Master of Information Systems: Digital Business Systems

An exploration of post-adoption evaluation and factors influencing IoT technology adoption in agriculture: Case study results from Norwegian agriculturists

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A report submitted in partial fulfillment of the requirement for the degree of Master of Information Systems: Digital Business Systems

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Abstract

Internet of things-based technologies have revolutionized and redesigned almost every industry, including agriculture. As the surge in global population and the increasing demand for food and water becomes more crucial in terms of both quantity and quality, IoT is providing revolutionary opportunities in the industry. Despite the great opportunities IoT can deliver, studies and researchers have found generally low adoption levels among agriculturists. In addition, IoT is still a new paradigm that has not been fully explored in the agriculture industry, compelling a need to investigate the current standings and capabilities of the new age IoT technologies.

This study aims to explore factors influencing IoT adoption, how such technologies have affected agriculturists and to reveal challenges and areas of concern that needs to be addressed in order to enhance IoT adoption. The research questions have been investigated in a multiple case study, where data is collected through individual semi-structured interviews with Norwegian agriculturists who have adopted IoT technologies. Even though some of the findings were aligned with other studies investigating IoT adoption in agriculture, several important and noteworthy differences were discovered. The findings indicates that the adoption of agricultural IoT technologies is much more complex than many previous studies have assumed, where various factors and determinants have the potential to influence the adoption, such as the degree of technical support, governmental policies and if the children of the agriculturists intend to take over the farming operations in the future.

It has also been revealed that the adoption of IoT technologies has resulted in several positive outcomes, such as improved decision-making, improved efficiency and increased control, but it is also evident that the agriculturists are not fully aware of all the consequences of adopting IoT technologies. Lastly, the findings indicate that there is a lack of support, as well as knowledge, among various stakeholders in the industry, something which has the potential to hamper the uptake of IoT technologies in the agriculture industry.

Keywords: Internet of things (IoT), Agriculture, Precision farming, Smart agriculture, Technology adoption, Post-adoption evaluation

Acknowledgements

I am indebted to the many people who have generously supported me through the process of completing this dissertation. Firstly, I would like to thank my supervisor, Moutaz Haddara, who provided me with valuable instructions, support and guidance during the dissertation period.

I would also like to express my deepest gratitude to the participants in the study. This dissertation would not have been possible without the agriculturists, who have been so kind to participate despite their busy schedules. Different stakeholders within the agriculture industry have also been exceptionally helpful, where interesting and informative conversations in the beginning of the dissertation period helped me to get a better understanding of the industry, as well as they provided me with important information sources and possible participants for my dissertation. Some of the suggested participants have taken part of this study, which I am truly grateful for.

Lastly, the support and encouragement I have gotten from my family and friends is also something that I am tremendously grateful for during this period.

I certify that the work presented in the thesis is my own unless referenced

Signature: Victoria Lillestrom ……………………………………

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Total number of words: 21184

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1. Introduction

According to a report by the United Nations (2019), the world's population is expected to be 9.7. billion in 2050. In addition, FAO et al (2020) predicts that also by the year of 2050, the world will need to produce about 50 percent more food to feed the growing world population. The estimated world population and demand for food, combined with diminishing natural resources, governmental policies, sociocultural development, climate changes and shortages of water, makes the security of agriculture a major concern for countries all around the world (Elijah et al, 2018). At the same time as the world are facing these challenges, we are in the middle of Covid 19, a global pandemic which has struck at a time when undernourishment and hunger keeps rising around the world. FAO et al (2020) states that due to the pandemic; income losses, increasing food costs, and soaring unemployment rates are jeopardizing food access in both developing and developed countries, something which will have long-term effects on food security.

In order to face these challenges, the adoption of IoT technology in agriculture can, and already is, creating tremendous opportunities. By implementing IoT technologies in different farming operations, it can help improving the solutions of many traditional agricultural issues, such as drought response, livestock- and crop diseases, land suitability, irrigation challenges, yield optimization and pest control (Ayaz et al, 2019). It also provides the opportunity to improve limited supply of water, fossil fuel and arable land, as well as it paves the way for sustainable and green agriculture. Last but not least; it can enable agriculturists to provide food safety, both in regard to quality and quantity (Jayashankar et al, 2018).

The implementation of IoT technologies is shaking the existing agriculture methods towards the concepts of Smart Farming and Precision Agriculture, something which means that several aspects of traditional agricultural methods will be fundamentally changed (Ayaz et al, 2019; Elijah et al, 2018). Some countries and agriculturists are already using IoT technologies in different agricultural processes, but it is still a new paradigm that has not been fully explored. According to Ayaz et al (2019) the current applications are only scratching the surface, where the real impact of IoT is not yet witnessed. In addition, with the initial diffusion of the 5G network, the opportunities are greater than ever as the 5G network is predicted to take IoT technology in agriculture to new heights (Tang et al, 2021).

1.1 Problem Statement

Despite the opportunities and potential of IoT in agriculture, studies and researchers have found generally low adoption levels (Barnes et al, 2019; Elijah et al, 2018; Knierim et al, 2018). This is also supported by Korsæth et al (2019) who found that the adoption of precision agriculture technologies is surprisingly low in Norway. According to Knierim et al (2018) adoption by agriculturists is characterized by skepticism and hesitancy. They argue that due to being in its infancy stage, knowledge and experience with smart farming technologies are limited, something which makes the access and reliability of information a bottleneck for agriculturists.

Albeit prior research has found that IoT can provide benefits and opportunities such as cost reduction and wastage, increased profitability, competitive advantages, increased efficiency and community farming (Elijah et al, 2018; Jakku et al, 2019; Jayashankar et al, 2018; Khanna & Kaur, 2019), Elijah et al (2018) and other researchers have compelled the need for more research on the monetary benefits of adopting IoT in agriculture. This was also supported in the AgTech2020 digital conference, where the need for examples and stories of how technologies affect agriculturists was highlighted as an important factor that can help Norwegian agriculturists towards adopting technology (Norsk Forskningsråd et al, 2020).

There is also a need to explore and understand which factors that influence the adoption of IoT technologies in agriculture, particularly in a Norwegian context. Albeit some Norwegian agriculturists have adopted IoT technologies, meager academic research and scholarly work are available in the area of technology adoption and digitalization in the agriculture industry. As agriculture differs from country to country, as well as one can assume that cultural differences, traditions, climatic conditions, governmental policies, and other factors will have an effect on the agriculturists production and their farming operations; there is an imperative need to inspect and explore IoT adoption in a Norwegian context.

Furthermore, it has been argued that the available literature of information systems (IS) and information technology (IT) shows a knowledge gap within sustainability and greening (Jenkin et al, 2011). This has also been supported by Landbruks & Matdepartementet (2020) where they specified the importance of research that contributes to promoting technology development and green transformation as a result of the Covid 19 pandemic and other concerns such as climate challenges and food security. As such, this study also investigates the growing interest in "green" IT and IS. Lastly, during the last couple of years, there has been a great increase in the number of associated terminologies i.e., big data and IoT. As technology is never static, there is a great need of revisiting the current standings and capabilities of new age agricultural IoT technologies (Khanna & Kaur, 2019).

1.2 Research Questions

In the light of the information provided in the previous section, exploring IoT adoption in Norway can contribute with important insights within IoT adoption literature. One can reveal factors influencing the adoption of IoT technologies, as well as by investigating post-adoption evaluation, one can be able to get an understanding of the outcomes by using such technologies. Based on the agriculturists experience and evaluation, it also provides the opportunity to reveal challenges which has the potential to negatively affect the adoption of agricultural IoT technologies. As such, this dissertation will thereby investigate and answer the following research questions:

1. *What are the key factors influencing the adoption of IoT technology among Norwegian Agriculturists?*

2. *How has the adoption of IoT technology affected Norwegian agriculturists and their farming operations?*

3. *What are the current challenges and areas of concern that can have a negative effect on IoT technology adoption in agriculture?*

To clarify, the objective of this thesis is:
(1) To explore factors influencing IoT adoption by studying agriculturists classified as "innovators" and "early adopters", as they were the first ones to adopt some of the newest innovations of agricultural IoT technologies. **(2)** To explore how the technologies has affected the agriculturists and their farming operations after being implemented, as well as how they have experienced and how they evaluate other aspects with the adoption process. **(3)** Based on

the agriculturist's evaluation and experiences; to explore current challenges and areas of concerns.

1.3 Outline

The dissertation is organized as follows: The literature review is presented in chapter 2, following by the methodology in chapter 3. In order to answer the research questions, a short-term, multiple case study design has been adopted, where the data has been collected through individual semi-structured interviews. The method chapter also includes ethical considerations when conducting research. Chapter 4 presents the findings obtained from the interviews in a cross-case analysis, where chapter 5 discusses the findings. The final chapters presents limitations (chapter 6), implications for research and practice (chapter 7) and suggestions for future research (chapter 8). Lastly, the conclusion of the thesis is presented in chapter 9.

2. Literature Review

This chapter is aimed at providing an overview of the core research on the key topics relevant to the dissertation. The first subsections presents the introduction, definitions and core aspects of IoT in general and in agriculture. Section 2.2 highlights key information about Agriculture in general, as well as the Norwegian agriculture industry. Smart farming and precision agriculture is then explained and defined, as IoT is the core technology in these concepts and as such, considerable research on IoT in agriculture is found under these index terms. Further, a review of IoT challenges in agriculture has been conducted, as well as the main applications and technologies. Lastly, literature on IoT adoption in agriculture is presented.

2.1 Internet of Things

2.1.1 Overview & Defining IoT

Internet of things (IoT) technologies have revolutionized and redesigned almost every industry. It has found its application in several areas such as manufacturing, logistics, smart-cities, healthcare, autonomous vehicles, and in the last couple of years, it has also found its application in the agriculture industry (Elijah et al 2018; Li et al, 2015). It is a relatively new technology paradigm, envisioned as a global network of devices and machines which are capable of interacting with each other (Lee & Lee, 2015). As the name depicts, “things” are associated throughout the Internet via technologies such as Bluetooth, Near-field communication (NFC), Wireless Sensor Networks (WSN), Radio-frequency Identification (RFID), Long term evolution (LTE) and other smart communication technologies (Khanna & Kaur, 2019; Uckelmann et al, 2011).

While there seems to be no global and accepted definition of IoT, the fundamental concept is that it is a complex cyber-physical system which integrates various devices equipped with processing, communication, sensing, identification, and networking capabilities (Da Xu et al, 2014). According to Li et al (2015) the definition of IoT varies depending on various technologies. However, Xu et al (2014,) states that a commonly accepted definition of IoT is “*a dynamic global network infrastructure with self-configuring capabilities based on standard and interoperable communication protocols, where physical and virtual "things" have identities, physical attributes, and virtual personalities and use intelligent interfaces, and are seamlessly integrated into the information network*“ (Xu et al, 2014, 243-244).

As we are now witnessing the evolving of fifth generation (5G) networks, this is promised to make significant contributions of the future IoT (Li et al, 2018). According to Sicari et al (2020) this means higher bit rates, more capacity and low latency, in addition to overcoming the current issues in IoT in terms of network response times and network resources management. It is also expected to tackle many of the challenges in the current 4G network, where it can boost cellular operations, IoT security and network challenges among some (Li et al, 2018).

2.1.2 IoT architecture

The IoT architecture is normally described in three layers, though some authors divide it into more layers depending on their definitions and to add more abstraction to the IoT architecture (Al-Fuqaha et al, 2015; Villa-Henriksen et al, 2020). According to Al-Fuqaha et al (2015) and Tzounis et al (2017) the most general trend is to divide the layers into perception layer, network layer and application layer (Figure 1).

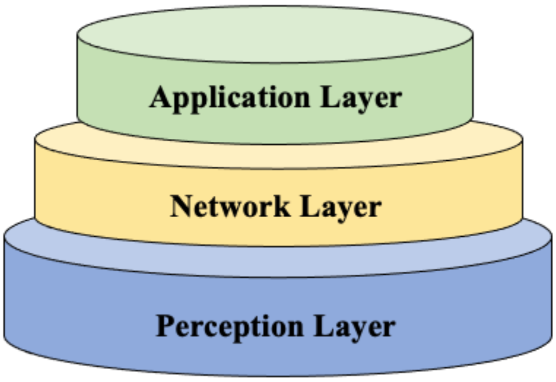

Figure 1. 3-layer architecture of IoT

In short, the perception layer is composed by different sensors and data collectors, while the network layer controls the transmission of the data where its task is to link every "things" collectively and enabling these to distribute information (AlHogail, 2018). The internet forms the core network layer and enables data to be available anywhere and anytime (Elijah et al, 2018). Lastly, the application layer typically stores and facilitates access for the end-user to the processed information (Villa-Henriksen et al, 2020). According to Ray et al (2017) the application layer is the most important in terms of the users, as it acts as an interface which provides necessary modules to control and monitor various aspects.

2.2 Agriculture

2.2.1 The agriculture industry

Agriculture underpins the livelihoods of over 2.8 billion people worldwide (FAO, 2021) and is referred as the basis of life for human beings as it is the main source of food and other raw materials (Khan & Ismail, 2018). It is an industry that is characterized as highly unpredictable due to its dependency on weather, price volatility, change in environmental conditions and unpredictable events such as pests and animal diseases (Kamilaris et al, 2016).

According to FAO (2021) given the industry's direct reliance on natural resources in order for production, its innate interactions with the environment, and its major significance for national socio-economic development; ambitious and urgent action is needed in order to build more resilient agricultural systems. In addition, previously mentioned challenges such as the estimated world population, the demand for food, Covid 19, governmental policies, climate changes and shortages of water, states the importance of the modernization and intensification of agricultural practices.

2.2.2 Norwegian Agriculture

Norwegian agriculture is strongly affected by the country´s geographical location and natural conditions. As illustrated in figure 2, the country is dominated by mountains, heathlands, grasslands and forest, where only about 3% of the entire land is arable land (Almås et al, 2020). The climatic conditions have a strong influence on yields, something which increase the risk associated with crop production (FAO, 1995). In addition, the growing seasons are short, as well as it is characterized by a rather unstable weather (Knutsen, 2020).

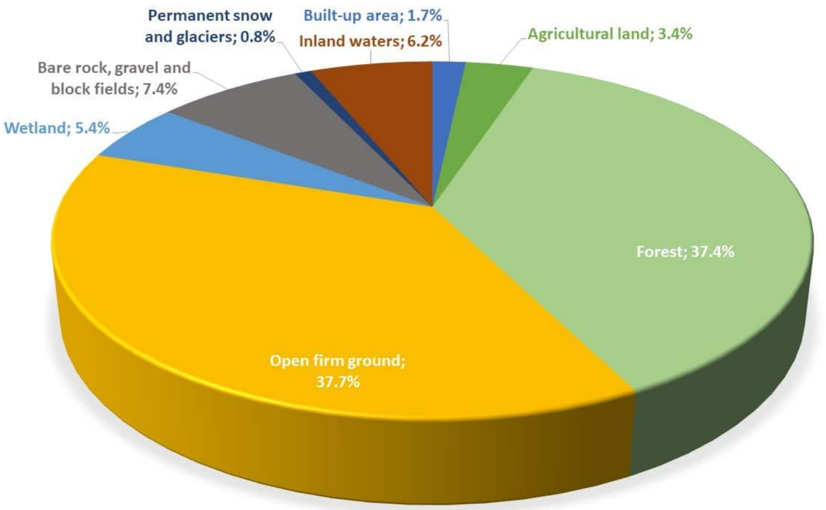

Figure 2. Overview of the Norwegian landscape, Illustration by LA Dahlman (November, 2020) based on Statistics Norway (2020).

With steep hills down to the fiords, high mountains, cold winters and short summers, Norway might seem an unlikely place with active agriculture across the country. They key to achieving this is the tradition of family farming, something which has continued for centuries (Almås, 2004). Hence, most of the farms are run by the family owning the enterprise, often with the help of some hired labor (Knutsen, 2020).

Despite the importance and tradition of family farming, the number of farms in Norway is decreasing. According to SSB (2021) there were 38 633 farms in Norway in the year of 2020, something that is an 17,1% reduction from the year of 2010 and an 1,2 % reduction from 2019, as can be seen in figure 3. At the same time as the number of farms are decreasing, the average farmland acreage on those farms which is still operating, is constantly increasing, going from 14.7 ha in 1999 to 24.9 ha in 2018 (Knutsen, 2020), meaning that the size of the farms is increasing, but there are also fewer Norwegians that continues to be, or are becoming, agriculturists.

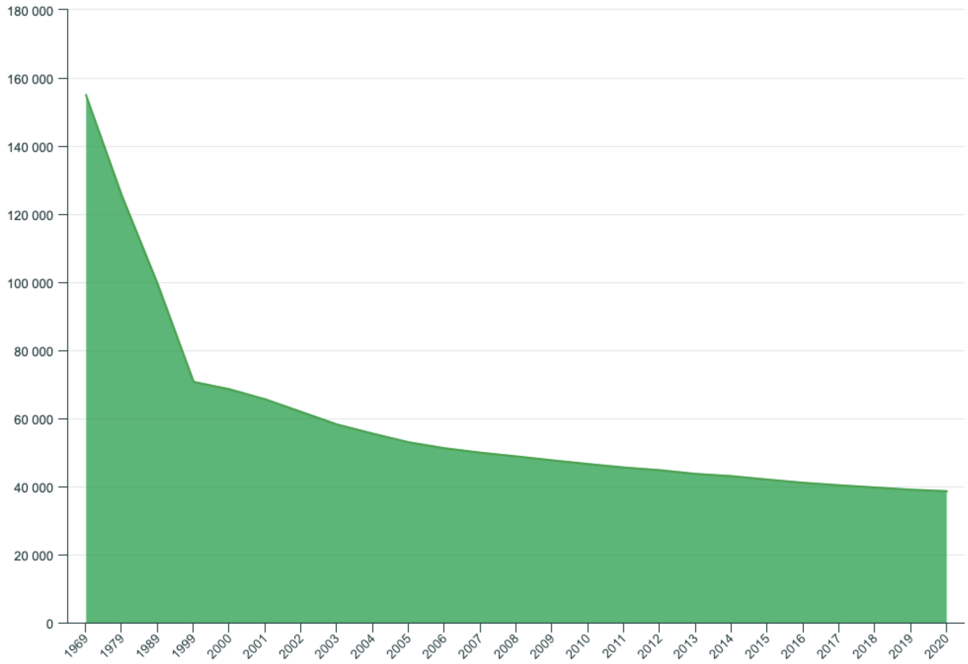

Figure 3. Number of farms in Norway (SSB, 2021)

Agriculture is a strictly regulated industry in Norway, where the Agricultural Policy has a big impact on what that is going to be produced, how much to produce as well as where the production takes place (Rognstad & Steinset, 2009). In addition, international agreements provide frameworks for the national policy. The industry also heavily depends on governmental subsidies, due to small farming units compared to other countries, as well as high costs (Lundekvam et al, 2005).

January 2021, the Norwegian government presented the Climate Action plan which is describing the plan for the transformation of Norwegian society as a whole by the year of 2030. It describes how Norway will achieve its climate target, and at the same time create green growth (Ministry of Climate and Environment, 2021). The agriculture industry plays an essential part in order to reduce the greenhouse gas emissions, without compromising the food production (Ministry of Agriculture and Food, 2021). In order to achieve the climate goals in the agriculture industry, a report by Norwegian Agricultural Cooperatives &

Norwegian Agrarian Association (2020) highlights that new, green technology is central and that IoT technologies are going to play a significant role in the years to come.

2.3 IoT in agriculture

2.3.1 Smart farming & Precision agriculture

The implementation of IoT technology is shaking the existing agriculture methods towards the concepts of Smart farming (an equivalent term in literature is Smart Agriculture and Digital Farming) and Precision agriculture. IoT is the key in these concepts, as it ensures data flow between sensors and devices, which makes it possible to add value to the obtained data by automatic processing, analysis and access (Villa-Henriksen et al, 2020).

While definitions of precision agriculture are somewhat inconsistent, the term that is adopted is "*a management strategy that gathers, processes and analyzes temporal, spatial and individual data and combines it with the other information to support management decisions according to estimated variability for improved resource use efficiency, productivity, quality, profitability and sustainability of agricultural production* (International Society of Precision Agriculture, 2018). As an example, rather than applying equal amounts of fertilizers on an entire agricultural field, precision agriculture methods will measure variations in conditions by using different IoT technologies and adapt its fertilizing strategy accordingly (Schrijver et al, 2016).

Smart agriculture is developing beyond the modern concept of precision agriculture. According to Villa-Henriksen et al (2020) it also bases its management tasks on spatial data, such as in precision agriculture, but is enhanced with context-awareness and is activated by real-time events, something which improves the performance of hitherto precision agriculture solutions. It emphasizes the use of information and communication technology, where the IoT technologies provides massive volumes of data which are being captured, analyzed and used for decision-making (Wolfert et al, 2017).

2.3.2 Overview & Current standings

The application of IoT technology in agriculture is about empowering the agriculturists with decision tools and automation technologies that seamlessly integrate products, knowledge and services for better quality, productivity and potentially profit (Elijah et al, 2018; Jayashankar et al, 2018). It is also at the center and forefront in making agricultural operations more sustainable (Ayaz et al, 2019). As IoT provides the agriculturists the opportunity to use their smart phones or their computers to access real-time agricultural data, such as irrigation, climate, weather, livestock monitoring etc., they can act and intervene based on solid data, rather than their traditional intuition (Boursianis et al, 2020). According to Elijah et al (2018) the data can range from sensor data, historical data, live streamed data, business data, and market related data. As such, Kamilaris et al (2016) states that it provides the opportunity for agriculturists to become more informed about their farms' conditions and risks in real-time, as well as providing them with the opportunity to take proper countermeasures to protect and improve their production.

Furthermore, in today's society, consumers and policy makers are being more and more concerned and engaged about topics such as animal welfare, ecological food and more sustainable ways of doing business. There is also an increasing demand from people who wants to understand where their food comes from and how it has been produced. This need is leading to an increasing interest in food supply chain traceability (Ferrag et al, 2020). According to Villa-Henriksen et al (2020) IoT eases supervision and documentation of different agricultural activities, as well as the traceability of products, which will improve the environmental surveying and control in farms by the appropriate authorities. As such, traceability in the farm and the whole supply chain is creating value for both agriculturists, retailers and processors, as well as the end-consumers (Ferrag et al, 2020).

As we are now witnessing the next generation of 5G networks being put in action, Tang et al (2021) states that it will be much easier to deploy, monitor and manage IoT devices on farms. As seen in Figure 4, there are several areas where the 5G network is beneficial in agriculture (Tang et al, 2021). The network is predicted to take IoT technology to new heights, and in the AgTech2020 conference, it was stated that "*for the digitalization to succeed, all the different machines and sensors need to be connected. 5G is key to this, as it can provide coverage in the countryside where the fields are*" (Norsk Forskningsråd et al, 2020). This actively demonstrates that IoT will take a gigantic leap in the agriculture industry in years to come.

Figure 4. Key areas where the 5G network is beneficial in Agriculture (Tang et al, 2021)

2.3.3 IoT challenges in Agriculture

IoT is rapidly changing the agriculture industry. Despite creating opportunities and benefits, there are also a great number of challenges that needs to be addressed and conquered in order to safeguard IoT adoption and diffusion. According to various researchers, the use of IoT devices introduce a vast exposure to general IoT challenges such as security and privacy issues, as well it introduces cybersecurity threats, the potential of agroterrorism, and other vulnerabilities in the agriculture environment that differs from typical IoT challenges (Ayaz et al, 2019; Barreto & Amal, 2018; Gupta et al 2020). Tzounis et al (2017) states that by introducing IoT in agriculture, new threats arise, which can result in negative consequences which was not possible or imaginable before. Table 1 presents an overview of identified IoT challenges in agriculture.

IoT challenges in agriculture	More specific
Security and Privacy in general	Authentication, Access control, Confidentiality
Supply Chain challenges	Supply chain attacks
Cyber security	Cyber-attacks, Agroterrorism
Technical challenges	Reliability, Mobility, Availability, Scalability, Interoperability, Compatibility with 5G
Hardware challenges	Temperature, Humidity, Durability, Weather, Topography

Table 1: Identified IoT challenges in agriculture

Privacy and security challenges

Privacy and security are key factors in order to provide a trustworthy IoT (Uckelmann et al, 2011). According to Farooq et al (2019) privacy in agriculture can be summarized in three requirements which are authentication, access control and confidentiality. As a farm that uses IoT technology consists of enormous amounts of dynamic, complex and spatial data generated from different heterogeneous sensors and devices, Gupta et al (2020) emphasizes how it has brought new opportunities to attack places that previous was difficult to strike or too remote.

Barreto & Amaral (2018) proposed a scenario, stating that if a malicious actor publish false data about disease outbreaks in livestock, or publishes unapproved genetic modifications of crops, this will have huge consequences for the agriculturist. Gupta et al (2020) proposed another scenario, where IoT devices could be infected by malware which are being controlled and commanded remotely. In such a scenario, they state that it could be possible to orchestra large scale attacks on all the farms that are utilizing those compromised technologies, something which ca result in massive disruption in the industry.

Some studies have also explained how agricultural IoT devices have the potential to not only affect the agriculturists, but also the supply chain, which is an essential part of agriculture (Barreto & Amal, 2018; Tzouniz et al, 2017). By using new IoT based solutions, supply chains can be controlled, monitored, planned and optimized remotely, but with IoT in each stage of the supply chain, this introduces several potential security threats (Tzounis et al, 2017).

Gupta et al (2020) also elaborated on how IoT has the potential to affect the consumers. They presented another scenario, claiming that if the devices that ensures the temperature when products are processed and packed gets manipulated by adversaries, this could result in inappropriate temperature conditions which could have an impact on not only the supply chain, but also the end-consumers.

Lastly, Barreto & Amaral (2018) also discuss that the possibility of cyber terrorism, known as agroterrorism, is threatening the agriculture industry. An agroterrorism attack could have major consequences like destroying a farms trust as a food supplier, but it can also have deep human and financial consequences. As it is a relatively low-cost venture with high payoff potential, Barreto & Amal (2018) argues that the risks of agroterrorism is too large to ignore.

Conceptual and fundamental challenges

There are also several conceptual and fundamental challenges identified with IoT, such as reliability, mobility, availability and scalability issues (Al-Fuqaha et al, 2015; Elijah et al, 2018; Farooq et al, 2019; Khanna & Kaur, 2019). According to Al-Fuqaha et al (2015) reliability refers to the proper working of the system based on its specification. In agriculture, it also refers to the fact that the IoT devices will be exposed to harsh environmental phenomena like strong winds, extreme humidity, extreme temperatures, and other dangers capable of destroying the hardware, which exists at the perception layer (Farooq et al, 2019). As such, Vuran et al (2018) states that the devices need to be durable and easy to maintain, as it can easily be damaged in such conditions.

Moreover, as billions of IoT devices are expected to be deployed in agriculture, this compels the need for scalability and interoperability (Elijah et al, 2018). According to Khanna & Kaur (2019), scalability refers to the concept of adding newer devices over existing infrastructure without affecting the capabilities of the framework. Hence, Elijah et al (2018) states that large numbers of gateways and protocols are needed in order to support IoT devices. In addition, as most of the services are expected to be delivered to mobile agriculturists, the challenge of mobility becomes prominent (Elijah et al, 2020; Khanna & Kaur, 2019).

There are also other challenges and issues that is important to address within IoT, such as interoperability, standardization, management of network, compatibility with 5G and standardization (Al-Fuqaha, 2015; Farooq et al, 2019; Khanna & Kaur; 2019; Elijah et al, 2020).

2.4 Applications of IoT in agriculture

The applications of IoT in agriculture is vast, ranging from crop and yield monitoring, weather and soil monitoring, greenhouse production, livestock monitoring, water management as well as disease and pest control, to mention some. An overview of the most typical IoT applications in agriculture can be seen in Table 2. In the following sections, some of the most important and newest applications of IoT in agriculture is presented.

Crop farming	Field monitoring (temperature, soil richness, climate, humidity, gas, crop) Water and irrigation management Disease & pest monitoring Irrigation monitoring Tracking and tracing Warehouse monitoring (temperature, CO2)
Forestry	Drones (different purposes) Forestry monitoring (temperature, gas, disease)
Livestock farming	Health monitoring (temperature, heart rate, digestion) Activity monitoring Dairy monitoring Virtual fencing
Supply chain management	Tracking Traceability Warehouse monitoring Temperature and humidity
Greenhouse	Condition monitoring (humidity, light, temperature, CO2, gas etc) Water management Plant monitoring

Table 2. IoT applications in agriculture

2.4.1 Livestock monitoring

IoT based solutions provides several opportunities within livestock farming. Livestock monitoring technologies provides the opportunity to monitor activity, real-time tracking, as well as monitoring health records (Karthick et al, 2020; Kvam, 2019). Karthick et al (2020) states that the use of IoT in animal healthcare is an upcoming paradigm, where different IoT devices are facilitated to autonomously acquire real-time data such as physiological parameters, the farm environment and behavioral features of the livestock. In order to acquire the data, devices can be placed on the animal, often around its neck as a collar or as an ear tag, where the devices are facilitated with machine-readable identification which transfers the data over the network. The data can then be analyzed for inferring useful insights, such as behavioral change prediction, estrus cycles, disease prediction, activity detection and feed consumption (Karthick et al, 2020; Neethirajan et al, 2017; Ray et al 2017).

2.4.2 Dairy monitoring

One of the agricultural robots that has played a significant role in Norwegian agriculture is milking robots, which provides the opportunity of livestock and dairy monitoring. According to Kvam et al (2019) a milking robot is associated with increased productivity and efficiency, and consequently profitability in dairy farming. By wearing IoT based collars or ear tags for identification, the machine provides a stream of information on each of the cows. As such, the agriculturist gains information on each of the animals in real-time, where they can do specific adjustments on each cow, depending on their needs (Kvam et al, 2019).

2.4.3 Virtual fencing

Another emerging technology that has a huge potential in livestock farming, is virtual fencing. Brunberg et al (2015) claims that a common problem in livestock farming is that the grazing areas are often large and remote, something which makes supervision of the animals challenging, as well as it is not easy to keep them within the intended pasture area. By implementing virtual fences, these issues can be solved as it provides the possibility to locate and to herd animals to different locations, without any labor input (Umstatter, 2011). Similar to a physical fence, virtual fences assist in providing a boundary in order to contain animals, but it does not implement a physical barrier (Muminov et al, 2019). As such, by selecting pre-defined pastures on a computer or in a mobile application, agriculturists can give the animals access to the pastures of their choice, exclude areas, as well as track them in real-time (Vik et al, 2020).

2.4.4 Crop farming

By deploying IoT technologies in crop farming, agriculturists can obtain detailed insight and information on various parameters, such as soil analysis and mapping, fertilizers, pesticides, yield prediction and irrigation (Tang et al, 2021). As an example, by gaining data on nutrient levels and weather, this can help determine the required amount of fertilizers for the growth of the crops, as excess levels affect the fertility level of the soil (Tang et al, 2021).

Different IoT technologies can also be deployed for disease and pest management in crop farming. According to FAO (2021) due to diseases and pests, up to 40% of crops are lost annually. In order to address this challenge, IoT devices such as robots, sensors and drones are being employed to detect pests and diseases, allowing precise usage of pesticides, and as such, minimizing the risks in crop production. As most of the pesticides are harmful to human and animal health, as well as it can leave significant contamination to the entire ecosystem, precise use of fertilizers also contributes with other positive outcomes than just minimizing the risks in crop production (Ayaz et al, 2019).

2.4.5 Water management & Irrigation

According to FAO (2011) agriculture is the largest water user worldwide, accounting for 70% of freshwater withdrawals on average. New and existing technologies are aiming to optimize water usage, improving the quality and quantity, in addition to minimizing the human intervention (Elijah et al, 2018). As crop quality and quantity are badly affected when facing shortages of water, irregular irrigation, and even excess, accurately estimates of water can provide better crops, as well as it can tackle water wastage issues (Ayaz et al, 2019). An example is how the use of remote sensors in the soil for measuring blueberry irrigation, reduced the volume of water used by 70% on a farm in Chile (Gupta et al, 2020). Furthermore, soil moisture sensors can be linked to irrigation systems, which provides the opportunity to irrigate the exact amount needed for the specific soil type (Boghossian et al, 2018).

2.5 IoT adoption in agriculture

2.5.1 Motivation factors

Relative advantage

Researchers and studies have found that one of the primary motivation factors of investing in IoT technology is to increase profitability (Batte & Arnholt, 2002; Jayashankar et al, 2018; Kutter et al, 2011; Pierpaoli et al, 2013; Tey & Brindal, 2012). Findings from Pierpaoli et al (2013) study showed that a profit motivation- either to earn profits or to better position the farm to be profitable in the future, was the top reason for why agriculturists adopted precision farming technologies. Likewise, Kutter et al (2011) found in their survey of 30 farmers in Germany, that economic reasons were the most important factor behind the adoption of precision agriculture adoption. Tey & Brindal (2012) claims that such a concept of profitability in agriculture is based on the assumption that the net savings made from the technology more than offset the costs of either the purchasing of more specialized equipment, additional labor or sacrifice of amenity.

Furhter, Batte & Arnholt (2002) found improved information to support decisions and risk reduction as important motives of adoption. The improved decision-making aspect was also shown to be one of the most important drivers of precision agriculture technology adoption in Reichardt & Jürgens (2009) study among German agriculturists.

Farmer characteristics

Agriculturist characteristics such as farm size, education, technical skills and the age of the farmer has often been found and considered as decisive factors in agricultural technology adoption (Barnes et al, 2019; Paustian & Theuvsen, 2017; Pierapaoli et al 2013). Pierapaoli et al (2013) states that a high level of farmer education, high farm income and location are all mentioned frequently as equally important factors for technology adoption. This is also supported by Barnes et al (2019), which stated that formal education, as well as age, is a common indicator of innovative behavior for most studies of technology adoption, and seem to support the notion that formally educated, as well as younger agriculturists are more likely to adopt precision agriculture technologies. However, some researchers have also found age and education to have no effect, such as Knierim et al (2018) which found that age or education had no effect on adoption among agriculturists from seven EU countries.

Information sources

Social influence has shown to profoundly affect human behavior in general, but also particularly in technology adoption (Graf-Vlachy et al, 2018). The cues-to-action construct assumes that previous interactions, activities and events with other people will influence people´s behavior and also motivate them to change their behavior (Geil et al, 2018). In a study among Indian farmers, it was found that social influence is a key predictor for adoption, as the farmers interacted with other villagers before adopting new technology, as well as they had community-wide discussions at a specific forum (Pillai & Sivathanu, 2020). This is also supported by Knierim et al (2018) where they found that the farmers community is the first choice in regard to information sources.

While social influence is incorporated as "*the interpersonal considerations*" of technology and use in IS research (Chan et al, 2010), marketing is the process of selling and promoting agricultural IoT technology-related products and services to agriculturists. This involves the activities of media, farm magazines, television, research publications, agricultural technology (AgTech) companies, tradeshows, retailers, manufacturers, input suppliers and the availability of technologies (Pathak et al, 2019). In Kutter et al (2011) study among German agriculturists, they found exhibitions, field days, agricultural fairs, seminars and workshops important in the context of information sources, where advertisement and the internet were considered to be of medium importance. They also found that agricultural technology firms, professional literature, and agricultural consultants were important information sources for spreading precision agriculture-relevant information.

Observability and trialability

Trialability refers to technologies that agriculturists can try on a limited basis before making the decision to adopt, while observability is the degree to which the results of an innovation are visible to others (Rogers, 2006). Observability in agriculture may apply during trialing of the technology, or when other industry members adopt the technology (Pathak et al, 2019). According to Rogers (2006) the easier it is for individuals to observe the results of an innovation, the more likely they are to adopt it. Knierim et al (2018) study showed that other farmers are an important source of information regarding the observability of smart agriculture technologies.

Regarding trialability, Pierpaoli et al (2013) findings showed that free trials were highly appreciated by agriculturists, as it promotes the perception that the use of a technology is easy. This is also supported by Knierim et al (2018), however, findings from their study revealed that there is no opportunity for the agriculturists to try and experiment with smart farming technologies. As such, the lack of trialability was perceived as an adoption barrier. According to Karahanna et al (1999) trialability of an innovation is important in reducing the risk and uncertainty of using the technology, as well as it provides the adopters a risk-free way to experiment and explore the technology. This can increase the adopters comfort level and the likelihood of adoption.

2.5.3 Adoption barriers

Financial factors

There are several costs associated with the deployment of IoT in agriculture, both in regard to setup costs and running costs. According to Elijah et al (2018), the setup costs include the purchase of the hardware, while the running costs involves continuous subscription for use of services and IoT platforms, management of IoT devices and sharing of information among other services. There are also additional running costs such as energy and maintenance.

According to Rogers (2003), the initial cost of an innovation can affect its rate of adoption. In previous literature on IoT adoption in agriculture, this has been found to be the most frequently mentioned adoption barrier. Several researchers and scholars have found that many agriculturists hesitate to adopt IoT technology due to the high costs (Barnes et al, 2019; Knierim et al, 2018, Norwegian Agricultural Cooperatives & Norwegian Agrarian Association, 2020; Pierpaoli et al, 2013; Pillai and & Sivathanu, 2020; Reichardt & Jürgens, 2009; Tey & Brindal 2012; Villa-Henriksen, 2020). In a study by Agjeld & Dyrdal (2019) on precision agriculture technology in Norway, this was also found to be one of the main barriers of adopting such technologies. This is also supported by Norwegian Agricultural Cooperatives & Norwegian Agrarian Association (2020) which indicated that a barrier for using new, green technology in agriculture in Norway is that the technology is non-competitive on price, especially in the beginning.

Security & privacy risks

Some studies have found that perceived risk of data being misused can adversely affect the adoption, and that agriculturists feel that adoption of IoT in agriculture is a high risk as their farm data might be shared with others without their consent (Farooq et al, 2019; Jayashankar et al, 2018; Kutter et al, 2011; Pillai & Sivathanu, 2020). Boghossian et al (2018) proposed a scenario where a malicious actor could potentially alter data or algorithms in livestock breeding management about a competitor´s breeding stock, something which can result in missing the breeding gestation windows for high value animals, causing significant financial losses to the agriculturist. As such, Kutter et al (2011) states that as farm data is considered sensitive, fears of data misuse are widespread among agriculturists. Adding on this, Gupta et al (2020) claims that most devices in agriculture are not built with security as concern, and even if they do, they found that agriculturists and other users often neglect the basic procedures and steps of setting adequate cybersecurity defense mechanisms.

Lack of knowledge and technological skills

What appears to be a frequently cited challenge is the agriculturists lack of awareness of IoT technologies and their lack of knowledge on how the adoption of IoT technologies will affect them and their farming operations after being implemented (Aubert et al, 2012; Ayaz et al, 2019; Elijah et al, 2018; Farooq et al, 2019; Knierim et al, 2018; Pillai & Sivathanu, 2020). Elijah et al (2018) found lack of adequate knowledge of IoT and its application as a major factor slowing the adoption, especially among agriculturists located in rural areas. In Farooq et al (2019) and Ayaz et al (2019) studies, the lack of knowledge aspect is also prominent, where their results indicated that uneducated farmers are a major problem when moving from traditional agriculture to IoT based agriculture. This has also been supported in the study by Agjeld & Dyrdal (2019) where “lack of knowledge” and “too expensive technologies” were found to be the main barriers for using precision agriculture technologies in Norway.

Complexity

The agriculturists opinion regarding ease of use of the technology is a feature of the innovation that can be defined as the complexity of the technology (Pathak et al, 2019).
In Kutter et al (2011) study, they claimed that one of the reasons for why precision agriculture technologies was applied less frequently than expected in Europe, was not only due to the high costs of the technologies, but also the high learning costs associated with the complexity of the systems. This is also supported by Knierim et al´s (2018) and Pillai & Sivanthanu

(2020), who found that perceived complexity is a barrier to use different technologies in agriculture. Aubert et al (2012) stated that lack of knowledge seems to be a major reason explaining the agriculturists impression that such technology is difficult to use. As such, agriculturist that perceives that the technology is complex and difficult to use, is therefore less likely to implement it in their farming operations (Aubert et al, 2012).

3. Method & Theoretical background

3.1 Research method

Research is defined by Oates (2006, 7) as "*the creation of new knowledge, using an appropriate process, to the satisfaction of the users of the research*". According to Seale (1999), research is repeatedly distinguished between quantitative and qualitative research, and have different applicability. Qualitative research is primarily exploratory research that emphasis on measuring data that is concerned with words, images, and sounds where one wants to gain an understanding of motivations, opinions and reasons; thus give insight into the research problem (Oates, 2006). Quantitative research, which is the other type of research, is used to quantify the problem based on numerical data and allows to generalize the results because of the larger sample (Oates, 2006). In this dissertation, a qualitative approach has been selected.

3.2 Research design

The following paragraphs present a clarification on the chosen research design, including how the data will be collected and analyzed in order to answer the research questions. Figure ** gives an overview and summary of the research process and its components based on Oates (2006). The adapted strategy, data generation method and data analysis for this dissertation is marked in green.

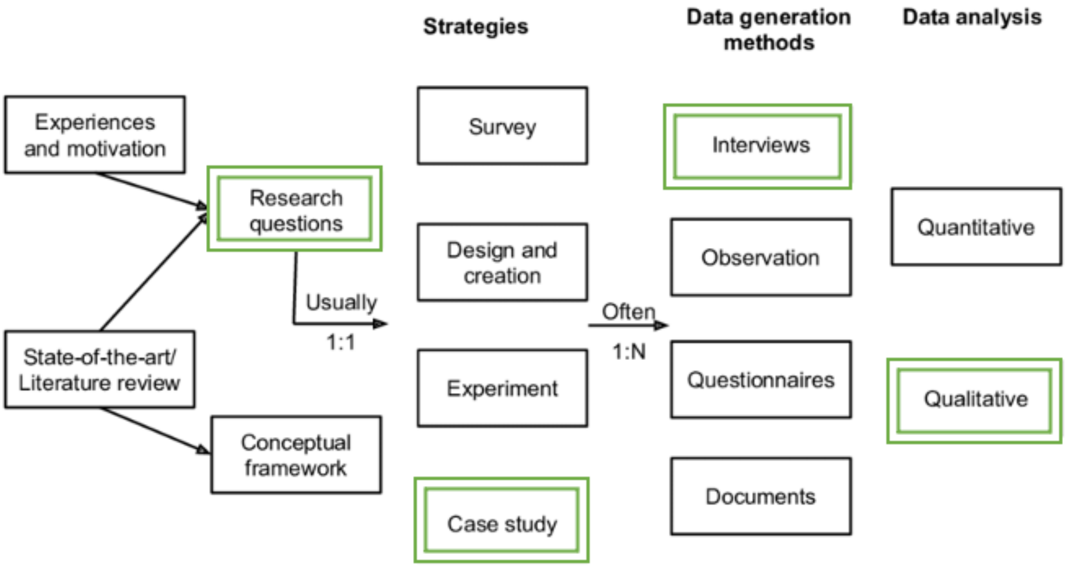

Figure 5. The research process by Oates (2006, 33)

3.3 Theoretical frameworks

Information systems literature presents several theories and models that are seeking to explain technology adoption, users´ acceptance and their intention to practice the technology. These include, but are not limited to, Technology Acceptance Model (Davis et al, 1986), Theory of Planned Behavior (Ajzen, 1991), Theory of Diffusion of Innovations (Rogers, 2003), the Technological, Organizational and Environmental framework (Tornatzky & Fleisher, 1990) and Determinants of Diffusion, Dissemination, and Implementation of Innovations (MDDDII) (Greenhalgh et al, 2004). In the following sections, the Diffusion of Innovations theory, by Rogers (2003) and the MDDDII conceptual model by Greenhalgh et al (2004) is presented, as these has been adopted in this study.

3.3.1 Diffusion of innovations theory

The diffusion of innovations (DOI) theory by Rogers (2003) provides a theoretical basis for explaining the process of technology adoption, the so called ''diffusion'' process. Four main elements in the diffusions of innovation are proposed: the innovation, communication channels, time and the social system. Within the innovation element, he presents five attributes of an innovation that affects its rate of adoption: relative advantage, compatibility, trialability, observability, complexity.

Rogers (2003) also proposes five adopter categories, which is a classification of the members of a social system based on their innovativeness. The four classifications are as follows: (1) Innovators, (2) Early adopters, (3) Early majority, (4) Late majority, and (5) Laggards. The ''innovators'' actively seek out new information and are the first to adopt an innovation. As they are the first ones to adopt a new idea, Rogers (2003) states that they cannot depend upon the subjective evaluations of the innovation from their social networks. The innovators are followed by a larger group of ''early adopters". Further, "early majority" adopt new ideas just before the average member of a system, while the group of ''late majority'' is generally more skeptical and they only accept the innovation when the majority is already using it. The last group, the ''laggards'' cling to the old ways and will only accept a new technology if it has already entered the mainstream or even become part of tradition (Rogers et al, 2003; Kutter et al, 2011). The adopter categories are illustrated in figure 6.

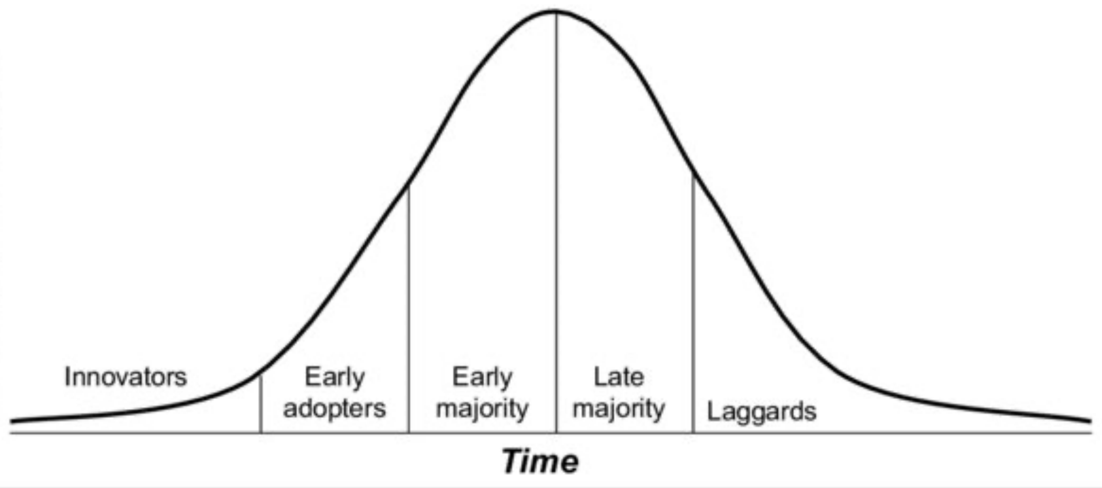

Figure 6. Adopter categories by Rogers (2003)

3.3.2 MDDDII Conceptual Model

The model of Determinants of Diffusion, Dissemination, and Implementation of Innovations (MDDDII) was derived from Greenhalgh et al (2004) synthesis and systematic review of theoretical and empirical findings, and was originally a unifying conceptual model for considering the diffusions of innovations in health services (figure 7). According to Greenhalgh et al (2004) the model is intended as a memory aide for considering the different aspects of a complex situation and their many interactions. It focuses on the entire adoption process, from early stages of adoption to the acceptance and integration (Greenhalgh et al, 2004).

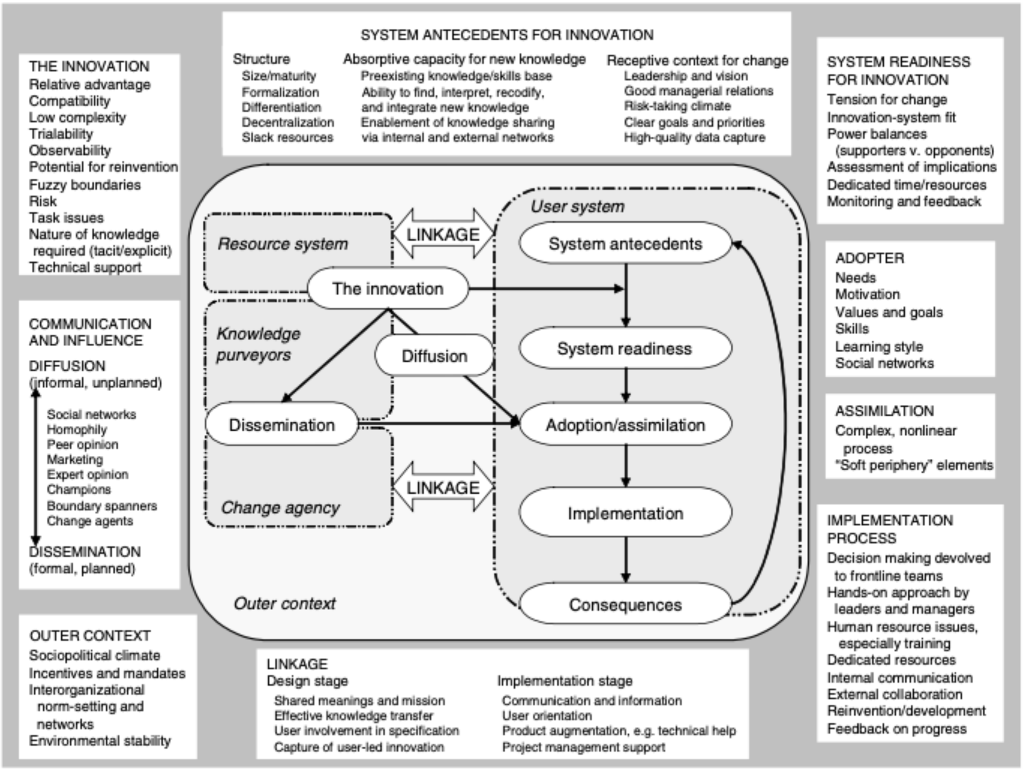

Figure 7. The Model of Determinants of Diffusion, Dissemination, and Implementation of Innovations (MDDDII) by Greenhalgh et al (2004)

The model is divided into nine broad components. The nine components are (1) The innovation, (2) Communication and influence (3) The outer context, (4) The adopter (5) System antecedents for innovation (6) System readiness for innovation (7) Linkage (8) Assimilation and (9) Implementation process, where each of the components incorporates a set of factors and processes that can influence the adoption of innovations (Greenhalgh et al, 2004).

3.3.3 Choice of Theoretical frameworks

In order to explore and explain factors influencing IoT adoption, as well as post-adoption evaluation, elements from DOI Theory (Rogers, 2003) and the MDDDII conceptual model (Greenhalgh et al, 2004) are integrated. These theoretical frameworks have been used when developing the questions in the interview guide, as well as the findings and discussion are structured and based on components and factors from both of them. The MDDDII model (Greenhalgh, 2004) adds additional features and components compared to the DOI theory (Rogers, 2003). As an example, while Rogers (2003) covers five factors of the innovation; relative advantage, compatibility, observability, complexity and trialability, the MDDDII adds additional features such as technical support, knowledge required and risk, in addition to covering the factors from the DOI theory (Rogers, 2003).

In Pathak et al (2019) systematic literature review on precision agriculture adoption, they used the MDDDII as theoretical basis in order to identify key aspects of the innovation adoption process in agriculture. It was found that the model could explain many of the factors affecting IoT adoption in agriculture. However, they also found that albeit there exist prior research on IoT adoption in literature linked to agriculture, few publications have examined multiple components of the adoption process, as well as most of the current research are narrowly focusing on assessing the impact of only a few aspects, such as only agriculturist characteristics or relative advantage. They concluded that in most of the current literature and research, the complexity and multidimensional nature of the adoption process is poorly represented (Pathak, 2019).

Pathak et al (2019) provided a systematic literature review where the MDDDII was the theoretical basis, however, to my knowledge, no other researchers have applied the model in a study on IoT adoption in agriculture. As the model was originally developed for service industries, where the unit of adoption is an organization or a team (Greenhalgh et al, 2004), it is acknowledged that not all the elements of the model are likely to affect IoT adoption in agriculture. In addition, the model is complex and introduces several components which are too vast for this thesis to explore. Due to the scope of this study, as well as time limitations, the following components and their incorporated factors from the MDDDII conceptual model are used in order to explore and answer the research questions in this dissertation: (1) The adopter, (2)The innovation (3) Communication & Influence and (4) Outer context. The study also incorporates components, factors and elements of the DOI theory (Rogers, 2003).

3.4 Research strategy

3.4.1 Case study

According to Yin (2018), the scope of a case study is defined as "*an empirical inquiry that investigates a contemporary phenomenon (the "case") in depth and within its real-world context, especially when the boundaries between phenomenon and context may not be clearly evident*". It focuses on different factors, issues, processes, relationships, and politics that constitute the messiness of the real world (Oates, 2006). Yin (2018) suggests that one might favor choosing case study research when (1) the main research questions are “why” and “how”, (2) one have little or no control over behavioral events, and (3), the focus of the study is a contemporary phenomenon.

Case studies can assume many compositional forms. In order to understand IoT adoption and evaluation in Norwegian agriculture, a multiple case study has been conducted. According to Oates (2006) most multiple-case studies are likely to be stronger than singe-case studies. However, Yin (2018) also states that multiple cases have disadvantages as it can be both time-consuming as well as expensive to conduct. Nevertheless, as this study is focused on the current situation, this research is classified as a short-term, contemporary study (Oates, 2006).

When conducting research, a well-known dilemma is deciding how many interviews that is going to be enough in order to answer the research question. In Marshall et al (2013) paper, they addressed the problem of estimating and justifying sample size of qualitative interviews. They examined 83 IS qualitative studies from leading IS journals and found an extreme variation in sample size in all research designs. Their main conclusion was that there is little rigor in justifying sample size. However, they stated that estimating adequate sample size is directly related to the concept of data saturation. According to Marshall et al (2013, 11) “*saturation is reached when the researcher gathers data to the point of diminishing returns, when nothing new is being added*”. Considering the data saturation in this research, a critical reflection of the number of participants has been conducted. After the sixth interview, no new topics or perspectives were introduced, and the right depth of the data was found.

3.5 Data collection

The data collection process took place in the beginning 2021 and lasted until the end of April 2021. Some of the secondary data was also collected earlier, as the literature has been part of previous exams, as well as a pre-project period. As this research will consist of complex questions and explore experiences that are not easily observed, in addition to focus on obtaining detailed information, individual in-depth interviews have been conducted (Gripsrud et al, 2016). According Gripsrud et al (2016), individual in-depth interviews are often used when the topics are sensitive, where the participants do not want to explain themselves in front of others, and when you want to gain insight in the respondent’s individual experience without being influenced by others. In addition, DiCicco-Bloom & Crabtree (2006) states that it allows the researcher to explore more deeply into personal and social matter compared to group interviews.

When conducting interviews, a choice can be made between three types: structured, semi-structured and unstructured interviews. In this thesis, semi-structured interviews have been conducted, as it allows the participants to speak their minds and as it is an in-depth investigation (Oates, 2006). This also gave the interview object and the interviewer the possibility to further elaborate on the questions that were found to be particularly interesting.

In regard to the question content and wording in the interview guide, an attempt was made to follow the guide by Oates (2006) by formulating the questions with the following criteria in mind: relevant, brief, specific, unambiguous and objective. The questions in the interview guide have been developed based on components and factors in the MDDDII conceptual model (Greenhalgh et al, 2004) and the DOI theory (Rogers, 2003). It was also influenced by conversations with agricultural stakeholders in Norway, as well as previous research on technology adoption in the agriculture. Lastly, due to the Covid-19 pandemic, it was not possible to conduct interviews face-to-face. As a result, the interviews were conducted digitally, something which also provided a natural setting as the participants were able to participate from home.

Furthermore, when one does not know much about the population, Oates (2006) states that non-probability sampling techniques can be conducted. One of the possible non-probability sampling techniques is “snowball sampling”, which is useful when the researcher does not know how to gain access to the target group (Oates, 2006). As the researcher did not have access to agriculturists that have adopted IoT technologies, this technique has been adopted and is explained in more detail in the next section.

3.5.1 The participants

Participant group: Stakeholders in agriculture

Stakeholders from the Norwegian agriculture industry were contacted in the beginning of the dissertation period in order to get a deeper understanding of the industry, as well as getting suggestions for other stakeholders and agriculturists that has adopted IoT technologies. Some of the stakeholders were contacted based on their attendance on the AgTech 2020 digital conference, while other stakeholders were collected based on their occupations and roles in the industry. During informal and unstructured meetings, interesting viewpoints from six stakeholders within different departments and with different agendas was obtained.

Due to the stakeholders' network and the fact that the researcher did not have access to agriculturists that have adopted IoT technologies, it was preferable to get recommendations for other information sources and possible agriculturists. As such, the snowball technique (Oates, 2006) was used. This was proven to be a great approach to find agriculturists, as well as other relevant stakeholders. In the following table, an overview of the stakeholders is presented.

Stakeholder	Description of the stakeholders	Duration
Stakeholder 1	Chief Advisor, Research & Innovation	32min
Stakeholder 2	AgriTech Expert & Advisor	55min
Stakeholder 3	AgriTech Company (1) CTO & Board member (2) Customer Support	43min
Stakeholder 4	Precision Agriculture Expert	59min
Stakeholder 5	CEO - AgriTech Company	58min

Table 3. Participant group: Stakeholders in Norwegian agriculture

The information obtained from the stakeholders has served as a guidance in regard to the questions in the interview guide, and as previously stated, to find agriculturists that has adopted IoT technologies. As the scope of this dissertation is to study agriculturists, and not perceptions and beliefs of agricultural stakeholders, information obtained from the meetings with the six stakeholders are not included in the dissertation. As such, the thesis will not contain citations or statements from the stakeholders, as these conversations were conducted in order to gain more knowledge about the industry, as well as to access to agriculturists.

Participant group: Norwegian agriculturists

The primary criteria for case selection were Norwegian agriculturists with medium to large farms, which has implemented IoT technology in their farming operations. As the goal is to explore IoT in agriculture in general, not only focusing on a specific agricultural area or a particular technology, three different agricultural areas with different IoT technologies have been selected. The chosen agricultural areas are dairy production, crop farming and livestock farming. These are some of the most important and central agricultural areas in Norway, as well as the technologies they have adopted are some of the newest innovations within agricultural IoT technologies. A total of six Norwegian agriculturists (two within each agricultural area), were approached to participate, where positive responses from all of them was received (See table 4).

Participants	Type of farming	Size	IoT Technology	Interview Time
Participant A	Dairy production	Medium/Large	Milking robot & Activity monitoring	1:45
Participant B	Dairy production	Large	Milking robot & Livestock monitoring	2:20
Participant C	Crop farming	Large	Irrigation & Crop monitoring systems	2:30
Participant D	Crop farming	Large	Storage & Crop monitoring systems	2:30
Participant E	Livestock	Medium/Large	Virtual Fence	2:15
Participant F	Livestock	Medium/Large	Virtual Fence & Activity monitoring	1:05

Table 4. Participant group: Norwegian agriculturists

3.6 Data analysis

Yin (2013 p 213) states that "*The analysis of case study evidence is one of the least developed aspects of doing case studies. Too many times, researchers start case studies without having the foggiest notion about how the evidence is to be analyzed. Such case studies easily become stalled at the analytic stages*". As such, deciding how to analyze the findings have been carefully selected with this in mind.

When analyzing the data, color-coding was conducted, where each of the themes and topics obtained from the data got their own color which made it easier to differentiate and analyze topics, similarities, and differences in the data. This was done in order to make the textual data more manageable as the colors visualized the factors and topics in the data, as well as it enabled a faster extraction into different matrix tables (Knafl et al, 1988). The data was also divided into four main components, based on the MDDDII conceptual model (Greenhalgh et al, 2004) and Diffusion of Innovations theory (Rogers, 2003), as the interview guide was made with these theoretical frameworks in mind. As previously mentioned, the four components are: The adopter, The innovation, Communication & Influence and Outer context. Further, subsections and factors within each of the four components were developed based on the data obtained from the participants, as well as the theoretical frameworks.

3.6.1 Data preparation

The interviews have all been digitally recorded after obtaining consent from the participants. According to Oates (2006) by recording, one will remove bias and error, as well as it is difficult for researchers to rely on their memory or notes. A disadvantage with this type of interview is the time-consuming transcribing process, as well as the time it takes to extract a set of useful data from it (Walsham, 1995). Oates (2006) states that many novice researchers underestimate how long the transcription process takes. Despite this, he also argues that it is rewarding as it brings the interview back to life and provides a chance to start thinking about and analyzing the data. Hence, the recorded interviews were transcribed manually.

3.6.2 Cross-case analysis

The goal of the case study is to understand, explain and answer the "how" and "why" questions regarding factors that influences adoption of IoT technology, how the technologies has affected agriculturist and which challenges that needs to be addressed in order to enhance IoT adoption. As the purpose is not to portray any single one of the agriculturists, but rather to synthesize the findings and results from each of them, they are cited sporadically in a cross-case analysis (Yin, 2018). Following Yins´ (2018) format, which applies as an option for multiple-case study, the information from each of the individual case studies have been dispersed throughout each chapter and section. As such, each topic and section draw appropriate examples and findings from the cases, but none of the cases is presented as a single-case study (Yin, 2018).

3.7 Ethical Considerations

To ensure considerations with respect to maintaining confidentiality and privacy, the guidelines from NSD (Norsk senter for forskningsdata) was followed. By following these guidelines, it protects both research ethics and the researchers to ensure that the participants are treated ethically. The project was also reported to NSD for approval to make sure that personal and sensitive data was managed in an ethical and safe manner. The application was conducted based on being able to do voice recording during the interviews as well as in order to use Zoom and Teams.

The participants got a consent form beforehand, where information about the dissertation, interview and the voice recording were presented. The consent form can be found in Appendix B. In order to ensure the participants anonymity, the participants are named "Participant A", "Participant B" etc. Furthermore, the approval received from the university's research ethics committee is shown in Appendix A.

For the recording purposes, a smartphone was used, which was set in flight mode during the interviews. After transcribing, the voice recordings were deleted to ensure privacy. The participants could, at any time, ask for their information to be deleted or to get access to their data. Moreover, once the transcribing process was completed, the participants had the opportunity to get the results from their interviews to observe if there was any information that could be traced back to them or if they wanted to add or change anything. All the participants declined this opportunity.

4. Findings

The following sections presents the results obtained from the interviews with Norwegian agriculturists. Through analyzing the data, similarities, differences, and area of concerns are identified. As previously mentioned, theoretical orientation, the questions in the interviews, and the obtained data, gave the opportunity to categorize some of the findings into sections influenced by components and factors by Greenhalgh (2004) conceptual model and Rogers (2003) DOI theory. The components are: 3.1 The Adopter, 3.2 The Innovation, 3.3 Communication & Influence and 3.4 Outer Context, where each of them is further divided into subsections. Furthermore, section 3.5 presents the outcomes by using the IoT technologies. Lastly, a summary of the main findings is presented in section 4.6.

4.1 The Adopter

As the process of adoption of an innovation involves decision-making by the agriculturists, characteristics such as needs, motivation, values and skills are important components in order to explore technology adoption (Greenhalgh et al, 2004).

When the participants were asked about their motivation for investing in new technology, knowing that **the future of the farm** is secured, meaning having someone to take over, was mentioned as a critical factor by three of the agriculturists (Participant A, B & F). Participant F believed that they would not "*have done the investments that we have done if our daughters did not give a signal that they are interested in taking over the farm".* A similar statement was provided by Participant A, "*If we did not have anyone to take over the farm, we would not have done the investments we have done so far*". Participant B, which is going to take over the family-farm in a couple of years, also elaborated on the topic and stated, *"My father's willingness to invest in technology is much stronger as he knows that I am going to take over. If I was not going to inherit the farm, we would not have made the investments we have done so far, then we would just have used the equipment we already have and at the end, shut down the operations".*

4.2 The Innovation

This component presents the features of IoT technologies that influences the adoption among the agriculturists, in addition to how they have experienced several aspects of the IoT adoption process in regard to different features with the technologies.

4.2.1 Motivation factors of relative advantage

When asked what motivated the participants to invest in the IoT technologies in regard to relative advantages, several factors were mentioned. Participant A stated that one of the drivers of adoption was in order to "***prepare the farm for the next generation**, as they will see it as a major benefit*". He also added that it was due to "*wanting a better and easier everyday life with more flexibility"*. Gaining more **flexibility** was also supported by participant B which stated that they wanted to "*release more time so I would be able to do other tasks and duties*". However, despite stating the importance of getting more time to do other tasks, participant B also mentioned that one the main reasons for adopting IoT technology was to **replace human effort**, "*when two of our workers retired, we decided to* *make the investment",* following by saying that by not paying the workers, this released capital which made it possible to do the investment. He further stated that "*It is difficult to find people in Norway that has this kind of occupation, as such, investing in the robot was the best solution"* (Participant B).

All of the participants mentioned **improved decision-making** as a motivation factor for investing in the IoT technologies "*It provided the chance to measure and get alerted about the cows estrus cycles as well as it alarms us if something is wrong with the animals"*(Participant F). Four of the participants also mentioned that they wanted to gain more **control**. This was clearly addressed by participant C, which answered "*Control, control and control"* when being asked why he wanted to invest, following by stating that "*it is also about eliminating pitfalls, as well as you become more* ***efficient****"*.

Another motivation factor that was mentioned by one of the participants was **increased animal health**, stating that he wanted to invest as "*it measures the animals health and alerts us if something is wrong, such as lack of movement"*. Lastly, one of the participants also explained that one of the main reasons for the investment was in order to be able to **utilize resources more effectively**, stating that "*We wanted to invest in virtual fences because we wanted to access the outfield resources which previously were inaccessible*" (Participant E).

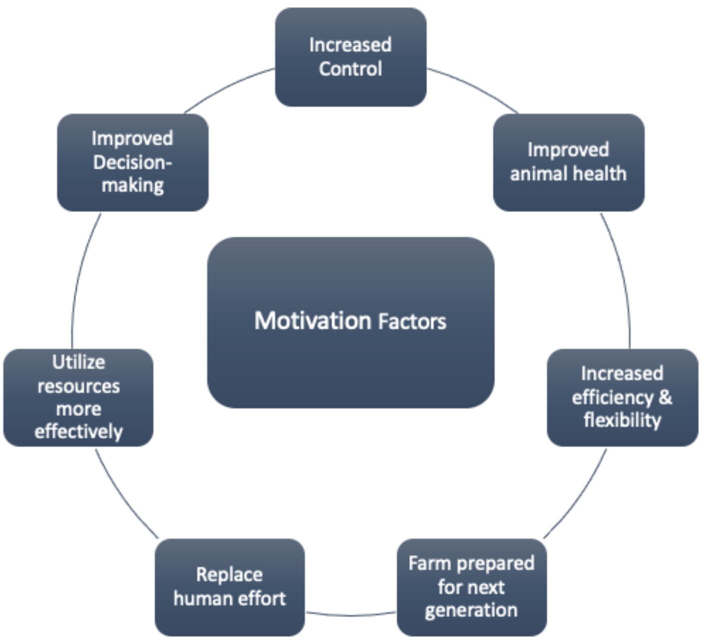

Figure 8. Motivation factors for adopting the IoT technologies

4.2.2 Suppliers & Technical Support

The participants got the opportunity to reflect on the suppliers and technical support. Participant C addressed the importance of **trust** and **cooperation**, in addition to emphasizing the benefits of the suppliers visiting their customers. He presented a business model that one of the suppliers adopted based on his recommendation. The business model involves what he calls "**flight checks"**, where he explains that "*Once a year, the suppliers visit the agriculturists and conducts a flight check. They go through all the sensors, replace batteries and checks the signals"* following by stating that this is something that is highly appreciated by the agriculturists (Participant C).

Three of the participants reflected on the importance of the service personnel due to the fact that by implementing such technologies, they become **dependent** of the support services, "*Our backup-plan is the technical support from the supplier, nothing else"* (Participant A). Participant B elaborated on the fact and added *"We are dependent on the robot. If there is a malfunction, we have no other way to milk our animals*". The importance of the suppliers and the technical support was further highlighted by Participant D, stating that *"If making an investment, the people are often more important than the technology itself"* (Participant D).

The participants provided various examples of both positive and negative experiences with the support provided from the suppliers. One of the participants expressed an unfortunate experience, saying *"We had some difficulties with technical support. This was a concern that we had when we were considering making the investment, which unfortunately were shown to be justified"* (Participant B). Participant D also elaborated on how they were not able to understand and use one of their IoT technologies, suggesting that one of the main reasons was "*due to not having sufficient follow-up from the suppliers"*. The participant added that it was a supplier from the Netherlands, and that this might be a factor explaining the lack of support.

Some of the participants also reflected on the importance of **supplier's knowledge**, where participant C stated that "*If you want to open the wallet of a farmer, you need to show your knowledge, if not, the farmer will not believe in you"*. However, the participant added that he often experiences **lack of knowledge** among the sellers, stating that*" Often, the factual knowledge of the people that are trying to sell you something is not good enough, but the* *eagerness to make money is huge"* This topic was also addressed by participant B, where he specified that he had "*a problem with the fact that the service personnel did not know how to help, as it was a new technology to them as well"* following by expressing that this resulted in frustration and dissatisfaction. The participant then added that in his experience, "*the ones that are selling the technologies are slow at teaching their service personnel"* (Participant B).

When investing in IoT technology, three participants also expressed the importance of the technologies being **tested in Norway** (Participant A, B & C). Participant A stated that the technology needs to be tested in Norway due to the fact that "*we have a challenging climate"* (Participant A). Participant B aligned with this and stated that *"When investing in such expensive technologies, it is extremely unfortunate if it turns out that it does not function in the conditions we operate in"* (Participant B). Despite stating the importance of being tested in Norway, Participant B also shared how he has experienced the suppliers in regard to informing agriculturists about the testing process, expressing that *"In most cases, the suppliers do not tell where the technology actually have been tested. They run universal- tests for all conditions, something that they believe is sufficient enough".* The participant then suggested that the suppliers of IoT technologies "*needs to test the technologies in the conditions that we operate in, as well as in different parts of the country"* (Participant B).

4.2.3 Observability & Trialability

Some of the participants elaborated on the importance of being able to **observe** IoT technologies. One of the participants stated that *"We always attempt to visit the different suppliers"* (Participant D). This was also supported by Participant B, adding that *"Agriculturists might be a bit eccentric. We do not trust something unless we get to see it ourselves".* One of the participants also emphasized the importance of being able to try IoT technologies as well, stating that "*Watching a YouTube video where everything appears great is not sufficient enough, we have to be able to try it ourselves when considering to make an investment"* (Participant B).

During the discussions, it was revealed that three of the participants had been part of **pilot studies**, either on their own initiative or by being contacted by suppliers (Participant C, E & F). As such, they were not able to observe the results of the innovation before adopting it, as they were the first agriculturists to try it. However, they stated that they were able to test the technologies, give feedback and provide suggestions for improvement. Participant E stated that they want to invest in innovations in the startup-phase "*as the suppliers often makes solutions that are more general or not suitable for your kind of production*". He then argues that by investing early, it provides the opportunity to "*influence and affect the solutions*".

4.3 Communication & Influence

Communication and influence ranges from the nature of social networks that the agriculturists engage with, to planned dissemination programs such as agricultural activities to promote the adoption and use of innovations (Pathak et al 2019, Greenhalgh, 2004 & Rogers, 2003). Figure 9 presents the information sources and communication channels the agriculturist mentioned when collecting information about agricultural technologies.

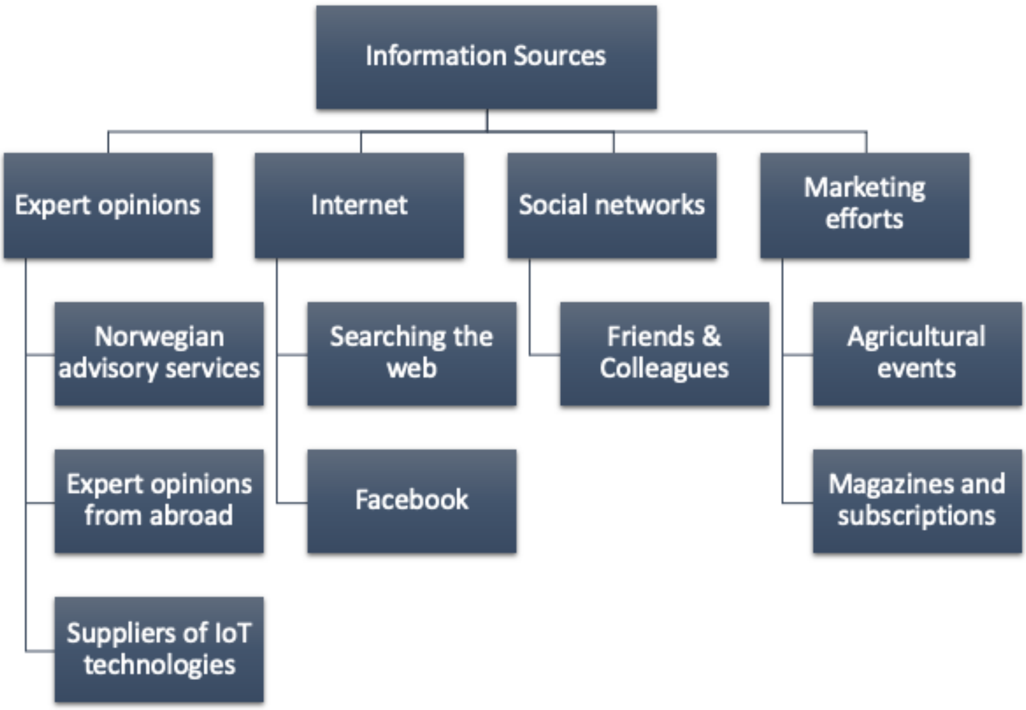

Figure 9. Overview of information sources and communication channels

4.3.1 Social networks

The agriculturists **social networks** were shown to be a central information source by four of the participants (Participant A, B, C & F). Participant A stated that: *When one is about to start such a process and spend so much money in investing, one needs to gain knowledge from other agriculturists that has already implemented such technologies*". Participant B also stated that when collecting information about technologies, he mainly uses "the *Internet and word of mouth*" specifying that "*by discussing with friends, I always get their honest opinion on their experiences with the technologies, as well as which challenges to expect".* Social media, particularity **Facebook** was also mentioned as an arena that has become essential in terms of sharing ideas, experiences and interests by four of the participants, "*a lot is happening at social media these days, where you can get access to different kinds of information. This is mainly through Facebook groups"* (Participant F).

The participants were also asked if they believed that they have influenced other agriculturists to invest in such IoT technologies. All of them implied that they had influenced other agriculturists in some way, where one of the participants stated that after he had implemented the technology, he had influenced seven agriculturists to adopt the technology, as "*the other agriculturists were able to see the benefits and the fact that the technology worked in our type of agricultural production"* (Participant B).

4.3.2 Expert opinions

All of the participants expressed the importance of **expert opinions**, particularly **advisory service providers.** Expert opinions from Norwegian advisory service providers were mentioned as an important information source by three of the participants (Participant A, B & C). However, similar to the statements on the evaluation of the technical support, some of the participants expressed **lack of knowledge** by advisors in the agriculture industry. One of the participants believed that one of the reasons are due to the fact that it is "*too early in the process concerning IoT technology*" (Participant E). Participant D also elaborated on the topic and stated that *"There is a need for a higher level of knowledge"* while participant C added that "*there are too few that are studying to become experts in agriculture, as well as there are too few that are passionate about it".* Participant C then underpinned the importance of having knowledgeable advisors particularly due to the fact that within many types of farming processes," *The production of agricultural products is once a year"* and as such "*If you make a critical mistake, it cannot be fixed until the year after".*

Further, two of the participants emphasized that their main source of information is **international experts**. Participant D claimed that the reason is due to "*The level in Norway is not sufficient enough, particularly within our type of production"* and as consultants and other agricultural stakeholders from abroad *"have other thoughts and perspectives which we can* *learn a lot from*". When asked if social network plays an important role in regard to affecting technology adoption, the participant said, "*To us, having knowledgeable advisors from abroad is the most important source of information*". Participant E clarified why they mainly use international advisors, stating that they are often ahead of their collages when it comes to innovation and new technologies. As such, speaking with friends and colleagues is unnecessary as they most often do not have experience with or knowledge about the innovations.

4.3.3 Marketing

In terms of **marketing** and promoting activities, all of the participants mentioned that they subscribe attend agricultural event such as conferences, demo-days and seminars. All of the participants claimed to have attended such events, however, they stated that the main reason for attending is to communicate with friends and colleagues, as well as expanding their **social networks**, where the topics and content of the event is not that important, "*Often, you learn more during the coffee breaks, compared to seminar itself"* (Participant A)**.** Participant C also stated that "*one can create relations and find new colleagues that has the same type of production as you*", where he additionally emphasized that it is a "*great arena to gain information about how other agriculturists have experienced different technologies".*

This was also supported by Participant B, which added an interesting statement in regard to why the social aspect is more important than the content of the events, *"Of course you will learn something, but usually it is not the right solution for your particular production"* (Participant B). The participant clarified his statement, saying that events such as demos can be beneficial, but that in most circumstances "*the technologies are mostly suitable for the US and Canada, meaning countries that are flat"* followed by stating that *"In Norway, we have mountains, difficult conditions and an unpredictable climate, something which provides challenges they are not used to"* (Participant B).

Some of the participants also mentioned that they subscribe to different **agricultural magazines**. One of the participants perceived agricultural magazines as an important source of information in regard to technologies as "*the magazines contain some articles about newer technologies in the industry"*(Participant A). This was also supported by participant B.

4.4 Outer Context

Outer context describes the effect of external factors on the adoption of technologies (Greenhalgh et al, 2004).

4.4.1 Incentives and funding

Some of the participants expressed the importance of **incentives**; "*Incentives are important in order for us to make changes, we are not able to do it ourselves"* (Participant A). Four of the participants expressed their content with Innovation Norway, which appears to be the main source to get financial support (Participant A, B, C & D). Despite Innovation Norway being an important resource, some of the participants expressed the need for more funding, *«It is so challenging to invest in something new that if we are going to have a functional agriculture industry in Norway, the government has to do something. Either by subsidization or by doing something with the prices"* (Participant A).

This was also supported by participant B, "*when the government presents such demands as they have been lately and during the last couple of years, they must provide help in order to adjust*", following by stating *"We barely break even throughout the year"*. Participant D also elaborated on the challenges with the prices of agricultural products. In his opinion agriculturists *"need to get **more paid** for the products*". He then added that he does not mean that agriculturists do not need subsidies, but that agricultural products are too underprized. He further justified his statement by giving an example, "*we get the same price for the lettuce as we did 20 years ago"* (Participant D).

4.4.2 Socio-political climate

As agriculture is a strictly regulated industry in Norway, the participants were also able to reflect on sociopolitical factors. One of the participants made an interesting statement on his thoughts about the future of his farm, saying "*It depends on the **politics**. If it will not be more predictable, I will no longer have the interest in doing what I do. There is too much uncertainty and diffuse opinions* (Participant B). Participant A also shared a similar view about the uncertainty as well as his concerns about governmental policies and directives in the time ahead, saying *"Agriculture is a long-term industry, and we need frameworks and directives that lasts longer than just two years. This is the current situation; there is* *something new almost year by year".* Adding on this, participant C stated that *«the ones that are making the decisions does not have the knowledge or experience on the topics they are addressing".*

The participants also had the opportunity to reflect on **sustainability** aspects. All of the participants agreed that the emphasis on sustainability has affected them in some way, but they also expressed that they do not feel pressured to invest in IoT technologies in order to become more sustainable in their agricultural practices, "I *do not feel any pressure, but I want everything to be in order. Hence, depending on what they demand from me, I am willing to adjust"* (Participant C). One of the participants also described how the customers are drivers of change, both in terms of sustainability demands but also in general, stating that *"if the customers demand it, of course we have to do something. Everybody believes that one have to do something for the environment, as such, we have to do something as well"* (Participant D). Similarly stated by participant E, adding why the customers are drivers of change; "*If we are not producing what the customers expect and want, our products will not be sold. In worst case, we will need to throw the food, something which means that we lose money. As such, we have to deliver what the customers want and demand".*

Some of the participants also elaborated on their thoughts on the Climate action plan. Participant A shared his frustration stating that "*in regard to the climate action plan, I believe it is madness*". Once again, some of the participants are pointing on the **lack of knowledge**, as well as **lack of information** on how to achieve the climate goals, "*it is sad that the policy makers make decisions on things that they do not have knowledge about. Right now, everything is uncertain, something which is exhausting"* (Participant A). A similar statement was obtained from participant B when asked how he believed the plan would affect him, "*I have not given it that much of a though as I feel that they are not sure what they are doing and what they are talking about at this point*". Despite some of the participants expressed their concerns, they all agreed that they are going to do what is expected from them, "*We are going to do what we can to achieve the climate targets, but it will be hard. If we are going to make it, I am not sure of, but at least we are going to try"*(Participant B).

Three of the participants shared their concern on the **economy** in agriculture, stating that it is a major challenge the industry is facing, *"The economy is a big challenge, without a doubt. We do not do what we do because of the money, we do it because we enjoy it"* (Participant F).

Participant B also shared a concern regarding low-incomes and the future generations of farmers, stating that *"Personally, I have feared that if I get a well-paid job, I might not want to work with dairy production at all. That is my biggest fear; that I find something better and will not be motivated to come back".* The participant is going to take over the family-farm in a couple of years and shared that he has an education which is not related to agriculture, something which is the case of many of the children that is supposed to take over farms after their parents. He further added that he "*did not believe this would happen to me personally*", but expressed concerns that the generation which is supposed to take over farms in Norway might not be motivated due to low incomes, as well as seeing other job opportunities in more lucrative industries and sectors (Participant B).

Lastly, some of the participants also shared how they have been affected by Covid 19. Participant C described how the pandemic has resulted in some positive effects in the industry, stating that «*During the pandemic, people have spent more time at home and they are spending more time and money on food. We have received inquiries that we can increase the production if we are able to. As such, corona has actually affected some agriculturists in a positive manner»* (Participant C). During the discussions, the importance of self-sufficiency was also addressed by one of the participants, stating that «*As a result of the pandemic, one can see the importance of producing food in our own country. If we did not have the production we have, it is not certain that the shelves in the stores would have been full"* (Participant A).

Despite Covid has not affected the agriculturists production, Participant D, which have foreign workers, described how the pandemic is changing their farming practices in regard to their employees, stating that *"Due to Corona, we have to reduce our working stack and become less dependent on foreign workers, as it is extremely vulnerable at this point".* He further clarified why they have had to reduce the working stack, "*This is both in order to minimize risks, as well as due to economic factors. As a result of this, we will need more IoT technologies and other mechanization processes in the time ahead"* (Participant D).

4.5 Outcomes by using IoT technologies

All the participants emphasized that their everyday life and farming operations have been improved in different ways by adopting IoT technologies. Only one undesirable outcome was mentioned, in addition to a couple of technical challenges that occurred after implementing the technologies. An overview of the benefits and positive outcomes are presented in Table 5.

Benefits & Positive outcomes
Increased control
Improved decision-making
Reduced uncertainty
Improved livestock and crop-health
New ways of using the technologies (Re-invention)
Quality label
Prepared for the next generation
Improved quality of products
Improved efficiency

Table 5. Identified advantages and positive outcomes by adopting IoT technologies

The outcomes that were mentioned most frequently and which were top of mind, were **increased control**,*"The technology resulted in more control of what is being produced, as well as what we can expect to produce in the future"* (Participant B) and improved **decision making**; *"We have gotten more data which gives us a better understanding of what has affected the production, resulting in increased knowledge and the opportunity to become better"*(Participant D). Other factors that were mentioned as advantages of using the different IoT technologies were **increased animal-** and **crop health,** farm is more prepared for **future generations, improved quality** of products**, improved efficiency,** and **reduced uncertainty**. Participant D also addressed how the technology has made it easier to follow required certifications and as such, the technology poses as **quality label**. Two of the participants also mentioned how it has resulted in **more sustainable practices**, where participant C stated that "*the technology makes the irrigation more correct, as such, I am using less water compared to before, as well as it is providing a lower chance of destroying the fields*". When being asked about how the adoption has affected their profits, none of the participants had given it much of a thought and they were not quite sure if it has affected their profits.. One of the participants just stated, *"That is a hard question"* (Participant D), another said *"I honestly do* *not know*" (Participant E), while Participant B believed that "*the profits are the same as before we implemented it*".

One of the participants also mentioned how recently has discovered unexpected advantages by using the technology, mentioning how it has contributed with increasing carbon storage (Participant E). The participant also shared that he has discovered **new ways of using the technology**, saying "*As we know how the technology works as a basic solution, it is interesting that we can implement it in other areas and for other purposes"* (Participant E).

The idea that by implementing IoT technologies results in both expected and unexpected positive outcomes is heavily represented in the findings, but despite the many advantages, two of the participants also mentioned undesirable outcomes. Two of the participants stated that the implementation resulted in having less contact with their animals (Participant A & B): "*We had much more contact with the animals before we implemented the robot. This is a negative side with the technology, that you have less interaction with the animals compared to before"* (Participant B). Despite resulting in having less contact with the animals, both of them claimed that this is not a critical outcome, as they now have insight and data on each of the animals, something which they previously had to predict themselves.

In regard to the functioning of the IoT technologies, all of the participants were asked if they had experienced any challenges or issues after adopting it. Almost all the participants had experienced some kind of difficulties. The challenges and issues mentioned were; difficulties with battery capacity, positioning error, no signal, errors when updating and functional problems. However, when asked about **privacy and security**, only one of the participants seemed to have given it any though. Despite knowing a bit about security and privacy challenges, the participant stated that "*I have neither any worries nor any roles to play if such security challenges should occur*" (Participant E). Participant C also mentioned how someone had gained access to his password and that they were *"checking the status of the products in the storage",* following by stating "*Of course this is not a good thing, but I do not mind, they cannot gain any significant secrets from the sensor*".

4.6 Summary of the findings

Table 6 presents a summary of the main findings of this study which is divided into three headings "Factors influencing IoT adoption", "Outcomes by using IoT technology" and "Challenges & Areas of concern". These headings are further used in the discussion-part in order to answer the research questions.

Factors influencing IoT adoption	Outcomes by using IoT technology	Challenges & Areas of concern
Knowing that someone is going to take over the farm	Increased control	Lack of information and knowledge by policy makers
Relative advantage: More control, replace human effort, better decision making , improved efficiency, increased flexibility and reduced uncertainty	Better decision-making	Lack of knowledge by different stakeholders in agriculture
Technical support	Reduced uncertainty	A great need for technology experts in Norway
Tech needs to be adapted to Norwegian climate and landscape	Improved efficiency	Privacy and security issues
Observability & Trialability	Improved production	A need for more subsidies and support
Expert opinions	Improved livestock and crop health	An industry which is characterized by uncertainty
Social networks	Less contact with animals compared to before (negative)	The economy in agriculture
Socio-political factors		

Table 6. Summary of the main findings

5. Discussion

As presented in the literature review and the findings, there are various of factors that influences IoT adoption, as well as there are several benefits by adoption IoT technologies. In addition, several challenges that can negatively affect the uptake of IoT technologies, and which can explain the low adoption levels among Norwegian agriculturists, have been identified. In the following sections, essential elements of the findings and its relation to the literature review and the theoretical background are discussed. In order to answer each of the research questions, the discussion has been divided into three main sections which are: 5.1 Factors influencing IoT adoption, 5.2 Outcomes by adopting IoT and 5.3 Challenges & Areas of concern.

5.1 Factors influencing IoT adoption

5.1.1 The adopter

As the process of adoption of an innovation involves decision-making by the adopter, characteristics such as needs, motivation, values and skills are important components in order to explore technology adoption (Greenhalgh et al, 2004). Various researchers have focused on agriculturist characteristics to explore and explain technology adoption in the industry (Pathak et al, 2019), where characteristics such as farm size, education, technical skills and the age of the farmer has often been found as decisive factors in agricultural technology adoption (Barnes et al, 2019; Paustian & Theuvsen, 2017; Pierapaoli et al 2013).

Characteristics with the agriculturists have not been the main scope of this study and has therefore not been investigated thoroughly. However, an interesting and important finding regarding the agriculturists values and motivations has been revealed, which is knowing someone is going to take over the farming operations in the future. This was mentioned by three of the participants as an essential determinant of whether or not to invest in IoT technologies. As Norwegian agriculture is based on family farming, the future of many Norwegian farms relies on the agriculturist's children (Almås, 2004). Knowing that someone is going to take over the farm has therefore shown to be a central factor for some of the agriculturists, where knowing that the future of the farm is secured influences the decision on whether to invest in IoT technologies or not.

5.1.2 The innovation

Relative advantage

Similar to previous literature on IoT adoption in agriculture, as well as technology adoption and diffusion in general, this study implies that relative advantage is the strongest predictor of IoT adoption among the agriculturists. According to Greenhalgh et al (2004), if the users do not see a relative advantage in the innovation, they generally will not adopt it; in other words, relative advantage is a *sine qua non* for adoption.

In this study, gaining more control and improving the decision-making process were shown to be the main motivation factors for adopting IoT technology. Similar results have also been found in previous research on relative advantage, however, a notable surprise, which is diverging from findings in other studies, is the participants low weighting of economic aspects. In most of the conducted research, increased profitability has been found as the main motivation factor when investing in agricultural IoT technology (Aubert et al, 2012; Batte & Arnholt, 2002; Knierim et al; 2018; Kutter et al, 2011; Pierpaoli et al 2013). Rogers (2003) also states that for some innovations and for some agriculturists, economic aspects of relative advantage might be the most important single predictor of rate of adopting. However, findings from this study imply that economic aspects as adoption drivers are close to absent.

Given the fact that farms are businesses, many studies have found, as well as anticipated, that adoption and usage of IoT technologies is heavily influenced by profitability and other economic benefits (Pathak et al, 2019). However, it is evident that farming in Norway is not only a business, but it is also a lifestyle and something the agriculturists are truly passionate about. It is also something which they spend all their time and effort on. As such, the findings indicate that making their farming operations less time-consuming, as well as gaining data to make better decisions and to achieve more control, becomes more important than to increase profits.

Further, this study has also exposed a factor of relative advantage which to my knowledge, no other studies have revealed. "Replacing human effort" was mentioned as a central driver of adoption by two of the participants. However, it was shown that both agriculturists had to adopt IoT technologies due to the fact that it is difficult to find someone to replace their current workers. As such, the IoT technologies had to be implemented in order to continue the farming operations. In addition, many Norwegian agriculturists are dependent on foreign workers. Because of the Covid 19 pandemic, there is a lack of foreign workers due to closed boarders and quarantine restrictions (Ministry of Agriculture and Food, 2020). This has been the case for one of the participants, where they had to reduce their working stack of foreign workers due to the pandemic. As a result, the participant stated that their farming operations needs to be even more digitalized in the time ahead (Participant D). This indicates the importance of IoT technologies, as it has become more challenging to find Norwegian workers, as well as unpredictable events such as the Covid 19 pandemic have made it difficult to access foreign workers. Hence, the use of IoT technologies have the potential to keep many aspects of the agriculture industry going, as it is replacing agricultural activities which used to be dependent on human interaction (Pillai & Sivathanu, 2020).

Suppliers & Technical Support

Pierpaoli et al (2013) found that support services at the implementation stage is highly appreciated by agriculturists, as it promotes the perception that the use of a technology is easy. Results from this study also implies that support services are appreciated at the implementation stage, however, the results also indicates that after adopting the technologies, the service personnel and the technical support provided by the suppliers is crucial. As many IoT technologies performs critical tasks, a malfunction could result in major negative consequences if not being fixed within a short amount of time. Some of the participants indicated that in many circumstances, it is not possible to have a backup-plan as the technologies performs tasks that is difficult to replace when first being implemented. As such, receiving help from technical support becomes the only solution when a problem occurs. As a result of this, the agriculturists do not only become dependent on the technologies, but it also creates a dependency of the supplier and the technical support they provide. Trustworthy suppliers who provide good service agreements, a high degree of help, and that are easily accessible, has therefore been found to be an important factor influencing the adoption among the agriculturists.

Further, the right choice of technology is a major challenge because a lot of investment is required for deploying the technologies (Elijah et al, 2018). In the AgTech 2020 conference, it was emphasized that it is important to produce and develop IoT technology that is suitable for a Nordic climate and topography (Norsk Forskningsråd et al, 2020). This has also been highlighted by the agriculturists in this study, as in many circumstances, IoT technologies are not adapted to the conditions Norwegian agriculturists operate in. Additionally, an assumption was made in the AgTech 2020 conference that IoT developers and brands from the Nordic was preferable among agriculturists in Norway, as this might create more trust in the devices (Norsk Forskningsråd et al, 2020). Some of the participants mentioned that they generally would prefer to buy Norwegian technologies, however, the majority of the participants underlined the attributes with the technologies, as well as trustworthy suppliers, well-tested technologies and having service personnel based in Norway, to be more important than where the technologies are developed.

Trialability & Observability

Trialability refers to technologies that agriculturists can try on a limited basis before making the decision to adopt (Rogers, 2006). Trialability of an innovation is important in reducing the risk and uncertainty of using the technology, as well as it provides the adopters a risk-free way to experiment and explore the technology (Karahanna et al, 1999). This can increase the adopters comfort level and the likelihood of adoption. Pierpaoli et al (2013) found in their study that free trials were highly appreciated by agriculturists, as it promotes the perception that the use of a technology is easy. Similar results have been identified in this study, as some of the agriculturists expressed the importance of being able to try IoT technologies because many agricultural IoT technologies often does not fit their particular type of farming operations. The importance of being able to try new technologies was also highlighted as an important factor in the AgTech 2020 conference (Norsk Forskningsråd et al, 2020). However, results from this study indicates that in most circumstances, the suppliers of IoT technologies does not offer the opportunity to try the technologies on a limited basis, unless the agriculturists participate in pilot-studies. This has also been supported in a study among European agriculturists, where the findings revealed that there is no opportunity for the agriculturists to try and experiment with smart farming technologies. As such, the lack of trialability was perceived as an adoption barrier among the European agriculturists (Knierim et al, 2018).

As previously addressed in the findings-part, three of the participants were part of pilot-studies, where they got the opportunity to test and provide feedback to the suppliers. The findings indicated the main reason for participating early and actively in the pilot studies was in order to customize the technologies in order to fit their unique situation. As such, they were also able to observe the technologies, as observability can apply during trialing of the technology (Pathak et al, 2019). Some of the participants had also attended demonstrations where they were able to observe the technologies, something they claimed to be central when investing in agricultural innovations. Hence, the demonstration of an innovation can be a useful strategy for suppliers to diffuse an innovation (Rogers, 2003). The results also clearly indicates that observability of IoT technologies in general poses as an important adoption driver as it is highly important for the agriculturists to know if the technologies work under their specific type of farming operations.

5.1.2 Communication & Influence

Similar with Ryan and Gross (1943), this study found that agriculturist-to-agriculturist exchanges of their personal experiences are at the heart of diffusion, concluding that the agriculture community is a social system which is a crucial element in the adoption process. The agriculturists social networks are shown to be the most trustworthy source of information and the results indicates that interpersonal communication among agriculturists could catalyze positive or negative attitudes as the agriculturist-to-agriculturist communication is based on trialability, observability and relative advantage.

All of the participants also mentioned expert opinions, particularly advisory service providers, to be an essential source of information. While four of the participants mentioned Norwegian advisory service providers as important information sources, two of the participants, which could be classified as "innovators" (Rogers, 2003), specified that the main source of information is international agricultural experts. The two participants perceive agriculturist-to-agriculturist communication to be important, however, as they are often the first ones to adopt new technologies, friends and colleagues does not have experience with the technologies, something which makes it needless to address them when considering adopting new agricultural IoT technologies. This aligns with Rogers (2003) statement about innovators, where the adopters cannot depend upon subjective evaluations from their social networks as they are the first ones to adopt a new idea. The participants also highlighted the significance of international experts, as they perceive them as more knowledgeable on IoT technologies compared to Norwegian experts. This shows that when venturing into more expensive and data demanding technologies, some agriculturists seek support from experts to validate their decisions (Barnes et al, 2019), where both international-, as well as Norwegian, experts are important sources in regard to technology adoption.

Furthermore, the participants all claimed to have influenced others to adopt IoT technologies. They stated that several agriculturists had reached out to them, something which in many cases ended in adoption. As such, one can assume that other agriculturists could perceive the participants as opinion leaders. Greenhalgh et al (2004) and Rogers (2004) states that influential persons can lead in the spread of new ideas, or they can head an active opposition. Results from this study implies that the participant has an influence on other agriculturists and that by sharing their experience and evaluation, it has the possibility to result in other agriculturists adoption (or the rejection) of an agricultural innovation. This demonstrates the importance of innovators and early adopters in technology adoption diffusion (Rogers, 2003), as other agriculturists are an important source of information regarding the observability of smart agriculture technologies (Knierm et al, 2018). It also validates that the agriculturist community is a central element in the adoption process of agricultural IoT technologies (Pillai & Sivathanu, 2020).

Agricultural events such as conferences, seminars, field days and demo days is found to be appreciated by the agriculturists. However, it was revealed that the main reason for attending such events is to communicate with friends and colleagues, as well as expanding their social networks, where the topics and content were shown to be less important. Similar findings were revealed by Kutter et al (2011) in their study among German agriculturists, who also found that agricultural events such as field days, exhibitions, seminars, and workshops are considered important among agriculturists, as they use such opportunities to exchange their knowledge.

5.1.3 Outer context

According to Greenhalgh et al (2004) an organizations decision to adopt an innovation and the effort to implement and sustain it depend on a number of external influences. Results from this study implies that external factors also play a significant role in influencing the adoption of IoT technologies among agriculturists in Norway.

Agriculture is currently under pressure in regard to coping with the social demands for enhanced environmental performance, traceability and accountability of product safety as well as quality (Ancev et al, 2005). Most of the previous literature is explaining how IoT in agriculture can create more sustainable ways of doing agricultural practices (Aubert et al, 2012; Ayaz et al, 2019; Jayashankar et al, 2018), but few have explored the agriculturists perceptions and thoughts towards the increasing pressure of being more sustainable in their agricultural practices. Results from this study indicates that despite being affected by sustainability initiatives and restrictions, the agriculturists do not feel any pressure by policy makers in investing in IoT technologies to become more sustainable. They all implied that they already are, and that they further want to, participate in the greening of the industry and that they are willing to adjust if the government demand it.

As Norway is a strictly regulated industry compared to many other countries and nations, the agriculturists are already regulated concerning several sustainability aspects such as animal welfare and food security (OECD, 2021). However, some of the agriculturists expressed their discontent and concerns about the Climate action plan and that the pressure of investing in technologies might become “relevant” along the way of achieving the climate action goals, indicating that this view might change when it becomes clearer how the plan will affect the industry.

Relating to sustainability, Jayashankar et al (2018) indicated in their study that sustainable agricultural practices have the potential to motivate agriculturists to adopt IoT technology. Results from this study has revealed that the potential opportunity of enhancing environmental stewardship is not an important driver of adoption among the participants. It is seen as more of an additional bonus when adopting innovations. However, the majority of the participants highlighted the customers as drivers of change, as it is the customers who have the power. As such, if the customers demand it, the agriculturists claims that they are willing to adjust and comply, just like they stated about demands from the government. This is consistent with Bhaskaran et al (2006), which stated that several researchers have discovered that demands by customers poses as a motivation in adopting environmental practices.

The importance of financial support was also mentioned by the majority of the participants. Four of the participants shared their content with Innovation Norway, which appears to be the main source to get financial support. The findings indicates that all of the agriculturists appreciate such financial support and that if getting supported, the chance of adopting the technologies increases. However, some of the participants also stated that they are not dependent on financial support and that the decision to adopt IoT technologies is not based on getting supported, but it is seen as a beneficial and positive contribution.

5.2. Outcomes by using IoT technologies

According to Rogers (2003) relative advantage have been found by diffusion scholars to be one of the best predictors of an innovations rate of adoption. It has been found that innovations that have a clear, explicit advantage in either cost-effectiveness or effectiveness are more easily adopted and implemented (Greenhalgh et al, 2004; Rogers, 2003). As previously mentioned, the adoption of IoT technologies was found not to be driven by a profitability motivation among the participants, something which conflicts with the current literature on IoT adoption in agriculture. The low weighing on economic factors were further justified when being asked how the IoT technologies have affected the agriculturists profits after being implemented. The findings revealed that the agriculturists were not sure if the adoption have resulted in increased profits. Unexpectedly, they had not given it much of a thought and stated that it is difficult to measure if the technologies have affected them on an economic level. Some of the agriculturists assumed that the implementation could have resulted in better use of resources, which could have an effect on decreasing costs, however, this was not something they had, or intended to, spend time on calculating. Luthra et al (2018) states that demonstrating return on investment is currently a key challenge and weak spot in IoT, something which is evident in this study. Nevertheless, results from this study actively demonstrate the low weighting on economic factors among the participants, both as a motivation factor (pre-adoption) and as an outcome by using the IoT technologies (post-adoption).

Despite not knowing or having measured how the IoT technologies has affected them on economic-aspects, the participants all agreed IoT technologies are highly valuable in regard to other outcomes and aspects than to increase profits. The main benefits of adopting IoT technologies were shown to be improved decision-making, improved efficiency and gaining more control. As such, many of the factors that posed as adoption drivers when deciding to adopt the IoT technologies were shown to be outcomes as well, something which can explain the agriculturists overall satisfaction with the IoT technologies. These outcomes are also aligned with previous literature, as these are some of the promised benefits by using IoT technologies (Elijah et al, 2018; Jayashankar et al, 2018). However, when asked if the IoT technologies has resulted in more sustainable farming operations, only two of the participants mentioned how they believed that the technologies had resulted in more sustainable ways of doing agricultural processes. The other participants were not sure and it was evident that they had not given it much of a thought. As IoT is said to be at the center and forefront in making agricultural operations more sustainable (Ayaz et al, 2019), it is interesting that the sustainability aspect has not gotten much attention by the agriculturists, neither as driver of adoption, nor as an outcome by using the IoT technologies.

Rogers (2003) and other researchers have expressed the complexity of studying outcomes and consequences. Rogers (2003) states that it is complex to study it as consequences usually occur over extended periods of time, in addition to being difficult to measure. This has been evident in this study, as it appears that the agriculturists are not sure fully aware of how the IoT technologies have affected them on different levels, particularly regarding economic- and sustainability aspects. The low weighting on such factors actively demonstrates that the adoption of IoT technologies among the agriculturists are driven by getting an easier and more predictable everyday life, where improved decision-making and increased control are some of the most frequently mentioned benefits of using IoT technologies.

5.3 Challenges & Areas of concern

5.3.1 Economic factors

According to Pierpaoli et al (2013) a high level of agriculturist education is an important factor for technology adoption, and they state that this result is found in most research conducted on IoT adoption in agriculture. Whether the participants education has an impact on the IoT adoption has not been investigated this study, however, an interesting finding is that formal education and job opportunities in other industries has the potential to affect the willingness of the agriculturists children in terms of taking over the farm. The results indicates that some children might not want to take over the farming operations as they are able to earn more in other types of jobs, as well as they see opportunities in industries and sectors which has a lower degree of uncertainty compared to the agriculture industry. As such, it appears that formal education might result in not wanting to take over the farm. Moreover, as three of the participants indicated, they believed that they would not have done the IoT investments if they were not certain that someone was going to take over the farm, meaning that IoT adoption among some agriculturists is influenced by the future of the farm, as well as external factors which affect the industry. If no one intend to take over the farms, this will in many circumstances result in having to shut down the farming operations, something which has been the case in the last couple of years. This is evident in the latest estimations by SSB (2021), which have revealed that 3 out of 4 farms have shut down their operations during the last 50 years.

5.3.2 Security and privacy issues

One of the most prominent challenges with IoT in agriculture, and within IoT in general, is security and privacy issues, as the applications and devices are going to deal with sensitive data about the farm and the agriculturist (Farooq et al, 2019). In addition, Sicari et al (2020) highlights the importance of security and privacy related issues as IoT devices is going to be connected to the network continuously, in an even more pervasive way as a result of the 5G network. Some researchers have found that perceived risk of data being misused can adversely affect the adoption, and that agriculturists feel that the implementation of IoT in agriculture is a high risk as their farm data might be shared with others without their consent (Farooq et al, 2019). This conflicts with the results from this study, as the agriculturists were not concerned about security and privacy issues, neither when deciding to adopt nor after having adopted the IoT technologies. One of the participants had even experienced a security breach, where someone had gained access to his data. Even after being affected, the participant mentioned that it was not of concern as he claimed that the accessed data did not contain any sensitive information.

It is evident that there is a lack of knowledge, as well as concern, on security and privacy issues among the participants. Some of the participants claimed that this was not something they should be concerned of, as they believed that it is the suppliers responsibility. However, Gupta et al (2020) claims that most devices in agriculture are not built with security as concern, and even if IoT technologies are, agriculturists and other users often neglect the basic procedures and steps of setting adequate cybersecurity defense mechanisms. Whether the suppliers have developed the technologies with security in min is not certain, however similar with Gupta et al (2020) findings, it was revealed that the participants have not done any procedures in order to prevent security and privacy issues.

In a study by Geil et al (2018), half of the agriculturists had been affected by a computer security incident and their findings revealed that those that had been affected were more likely to have a higher level of computer security, meaning that many security installations are done for reactive purposes after an incident has occurred, rather than before. Even though one of the participants in this study had experienced a security breach, he was still not concerned about such issues. As the use of IoT devices introduces the possibility of cybersecurity threats, agroterrorism and vulnerabilities in the agriculture environment, such threats have the potential to disrupt not only the agriculturist and the farm itself, but also the whole supply chain and in in worst case, disrupt the economies of countries (Barreto & Amal, 2018; Gupta et al, 2020). This actively demonstrates the importance and need of increasing agriculturists knowledge on how to prevent security and privacy challenges, as the consequences can be crucial.

5.3.4 Lack of knowledge & Support

As three of the participants were part of pilot-studies, they were able to have a close relationship with the suppliers throughout the whole adoption process, something which can explain their satisfaction with the technical support. However, when considering to invest in new IoT technologies, some of the participants expressed that they often feel that the suppliers and the sellers do not have enough knowledge about their type of farming operations and as such, it becomes difficult for agriculturists to know if the technology actually works in their type of farming operations.

It was also found that after having implemented the IoT technologies, some of the participants have had unfortunate experiences with technical support, where they have experienced that the service personnel are not qualified enough to help them, as well as that it has been difficult to get in touch with the suppliers, something which has resulted in dissatisfaction and frustration. According to Greenhalgh et al (2004) the success of an adoption is more likely if the intended adopters have access to sufficient training and support on task issues. As such, the need of more knowable sellers and better service agreements has been shown to be essential in order to succeed with IoT adoption among the Norwegian agriculturists. The need of technical support was also addressed in the AgTech2020 conference, where it was assumed that for some agriculturist, new technology is perceived as difficult and advanced, as such, there is a great need for technical support in order to overcome this barrier (Norsk forskningsråd et al, 2020).

There is not only a need for better technical support, but results from this study also shows that there is a great need for more agricultural experts in Norway, particularly advisory service providers. This has also been supported in a study by Knierim et al (2018) which found that a Europa-wide barrier to the widespread use of smart farming technologies is the lack of individual and impartial advisory services for agriculturists. This challenge was addressed the majority of the participants. As previously mentioned, two of the agriculturists uses international experts due to the lack of Norwegian experts, as well as the lack of knowledge among the current advisory services in Norway. As agriculture is an industry that is characterized as highly unpredictable (Kamilaris et al, 2016), making the right decisions in the farming operations are crucial. If not having access to, or if the advisors are not knowledgeable enough, this could potentially result in negative consequences for the agriculturists, such as investing in expensive IoT technologies that are not suitable for their type of farming operations.

It is evident that one of the main challenges the agriculture industry is facing is lack of knowledge. The results clearly indicates that lack of knowledge, both from policy makers, suppliers and other stakeholders can explain many of the challenges and concerns in the agriculture industry. What is concerning is that the challenges identified does not only influence the adoption of IoT technologies, but it can also influence if the agriculturists will continue with farming at all. As some of the participants has stated, the industry is highly unpredictable, and there are continuously new restrictions and regulations, in addition to the fact the incomes of Norwegian agriculturists are too low. In addition, fewer wants to take over the farms after their parents, indicating that something needs to be done by the government in order to protect the Norwegian agriculture industry. It is evident that knowledge sharing and cooperation between agriculturists and stakeholders is essential in order to overcome such challenges.

6. Limitations

The conducted study holds an important limitation in regard to the available literature, as there are only a few scholars that have contributed to the body of knowledge on IoT in agriculture. There is also a scarcity of research investigating outcomes and post-adoption evaluation of IoT technologies among agriculturists. As the study has revealed several factors and determinants that has not been found in previous literature on IoT adoption in literature, it was difficult to find relevant literature to include in the discussion-part. It would be preferable to include more references, however, this was not achievable.

Regarding the secondary literature, it would be preferable to include articles from the "basket of eight". However, this was not possible as the articles and journals holds a limited amount of articles on the topic of this thesis. Furthermore, as a lot has happened within agricultural IoT in the last couple of years, it was preferable to include literature of newer contributions. As a result, some of the included literature are not peer-reviewed or does not have the desired number of citations, but they were carefully reviewed, evaluated, and included based on their relevance and contribution.

Another limitation is in regard to the interviews. As the collection of primary data was based on interviews, this naturally contains several limitations (Oates, 2006). The snowball sampling technique also holds a limitation regarding sampling bias. Furhtermore, only six interviews with Norwegian agriculturists were carried out, as it was difficult to find more participants that have adopted new agricultural IoT technologies, as well as it is difficult to find participants classified as "innovators" and "early adopters". In addition, the agriculturists only represent three types of farming, as well as the study is only investigating a few of the many types of agricultural IoT technologies. As such, the sample is not representative of Norwegian agriculturists, something which should be taken into account when interpreting the results.

This study also holds a limitation in regard to the structuring of the thesis. Due to many components and factors, the researcher found it difficult to structure the thesis. It is preferred to not have more than three levels, however, the researcher found it necessary to have four levels in some circumstances, despite not being of preference.

Lastly, this study has investigated several aspects of IoT adoption in agriculture and not only one specific component such as "Outer context" or only looking at how the technologies has affected the agriculturist. Due to the limited amount of literature on IoT adoption in agriculture and the fact that few publications have examined multiple components of the adoption process, this was the intention of the researcher. However, one can argue that the study holds a limitation in regard to the depth of the study.

7. Implications

7.1 Implication for Practitioners

For suppliers, providing good technical support and having knowledgeable sellers is key. In addition, the results indicates that agriculturists appreciate to both try and observe IoT technologies. According to Rogers (2003) by trying an innovation in person, this is one way for an individual to give meaning to the innovation and to understand and explore how it will work under one´s own conditions. This has shown to be important among the participants, and as such, AgTech companies and suppliers should provide agriculturists with the opportunity to not only observe IoT technologies, but also the opportunity of trying them on a limited basis. It is also recommended to test new IoT technologies in Norwegian conditions. The test results should be visible to the agriculturists as this was shown to be an important factor which could reduce the uncertainty of adopting IoT technologies.

This study has also revealed some challenges that can explain the low adoption rates in the industry. Albeit not presenting direct "solutions" to the identified challenges, the information is valuable to various stakeholders. It has been revealed that there is a need for knowledgeable technology experts in Norway, as some agriculturists perceive and have experienced knowledge gaps in regard to IoT technologies in agriculture. It has also been revealed that the agriculturists are not aware, or concerned, about security and privacy challenges. As this could potentially have major negative consequences, suppliers should be better in informing agriculturists about such challenges, in addition to inform them about procedures in order to prevent security and privacy issues. It is also evident that in order to have a well-functioning Norwegian agriculture in the time ahead, something has to be done by the government and other policymakers, where it is essential to reduce the uncertainty which currently characterizes the industry.

Lastly, this study can contribute to help non-adopters in understanding how IoT technologies affects them and their farming operations. As the study presents challenges and concerns from experienced agriculturists, it can also help non-adopters regarding which pitfalls to avoid. The findings on outcomes by adopting the IoT technologies are also important for the suppliers and AgTech companies, as it could be used in marketing efforts. As increased profits was not mentioned as an adoption driver, nor as an outcome of the adoption, other factors such as improved decision making, increased control and improved efficiency should be highlighted. However, it is important to bear in mind that this study has investigated agriculturists classified as "innovators" and "early adopters" and that the perceptions might differ for other agriculturists who can be classified as "Early majority", "Late majority" or "Laggards" (Rogers, 2003). As such, even though this study found a low weighting on profitability-aspects, it is important to explore how different IoT technologies influences profits, as it has been found as one of the main adoption drivers in previous literature.

7.2 Implication for Research

This thesis contributes with new insights in IoT adoption in the agriculture industry as well as it also contributes with new insights on sustainable IT and IS, as IoT is at the center and forefront in making agricultural practices more sustainable (Ayaz et al, 2019). While most of the current research has examined relative advantage and agriculturist characteristics in order to explain technology adoption, this study reveals that there are several other factors and determinants that influences the adoption process among agriculturists. It has been found that determinants such as socio-political factors have often been overlooked, as well as the importance of technical support and expert opinions. The results indicates that agricultural technology adoption is more complex and multi-facetted than many previous studies assume and that many of the previous studies on technology adoption in agriculture only examines some of the many interacting factors.

This study has explored factors that has the potential to influence IoT adoption by using the MDDDII model (Greenhalgh et al, 2004) and Diffusion of innovation theory (Rogers). Even though the MDDDII model was mainly intended for service industries, it has been revealed that several components and factors in the MDDDII model can explain technology adoption among the agriculturists. Many of these components and factors are not addressed by Rogers (2003), which indicates that the MDDDII model can be valuable for researchers trying to explore technology adoption in agriculture in future research. The MDDDII model has previously, as far as the researcher know, not received attention within research on technology adoption in agriculture, except for the literature review presented by Pathak et al (2019).

8. Future research

1) As previously mentioned, this study has revealed that IoT adoption among agriculturists is much more complex and multi-facetted than many previous studies assume. As Pathak et al (2019 and Aubert et al (2012) stated, many of the studies on technology adoption in agriculture only examines some of the many interacting factors. This study tried to get an overview several components and factors which could influence the IoT adoption, not only focusing on one specific component. As this study presents a vast number of components and factors, it has not been possible to explore each of them in detail. As such, it could be interesting to explore these components separately, in order to get a deeper understanding of IoT adoption among agriculturist, both in a Norwegian context, but also in other countries. As an example, socio-political factors have been shown to play a significant role in the adoption process among agriculturists. Gaining more detailed insight on how such external factors influences IoT adoption could be a great contribution in understanding technology adoption in the agriculture industry.

2) As mentioned, this study has used the MDDDII conceptual model by Greenhalgh (2004) and Rogers (2003) Diffusion of Innovations theory in order to explore the research questions

of this thesis. It has been revealed that the MDDDII models contains influential components and factors which the Diffusion of Innovations theory does not cover. Despite the MDDDII model originally being developed for service industries, this study has showed that some of the components can be applied in technology adoption in agriculture. For future research, it could be interesting to explore other components of the model, as one can assume that there are several components which can have the potential to influence the adoption and usage of IoT technologies in the agriculture industry.

3) This study has been conducted in a Norwegian context. As there is a limited amount of research on agricultural IoT adoption in Norway, it has not been possible to compare the result with previous Norwegian literature. As such, most of the literature used in this thesis are based on findings from international studies and research. This actively states a research gap in Norwegian literature, where it is recommended to conduct several studies on IoT adoption in Norwegian agriculture in future research. Researchers should investigate agriculturists that already has adopted IoT technologies, but it can also be valuable to explore motivation factors and barriers among non-adopters.

4) It is recommended to investigate other technologies than the ones in this study, as well as to study IoT technologies separately, such as only virtual fences. This could be valuable as it can be assumed that motivation factors, as well as barriers, can vary depending on the types of IoT technologies, as well as the size of the investment.

5) Furthermore, this study has explored agriculturists classified as "innovators" and "early adopters" according to Rogers (2003) adopter categories. Exploring IoT adoption among other adopter categories would be beneficial in order to explore differences and similarities. As an example, Beal & Rogers (1960) found in their study on the adoption of two new farm practices in the 60´s that agency-impersonal sources were the most important sources of information for early adopters, while informal sources (friends, neighbors, and relatives) were more important for later adopters.

6) Lastly, this study has tried to study outcomes and consequences of using IoT technologies, However, this was proven to be difficult. The difficulty of studying consequences has also been addressed by Rogers (2003) where he states that it can be difficult to measure consequences as individuals using an innovation might not be fully aware of all the

consequences of their adoption. In addition, it is also complex to study consequences as they usually occur over extended periods of time (Rogers, 2003). As several researchers and practitioners have compelled the need and importance of research on the consequences and benefits of using IoT technologies in agriculture (Agjeld & Dyrdal, 2019; Elijah et al, 2018; Norsk Forskningsråd et al, 2020), it is recommended to explore consequences of IoT adoption in more detail, despite might being difficult. Rogers (2003) presents three classifications of consequences, which could pose as a theoretical guidance in order to explore the consequences of IoT adoption in Norway, as well as in other countries.

9. Conclusion

By investigating IoT adoption among Norwegian agriculturists that has adopted IoT technologies in their farming operations, several discoveries with important implications for both practice and research have been made. Results from this study has revealed that achieving an easier and more flexible everyday life, poses as the main drivers of adoption and continued usage among Norwegian agriculturists. This conflicts with previous research, where increased profits have been found to be the most important adoption driver. However, it is not only the economic aspect which differs from previous literature. Several factors which previously have not been explored has been identified as important adoption drivers in this study, such as knowing that the future of the farm is secured, the importance of technical support, as well as the impact of governmental policies. This indicates that the adoption process among Norwegian agriculturists differs from agriculturists in other countries, something which is stating the importance conducting research on IoT adoption on a national level. It also actively demonstrates that IoT adoption in agriculture is more complex than anticipated, as well as it indicates that most of the current research on IoT adoption agriculture is narrowly focusing on assessing the impact of only a few aspects and not the multiple components which could influence the adoption process.

The findings has also revealed several challenges and factors that could negatively affect the adoption of IoT technologies in agriculture. The agriculturists indicates that there exists lack of knowledge, as well as lack of support among various stakeholders in Norway. In addition, the findings shows that external factors does not only influence IoT adoption, but it also indicates that political and socio-political aspects have a crucial impact on wanting to continue with their farming operations or not. Despite the challenges, there is no doubt that agricultural IoT technologies provides great benefits to agriculturists, where positive outcomes such as improved decision-making, increased control and improved efficiency is making the life's of the agriculturists easier, more predictable, as well as less time-consuming.

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11. Appendix

Appendix A: Ethical approval

Kristiania University College

15th of May 2021

STATEMENT OF ETHICS APPROVAL

Proposer: Victoria Lillestrøm

The school´s research ethics committee has considered your submitted proposal. Acting under delegated authority, the committee is satisfied that there is no objection on ethical grounds to the proposed study.

Approval is given on the understanding that you will adhere to the terms agreed with participants and to inform the committee of any change of plans in relation to the information provided in the application form.

Yours sincerely,

Asle Fagerstrøm
Professor

Appendix B: Consent form

Vil du delta i forskningsprosjektet:

An exploration of motivation factors and post-adoption evaluation of IoT technology in Norwegian Agriculture: Case study results from Norwegian agriculturists

Dette er et spørsmål til deg om å delta i et forskningsprosjekt som er en del av min masteroppgave, hvor formålet er å intervjue deg angående din investering og bruk av i IoT teknologi (tingenes internett/sensorteknologi og data som gir deg beslutningsstøtte). I dette skrivet finner du informasjon om målene for prosjektet og hva deltakelsen vil innebære for deg.

Formål

Formålet med denne masteroppgaven er å avdekke hvorfor du og andre norske bønder har valgt å investere i IoT teknologi, hvor jeg skal se på de viktigste motivasjonsfaktorene (feks økte inntekter, mer klimavennlig/bærekraft, effektivitet), om det var noen utfordringer under implementeringen (feks IT support, om det var vanskelig å bruke teknologien etc), hvordan du innhenter informasjon om ting som skjer i landbruket (bondens nettverk, konferanser, seminarer osv). Jeg skal også avdekke hvordan teknologien har påvirket deg og din gård etter at teknologien har blitt implementert og tatt i bruk (feks økonomi, bærekraft, dyre/plante helse). Dette er områder hvor det per dags dato har blitt gjort relativt lite forskning og det er derfor viktig å avdekke disse faktorene. Målet med oppgaven er å se på temaet i en norsk kontekst, men resultatene kan også hjelpe andre land og nasjoner som ikke har kommet like langt i teknologi-utviklingen som vi har i Norge.

Dette gjelder min masteroppgave ved Høyskolen Kristiania, hvor jeg går masterstudiet «Information Systems: Digital Business Systems». Oppgaven skal skrives på engelsk, men intervjuene vil være på norsk. Alle dine opplysninger vil være anonyme og det vil ikke være mulig for andre å kunne gjenkjenne deg på noen måte. Navnet ditt vil bli byttet ut med for eksempel «Kandidat B» og spørsmålene vil ikke innebære personlige opplysninger slik som bosted/lokalisering, utdanning, navn og andre opplysninger som gjør at man kan bli identifisert.

Hvem er ansvarlig for forskningsprosjektet?

Meg: Victoria Lillestrøm
Veileder: Moutaz Haddara
Skole: Høyskolen Kristiania i Oslo

Hvorfor får du spørsmål om å delta?

Basert på tidligere samtaler/møter ønsker jeg svært gjerne at du skal delta på forskningsprosjektet mitt ettersom jeg mener du er en god kandidat som har mye å bidra med i oppgaven min. Du vil da være en av de fem bøndene jeg har valgt ut, hvor dere alle vil bli stilt de samme spørsmålene i individuelle intervjuer.

Hva innebærer det for deg å delta?

Dersom du ønsker å delta i prosjektet, innebærer det at du deltar på et video-intervju (Zoom eller Teams) som blir en del av et case-studie. Intervjuet vil ha en varighet på ca 1,5 time, med forbehold om at det kan ta lengre eller kortere tid. Intervjuet vil gjennomføres på norsk og vil bli spilt inn på lydopptak, samt jeg vil notere underveis. Når intervjuet er over, vil lydopptaket transkriberes fra muntlig til skriftlig form, for å så oversettes til engelsk. Dine svar/data vil da bli brukt som hovedresultatene i oppgaven min.

Hele intervjuet, både intervjuspørsmålene, samt dine svar, vil bli lagt ved som et skriftlig vedlegg når oppgaven skal leveres inn. Lydopptaket vil IKKE bli publisert eller lagt ved i oppgaven. Det vil si at lydopptaket kun skal brukes for min egen del. Spørsmålene som blir stilt vil være basert på internasjonal forskning innenfor adopsjon av teknologi generelt og i landbruket, samt samtaler med nøkkelpersoner i norsk landbruk. Det vil ikke bli stilt vanskelige og tekniske spørsmål, kun generelt om bruken og utfallet av teknologien.

Dersom du ønsker å få tilgang til enten lydopptaket eller dine utsagn/sitat som skal tas med i oppgaven, er det bare til å sende meg en melding, så order vi dette. Du har også muligheten til å endre, legge til, eller fjerne dine utsagn/sitat dersom du ønsker det.

Det er frivillig å delta

Det er frivillig å delta i prosjektet. Dersom du velger å delta, kan du når som helst trekke samtykket tilbake uten å oppgi noen grunn. Alle dine opplysninger vil da bli slettet. Det vil ikke ha noen negative konsekvenser for deg hvis du ikke vil delta eller senere velger å trekke deg.

Ditt personvern – hvordan dine opplysninger vil bli brukt og behandlet

Dine opplysninger vil kun brukes til formålene jeg har fortalt om i dette skrivet. Opplysningene blir behandlet konfidensielt og i samsvar med personvernregelverket.

Hvem vil ha tilgang til resultatet?

- Moutaz Haddara, min masterveileder ved Høyskolen Kristiania
- Personene som skal vurdere og sette karakteren på masteroppgaven.
- Nøkkelpersoner og interessenter kan få tilgang til masteroppgaven dersom de ønsker

Tiltak for å sikre personvern:

- Du vil være anonym
- Lydopptaket er kun for min egen del og skal ikke deles med noen andre
- Ditt navn vil bli erstattet med en kode som lagres på en egen navneliste adskilt fra øvrige data
- Det vil ikke tas med spørsmål eller svar som gjør det mulig for andre å identifisere deg
- Dersom det blir mulighet for at oppgaven kan bli publisert som forskningsartikkel på et senere tidspunkt, vil du få et nytt samtykke-skriv, hvor mer informasjon vil bli gitt.

Hva skjer med opplysningene dine når forskningsprosjektet avsluttes?

Når lydopptaket har blitt transkribert fra muntlig til skriftlig, vil lydopptaket bli slettet. Det skriftlige intervjuet vil ikke slettes ettersom det potensielt kan bli brukt i videre forskning eller publiseringer.

Informasjon fra NDS (Norsk senter for forskningsdata)

Dine rettigheter
Så lenge du kan identifiseres i datamaterialet, har du rett til:
- Innsyn i hvilke personopplysninger som er registrert om deg, og å få utlevert en kopi av opplysningene,
- Å få rettet personopplysninger om deg,
- Å få slettet personopplysninger om deg, og
- Å sende klage til Datatilsynet om behandlingen av dine personopplysninger.

Hva gir oss rett til å behandle personopplysninger om deg?
Vi behandler opplysninger om deg basert på ditt samtykke.

På oppdrag fra Høyskolen Kristiania, Oslo har NSD – Norsk senter for forskningsdata AS vurdert at behandlingen av personopplysninger i dette prosjektet er i samsvar med personvernregelverket.

Hvor kan jeg finne ut mer?
Hvis du har spørsmål til studien, eller ønsker å benytte deg av dine rettigheter, ta kontakt med:
- Høyskolen Kristiania ved Moutaz Haddara: Moutaz.haddara@kristiania.no
- Vårt personvernombud: Taisiia Demina: Taisiia.demina@kristiania.no

Hvis du har spørsmål knyttet til NSD sin vurdering av prosjektet, kan du ta kontakt med:
- NSD – Norsk senter for forskningsdata AS på epost (personverntjenester@nsd.no) eller på telefon: 55 58 21 17.

Samtykke

Jeg har mottatt og forstått informasjon om prosjektet "An exploration of motivation factors and post-adoption evaluation of IoT technology in Norwegian Agriculture: Case study results from Norwegian agriculturists" og har fått anledning til å stille spørsmål. Jeg samtykker til:

- ☐ Å delta i et videointervju (Zoom eller Teams)
- ☐ At intervjuet blir spilt inn på lydopptak
- ☐ Intervjuet-resultatene vil bli brukt i masteroppgaven

Jeg samtykker til at mine opplysninger behandles frem til prosjektet er avsluttet

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(Signert av prosjektdeltaker, dato)

Appendix C: Interview guide

Interview Guide

<u>The Adopter</u>

1. What type of agricultural practices do you have?
2. Compared to other farms with similar agricultural practices, would you classify your farms as small/medium or large?
3. Are you running the farm alone or with someone else?
   a) Is it decided who is going to take over the farm?
4. Do you have any employees?
5. What are your goals for the farm?

<u>The innovation</u>

Before and during the investment

6. What kind of IoT technologies do you have?
7. Why did you invest in the technology?
8. Did you get the chance to see and observe the technology before you made the investment?
9. Did you get the chance to try the technology before you made the investment?
10. Did you have any concerns when you considered to invest?
11. How did you choose the supplier of the technology?
12. Did you receive any technical support when you implemented the technology?

After implementing the technology

13. How has the implementation affected you and your farm, compared to when you did not have the technology?
    a) Has the technology affected your livestock/crops/products/farming operations etc?
    b) Has the technology affected your economy?
14. Have you experienced any challenges after the technology was implemented?
15. What are your thoughts about security or privacy issues in IoT technologies?
16. How has the suppliers been in regard to technical support?

<u>Communication & influence</u>

17. Where do look for information about technology?
18. Do you participate on agricultural events?
19. Who you do you talk to when you consider to invest in new technologies?
20. Before you implemented the technology, did you know anyone that had already implemented it?
21. Do you use any agricultural technology experts, such as advisory service providers?

External factors

22. Have external factors such as the Climate Action plan and other regulations from the government affected you and your farm in regard to technology adoption?
23. For the end consumers there has been an increasing interest on sustainability, knowing where their food comes from etc. Is this something that has affected you and your farm in regard to technology adoption?
24. Do you feel a pressure from the consumers or by the government to become more sustainable?
25. What are your thoughts about subsidies and funding in Norwegian agriculture, in regard to technology investments?
26. What do you consider to be the most positive aspects of Norwegian agriculture and agricultural policy?
27. What do you consider to be the major challenges and weaknesses in Norwegian agriculture and agricultural policy?
28. How do you believe your farm will look like 10 years from now?