanding these farming conditions to promote the best-fit technology in the sector in developing nations to address the issue of low technology adoption levels.

7.6 Conclusion

This study has provided new insights with regards to the antecedents determining technology adoption in the agriculture sector in developing nations. As reviewed in the literature, technology adoption in agriculture in these nations is essential to improve the development of the sector. Despite this, there is little evidence of effective integrated strategies to address low technology adoption levels based on the antecedents determining technology adoption. This research aimed to contribute to the literature by identifying and understanding these antecedents according to the perception of people directly involved in agriculture activities. Furthermore, findings from this study resulted in the development of 'the antecedents determining technology adoption in agriculture in developing nations' framework, which integrates the five identified antecedents to explain how their interaction determines technology adoption in agriculture in developing nations.

Findings from the 12 interviews with participants directly involved in agriculture activities provided a clear understanding of these antecedents and how their interaction is essential to foster technology adoption in agriculture in developing nations. Moreover, this study contributes to the literature through empirical research by providing useful insights to understand the complexity of the phenomenon of interest of this study, which was the decrease on agricultural productivity due to low technology adoption levels. This study aspires to serve as a contribution for the development of the agriculture sector in developing nations with the practical application of the proposed framework. This can provide entities working in the development of this sector with guidance for the creation of integrated strategies to promote technology adoption and improve the agriculture sector in developing nations by addressing all the identified antecedents successfully.

8. Reference list

- Adebiji, S., & Okunlola, J. O. (2013). *Factors affecting adoption of cocoa farm rehabilitation techniques in Oyo state of Nigeria*. 8.
- Alexander, C. E., & Mellor, T. V. (2005). *Determinants of corn rootworm resistant corn adoption in Indiana*. 8.
- Alkhwaldi, A. F. A., & Kamala, M. A. (2017). *Why do users accept innovative technologies? A critical review of models and theories of technology acceptance in the information system literature*. Retrieved from <https://bradscholars.brad.ac.uk/handle/10454/13221>
- Allen, F., Demirguc-Kunt, A., Klapper, L., & Martinez Peria, M. S. (2016). The foundations of financial inclusion: Understanding ownership and use of formal accounts. *Journal of Financial Intermediation*, 27, 1–30. <https://doi.org/10.1016/j.jfi.2015.12.003>
- Arslan, A., McCarthy, N., Lipper, L., Asfaw, S., Cattaneo, A., & Kokwe, M. (2015). Climate smart agriculture? Assessing the adaptation implications in Zambia. *Journal of Agricultural Economics*, 66(3), 753–780. <https://doi.org/10.1111/1477-9552.12107>
- Assa, H., Sharifi, H., & Lyons, A. (2021). An examination of the role of price insurance products in stimulating investment in agriculture supply chains for sustained productivity. *European Journal of Operational Research*, 288(3), 918–934. <https://doi.org/10.1016/j.ejor.2020.06.030>
- Awokuse, T. O. (2015). Does agriculture really matter for economic growth in developing countries? <https://doi.org/10.22004/ag.econ.49762>
- Babin, B. J., Quinlan, C., Zikmund, W. G., Carr, J. C., & Griffin, M. (2019). *Business research methods* (Second edition). Cengage Learning Emea.
- Bandiera, O., & Rasul, I. (2002). Social networks and technology adoption in Northern Mozambique. *The Economic Journal*, 116(514), 869–902. <https://doi.org/10.1111/j.1468-0297.2006.01115.x>
- Bardhan, P., & Mookherjee, D. (2011). *Clientelistic politics and economic development: An overview*. Retrieved from <https://pdfs.semanticscholar.org/cbe3/dadaea75c2e8a6b09db7eb2e3d6e06fed371.pdf>

- Barrera, V., Norton, G. W., Alwang, J. R., & Mauceri, M. (2005). Adoption of integrated pest management technologies: A case study of potato farmers in Carchi, Ecuador. <https://doi.org/10.22004/ag.econ.19400>
- Bekun, F. V. (2015). *The contribution of agricultural sector on the economic growth of Nigeria*. 51.
- Ben Slimane, M., Huchet-Bourdon, M., & Zitouna, H. (2016). The role of sectoral FDI in promoting agricultural production and improving food security. *International Economics*, 145, 50–65. <https://doi.org/10.1016/j.inteco.2015.06.001>
- BenYishay, A., & Mobarak, A. M. (2019). Social learning and incentives for experimentation and communication. *Review of Economic Studies*, 86(3), 976–1009. <https://doi.org/10.1093/restud/rdy039>
- Blanchard, E. J., & Olney, W. W. (2017). Globalization and human capital investment: Export composition drives educational attainment. *Journal of International Economics*, 106, 165–183. <https://doi.org/10.1016/j.jinteco.2017.03.004>
- Blanco-Gómez, P., Jimeno-Sáez, P., Senent-Aparicio, J., & Pérez-Sánchez, J. (2019). Impact of climate change on water balance components and droughts in the Guajoyo river basin (El Salvador). *Water*, 11(11), 2360. <https://doi.org/10.3390/w11112360>
- Blut, M., & Wang, C. (2020). Technology readiness: A meta-analysis of conceptualizations of the construct and its impact on technology usage. *Journal of the Academy of Marketing Science*, 48(4), 649–669. <https://doi.org/10.1007/s11747-019-00680-8>
- Blut, M., Wang, C., & Schoefer, K. (2016). Factors influencing the acceptance of self-service technologies: A meta-analysis. *Journal of Service Research*, 19(4), 396–416. <https://doi.org/10.1177/1094670516662352>
- Boddy, C. R. (2016). *Sample size for qualitative research*. Retrieved from <https://www.emerald.com/insight/content/doi/10.1108/QMR-06-2016-0053/full/pdf?title=sample-size-for-qualitative-research>
- Bonabana-Wabbi, J. (2002). *Assessing factors affecting adoption of agricultural technologies: The case of integrated pest management (IPM) in Kumi district*,

- Eastern Uganda* (Thesis, Virginia Tech). Virginia Tech. Retrieved from <https://vtechworks.lib.vt.edu/handle/10919/36266>
- Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, 3, 77–101. <https://doi.org/10.1191/1478088706qp063oa>
- Bustos, P., Caprettini, B., & Ponticelli, J. (2016). Agricultural productivity and structural transformation: Evidence from Brazil. *American Economic Review*, 106(6), 1320–1365. <https://doi.org/10.1257/aer.20131061>
- Carter, L., & Schaupp, L. C. (2008). *Efficacy and acceptance in E-File adoption*. 12.
- Chandra, A., McNamara, K. E., & Dargusch, P. (2018). Climate-smart agriculture: Perspectives and framings. *Climate Policy*, 18(4), 526–541. <https://doi.org/10.1080/14693062.2017.1316968>
- Chao, C. M. (2019). *Factors determining the behavioral intention to use mobile learning: An application and extension of the UTAUT Model*. Retrieved from <https://www.frontiersin.org/articles/10.3389/fpsyg.2019.01652/full>
- Che, Y., & Zhang, L. (2018). Human capital, technology adoption and firm performance: Impacts of China's higher education expansion in the late 1990s. *Economic Journal*, 128(614), 2282–2320. <https://doi.org/10.1111/eoj.12524>
- Chong, A. Y.-L. (2013). Predicting m-commerce adoption determinants: A neural network approach. *Expert Systems with Applications*, 40(2), 523–530. <https://doi.org/10.1016/j.eswa.2012.07.068>
- Creswell, J. W. (2007). *Qualitative inquiry and research design: Choosing among five approaches* (Second edition).
- Creswell, J. W. (2013). *Qualitative inquiry and research design: Choosing among five approaches* (Third edition).
- Deichmann, U., Goyal, A., & Mishra, D. (2016). *Will digital technologies transform agriculture in developing countries?* The World Bank. <https://doi.org/10.1596/1813-9450-7669>
- Dhahri, S., & Omri, A. (2020). Foreign capital towards SDGs 1 & 2—Ending poverty and hunger: The role of agricultural production. *Structural Change and Economic Dynamics*, 53, 208–221. <https://doi.org/10.1016/j.strueco.2020.02.004>

- Diirro, G. M. (2013). *Impact of off-farm income on agricultural technology adoption intensity and productivity: Evidence from rural maize farmers in Uganda*. 15.
- Doss, C., & Morris, M. L. (1999). How does gender affect the adoption of agricultural innovations? Retrieved March 2, 2021, from <https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1574-0862.2001.tb00233.x>
- Dwivedi, Y. K., Rana, N. P., Jeyaraj, A., Clement, M., & Williams, M. D. (2019). Re-examining the Unified theory of acceptance and use of technology (UTAUT): Towards a revised theoretical model. *Information Systems Frontiers*, 21(3), 719–734. <https://doi.org/10.1007/s10796-017-9774-y>
- Elijah, O., Abd Rahman, T., Orikumhi, I., Leow, C. Y., & Hindia, M. (2018). An overview of internet of things (IoT) and data analytics in agriculture: Benefits and challenges. *IEEE Internet of Things Journal*, PP, 1–1. <https://doi.org/10.1109/JIOT.2018.2844296>
- Emerick, K., de Janvry, A., Sadoulet, E., & Dar, M. H. (2016). Technological innovations, downside risk, and the modernization of agriculture. *American Economic Review*, 106(6), 1537–1561. <https://doi.org/10.1257/aer.20150474>
- FAO. (2009). *Draft declaration of the world summit on food security*. Retrieved from http://www.fao.org/fileadmin/templates/wsfs/Summit/Docs/Declaration/WSFS09_Draft_Declaration.pdf
- FAO. (2018). *Transforming food and agriculture to achieve the SDGs*. Retrieved from <http://www.fao.org/3/I9900EN/i9900en.pdf>
- Fink, G., Jack, B. K., & Masiye, F. (2018). Seasonal liquidity, rural labor markets and agricultural production. *IDEAS Working Paper Series from RePEc*. Retrieved from <http://search.proquest.com/docview/2059268141/5FCBFAA91B7141BCPQ/3>
- Foster, A. D., & Rosenzweig, M. R. (1995). Learning by doing and learning from others: Human capital and technical change in agriculture. *Journal of Political Economy*, 103(6), 1176–1209.
- Friese, S. (2019). *Qualitative data analysis with ATLAS.ti*. SAGE.
- Fuglie, K. O. (2018). Is agricultural productivity slowing? *Global Food Security*, 17, 73–83. <https://doi.org/10.1016/j.gfs.2018.05.001>

- Gacar, A., Aktas, H., & Ozdogan, B. (2017). Digital agriculture practices in the context of agriculture 4.0. *Pressacademia*, 4(2), 184–191. <https://doi.org/10.17261/Pressacademia.2017.448>
- Gondchawar, N., & Kawitkar, D. R. S. (2016). *IoT based smart agriculture*. 5(6), 5.
- Goodwin, B. (2004). Farming efficiency and the determinants of multiple job holding by farm operators. *American Journal of Agricultural Economics*, 86, 722–729. <https://doi.org/10.1111/j.0002-9092.2004.00614.x>
- Goswami, A., & Dutta, S. (2016). Gender differences in technology usage—A literature review. *Open Journal of Business and Management*, 04(01), 51–59. <https://doi.org/10.4236/ojbm.2016.41006>
- Gui-Diby, S. L., & Renard, M.-F. (2015). Foreign Direct Investment inflows and the industrialization of African countries. *World Development*, 74, 43–57. <https://doi.org/10.1016/j.worlddev.2015.04.005>
- Henderson, J. V., Squires, T., Storeygard, A., & Weil, D. (2018). The global distribution of economic activity: Nature, history, and the role of trade. *Quarterly Journal of Economics*, 133(1), 357–406. <https://doi.org/10.1093/qje/qjx030>
- Hunecke, C., Engler, A., Jara-Rojas, R., & Poortvliet, P. M. (2017). Understanding the role of social capital in adoption decisions: An application to irrigation technology. *Agricultural Systems*, 153, 221–231. <https://doi.org/10.1016/j.agsy.2017.02.002>
- Iamsiraroj, S., & Ulubaşoğlu, M. A. (2015). Foreign direct investment and economic growth: A real relationship or wishful thinking? *Economic Modelling*, 51, 200–213. <https://doi.org/10.1016/j.econmod.2015.08.009>
- Jain, R., Arora, A., & Raju, S. S. (2009). *A novel adoption index of selected agricultural technologies: Linkages with infrastructure and productivity*. 22.
- Juma, C. (2015). *The new harvest: Agricultural innovation in Africa*. Oxford University Press.
- Karlan, D., Osei, R., Osei-Akoto, I., & Udry, C. (2014). Agricultural decisions after relaxing credit and risk constraints. *The Quarterly Journal of Economics*, 129(2), 597–652. <https://doi.org/10.1093/qje/qju002>
- Keelan, C., Thorne, F. S., Flanagan, P., Newman, C., & Mullins, E. (2014). *Predicted willingness of Irish farmers to adopt GM technology*. 10.

- Kijima, Y., Otsuka, K., & Sserunkuuma, D. (2011). An inquiry into constraints on a green revolution in Sub-Saharan Africa: The case of NERICA rice in Uganda. *World Development*, 39(1), 77–86. <https://doi.org/10.1016/j.worlddev.2010.06.010>
- Kiwanuka, A. (2015). Acceptance process: The missing link between UTAUT and diffusion of innovation theory. *American Journal of Information Systems*, 6.
- Larson, N., Sekhri, S., & Sidhu, R. (2016). Adoption of water-saving technology in agriculture: The case of laser levelers. *Water Resources and Economics*, 14, 44–64. <https://doi.org/10.1016/j.wre.2015.11.001>
- Lavison, R. K. (2013). *Factors influencing the adoption of organic fertilizers in vegetable production in Accra*. 131.
- Lekobane, K. R., & Seleka, T. B. (2017). Determinants of household welfare and poverty in Botswana. *Journal of Poverty*, 21(1), 42–60. <https://doi.org/10.1080/10875549.2016.1141381>
- Linh, T. N., Long, H. T., Chi, L. V., Tam, L. T., & Lebailly, P. (2019). Access to rural credit markets in developing countries, the case of Vietnam: A literature review. *Sustainability*, 11(5), 1468. <https://doi.org/10.3390/su11051468>
- Liu, T., Bruins, R. J. F., & Heberling, M. T. (2018). Factors influencing farmers' adoption of best management practices: A review and synthesis. *Sustainability*, 10(2), 432. <https://doi.org/10.3390/su10020432>
- López-Riquelme, J. A., Pavón-Pulido, N., Navarro-Hellín, H., Soto, F., & Torres, R. (2016). A software architecture based on FIWARE cloud for precision agriculture. *Agricultural Water Management*, 183. <https://doi.org/10.1016/j.agwat.2016.10.020>
- Magruder, J. R. (2018). An assessment of experimental evidence on agricultural technology adoption in developing countries. *Annual Review of Resource Economics*, 10(1), 299–316. <https://doi.org/10.1146/annurev-resource-100517-023202>
- Marcus, B., Weigelt, O., Hergert, J., Gurt, J., & Gelléri, P. (2017). The use of snowball sampling for multi source organizational research: Some cause for concern. *Personnel Psychology*, 70(3), 635–673. <https://doi.org/10.1111/peps.12169>

- McNally, S. (2002). Are 'other gainful activities' on farms good for the environment? *Journal of Environmental Management*, 66(1), 57–65. <https://doi.org/10.1006/jema.2002.0576>
- Midingoyi, S. G., Kassie, M., Muriithi, B., Diiro, G., & Ekesi, S. (2019). Do farmers and the environment benefit from adopting integrated pest management practices? Evidence from Kenya. *Journal of Agricultural Economics*, 70(2), 452–470. <https://doi.org/10.1111/1477-9552.12306>
- Mignouna, D. B., Manyong, V. M., Rusike, J., Mutabazi, K. D. S., & Senkondo, E. M. (2011). *Determinants of adopting imazapyr-resistant maize technologies and its impact on household income in Western Kenya*. 6.
- Momani, A. M., & Jamous, M. M. (2017). *The evolution of technology acceptance theories*. 8.
- Mottaleb, K. A. (2018). Perception and adoption of a new agricultural technology: Evidence from a developing country. *Technology in Society*, 55, 126–135. <https://doi.org/10.1016/j.techsoc.2018.07.007>
- Muangprathub, J., Boonnam, N., Kajornkasirat, S., Lekbangpong, N., Wanichsombat, A., & Nillaor, P. (2019). IoT and agriculture data analysis for smart farm. *Computers and Electronics in Agriculture*, 156, 467–474. <https://doi.org/10.1016/j.compag.2018.12.011>
- Mwangi, M., & Kariuki, S. (2015). *Factors determining adoption of new agricultural technology by smallholder farmers in developing countries*. 6. Retrieved from https://www.researchgate.net/publication/303073456_Factors_determining_adoption_of_new_agricultural_technology_by_smallholder_farmers_in_developing_countries
- Myres, K. (2020). *Innovation & Design—Session 3: Entrepreneurial thinking and acting*.
- Obisesan, A. (2014, August 15). Gender differences in technology adoption and welfare impact among Nigerian farming households [MPRA Paper]. Retrieved March 2, 2021, from <https://mpra.ub.uni-muenchen.de/58920/>
- Okoro, I. (2011). *Analysis of the contribution of agricultural sector on the Nigerian economic development*. 1, 191–200.

- Olanipekun, I. O., Olasehinde-Williams, G. O., & Alao, R. O. (2019). Agriculture and environmental degradation in Africa: The role of income. *Science of The Total Environment*, 692, 60–67. <https://doi.org/10.1016/j.scitotenv.2019.07.129>
- Olujenyo, F. O. (2008). The Determinants of agricultural production and profitability in Akoko land, Ondo-State, Nigeria. *Journal of Social Sciences*, 4(1), 37–41. <https://doi.org/10.3844/jssp.2008.37.41>
- Oluwatoyese, O. P., & Applanaidu, D. (2014). Effect of agricultural sector determinants on economic growth. *Australian Journal of Basic and Applied Sciences*, 6.
- Omonona, B. T., Oni, O. A., & Uwagboe, A. O. (2006). Adoption of improved cassava varieties and its welfare impact on rural farming households in Edo State, Nigeria. *Journal of Agricultural & Food Information*, 7(1), 39–55. https://doi.org/10.1300/J108v07n01_05
- Oster, E., & Thornton, R. (2009). *Determinants of technology adoption: Private value and peer effects in menstrual cup take-up* (No. w14828; p. w14828). Cambridge, MA: National Bureau of Economic Research. <https://doi.org/10.3386/w14828>
- Raithatha, R. (2020, April). *AgriTech in Nigeria: Investment opportunities and challenges*. Retrieved from https://www.gsma.com/mobilefordevelopment/wp-content/uploads/2020/04/AgriTech_in_Nigeria_Investment_Opportunities_and_Challenges1.pdf
- Rehman, A., Jingdong, L., Khatoon, R., Hussain, I., & Iqbal, M. (2017). *Modern agricultural technology adoption: Its importance, role and usage for the improvement of agriculture*. Retrieved from http://www.lifesciencesite.com/ljsj/life140217/10_29837ljsj140217_70_74.pdf
- Rodrik, D. (2018). *New Technologies, global value chains, and developing economies* (No. w25164; p. w25164). Cambridge, MA: National Bureau of Economic Research. <https://doi.org/10.3386/w25164>
- Rönnbäck, K., & Theodoridis, D. (2019). African agricultural productivity and the transatlantic slave trade: Evidence from Senegambia in the nineteenth century. *Economic History Review*, 72(1), 209–232. <https://doi.org/10.1111/ehr.12697>

- Salloum, S. A., Alhamad, A. Q. M., Al-Emran, M., Monem, A. A., & Shaalan, K. (2019). Exploring students' acceptance of E-Learning through the development of a comprehensive technology acceptance model. *IEEE Access*, 7, 128445–128462. <https://doi.org/10.1109/ACCESS.2019.2939467>
- Santangelo, G. D. (2018). The impact of FDI in land in agriculture in developing countries on host country food security. *Journal of World Business*, 53(1), 75–84. <https://doi.org/10.1016/j.jwb.2017.07.006>
- Saunders, M., & Lewis, P. (2018). *Doing research in business & management: An essential guide to planning your project* (Second edition).
- Saunders, M., Lewis, P., & Thornhill, A. (2016). *Research methods for business students* (Seventh Edition).
- Senyolo, M. P., Long, T. B., Blok, V., & Omta, O. (2018). How the characteristics of innovations impact their adoption: An exploration of climate-smart agricultural innovations in South Africa. *Journal of Cleaner Production*, 172, 3825–3840. <https://doi.org/10.1016/j.jclepro.2017.06.019>
- Taherdoost, H. (2018). A review of technology acceptance and adoption models and theories. *Procedia Manufacturing*, 22, 960–967. <https://doi.org/10.1016/j.promfg.2018.03.137>
- Takahashi, K., Mano, Y., & Otsuka, K. (2019). Learning from experts and peer farmers about rice production: Experimental evidence from Cote d'Ivoire. *World Development*, 122, 157–169. <https://doi.org/10.1016/j.worlddev.2019.05.004>
- Tchamyou, V. S., Erreygers, G., & Cassimon, D. (2019). Inequality, ICT and financial access in Africa. *Technological Forecasting and Social Change*, 139, 169–184. <https://doi.org/10.1016/j.techfore.2018.11.004>
- The World Bank. (2008). World development report 2008: Agriculture for development. Retrieved August 2, 2020, from <https://openknowledge.worldbank.org/handle/10986/5990>
- Venkatesh, V., Thong, J. Y. L., Chan, F. K. Y., Hu, P. J.-H., & Brown, S. A. (2011). Extending the two-stage information systems continuance model: Incorporating UTAUT predictors and the role of context. *Information Systems Journal*, 21(6), 527–555. <https://doi.org/10.1111/j.1365-2575.2011.00373.x>

Waller, B. E., W. Hoy, C., Henderson, J. L., Stinner, B., & Welty, C. (1998). Matching innovations with potential users, a case study of potato IPM practices. *Agriculture, Ecosystems & Environment*, 70(2), 203–215. [https://doi.org/10.1016/S0167-8809\(98\)00149-2](https://doi.org/10.1016/S0167-8809(98)00149-2)

9. Appendix list

Appendix 1: Consent Form

Interview Consent Letter

I am currently a student of the University of Pretoria's Gordon Institute of Business Science and completing my MBA research Project.

I am conducting research on the antecedents that determine technology adoption in agriculture in developing nations. Therefore, I am trying to find out more about the different perceptions about technology adoption in agriculture from the entities who are directly involved with these activities. Our interview is expected to last about an hour and will help me to better understand the determinants of technology adoption in agriculture in emerging nations. **Your participation is voluntary, and you can withdraw at any time without penalty.** All data will be reported without identifiers. If you have any concerns, please contact my supervisor or me. Our details are provided below:

Research Supervisor

Craig Penfold
craig@bloxadvisory.com
+44 7765 660685

Student

Saul Maldonado
19410957@mygibs.co.za
+50377432100

Participant's
name:

Date:

Appendix 2: Interview Guideline

Interview Schedule

Name:	
Age:	
Gender:	
Country:	
Start Time:	
End Time:	
Date:	

Good morning/evening, my name is Saul Maldonado. Thank you for your cooperation and time for this interview. I really appreciate the contribution provided by your insights to this research.

As you may know, I am conducting a study about the factors that determine technology adoption in agriculture in developing nations. The main purpose of this study is to understand these factors based on perceptions of the entities involved in agricultural practices.

This interview aims to explore your perceptions about technology adoption in agriculture. Therefore, you are more than welcome to give your opinions confidently, being aware that all the information shared during this process will remain confidential and will be used only for academic purposes.

Before we begin, can I ask you to sign this consent form in which you confirm that this interview can be recorded for further transcription and analysis?

Participant's name: _____

Interview questions

1. What is your perception about technology adoption to improve agricultural productivity?
2. What is your understanding about the benefits offered by technology implementation in agricultural practices?
3. What have your experiences been with technology implementation in your agricultural practices?
 - a. If participant has not had any experience with technology implementation:**
 - i. What are the reasons you have not adopted technology in your agricultural practices?
 - ii. Under what circumstances would you consider technology adoption?
 - b. If participant has had experiences with technology implementation:**
 - i. What are the benefits that you have experienced with technology implementation?
 - ii. What influenced your decision to adopt technology in your agricultural practices?
 - iii. What are the challenges experienced with the implementation of technology in your agricultural practices?
 - iv. How did you overcome these challenges?
 - v. Under what circumstances would you consider further technology adoption?
4. How do you consider these circumstances work together or complement each other to influence decision making regarding technology implementation in agricultural practices?

Interview finalisation thanking the participants for their time and participation.

Appendix 3: Data code list

Code Group	Code	Theme
Technology productivity benefits	Better productivity	Perception of people involved in agriculture in developing nations about how technology adoption can improve agricultural productivity
	Better productivity and farmers' life quality	
	Cost reduction	
	Implementation knowledge	
	Production control	
	Resource efficiency	
	Time reduction	
	Trade improvement	
Perception of benefits	Diversification of production	Perception of people involved in agriculture in developing nations about the benefits of technology adoption in agriculture
	Efficiency improvements	
	Higher production volumes	
	Improves adaptation to non-controllable factors	
	Improves commercialisation	
	Improves farmers' health	
	Improve farmers' income	
	Improves farmers' quality of life	
	Improves production controls	
	Improves production quality	
	Job generation	
	Makes work easier	
	Makes work more precise	
	Promotes education	

	Promotes growth in the sector	
	Promotes taking care of the environment	
	Reduces labour costs	
	Social prosperity	
Circumstances tech	Awareness	Circumstances which could influence technology adoption for participants who did have experience with technology in the sector
	Training and technical support	
	financial assistance	
	Demonstrations	
	Applicability	
Circumstances no tech	Awareness	Circumstances which could influence technology adoption for participants who did not have experience with technology in the sector
	Training and technical support	
	financial assistance	
	Demonstrations	
Reasons no tech	Awareness	Reasons of lack of experience with technology implementation of participants
	financial assistance	
Benefits cat	Cost reduction	Benefits perceived from technology implementation by participants who had experience with technology applications in their practices
	Higher production volumes	
	Improves farmers' quality of life	
	Improves production quality	
	Better commercialisation	
	Easier adaptation to non-controllable factors	
	Economic growth	
Influencing factors	Demonstrations	Factors that influenced decision of participants who had experience with
	Awareness campaigns	
	Technical assistance	

	Trials	technology implementation of acquiring technology in their practices
	Ambition	
	Benchmark	
	Market competitiveness	
	Sense of urgency to improve economic situation	
	Sense to improve farmer's life conditions	
Challenges	Technical	Challenges faced by participants who had experience with technology implementation during the implementation process
	Economic	
	Social	
	Attitude	
	Environmental	

Appendix 4: Ethical Clearance Approval Letter

Gordon Institute of Business Science University of Pretoria	Ethical Clearance Approved
<p>Dear Saul Maldonado,</p> <p>Please be advised that your application for Ethical Clearance has been approved. You are therefore allowed to continue collecting your data. We wish you everything of the best for the rest of the project.</p> <p>Ethical Clearance Form</p> <p>Kind Regards</p>	
<p>This email has been sent from an unmonitored email account. If you have any comments or concerns, please contact the GIBS Research Admin team.</p>	