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Faculty of Business Economics

Master of Management

Master's thesis

Digitalisation of Agriculture: How to align and engage partners to move the industry into precision farming. Case study, Maize farming in Belgium.

Mercy Nafulah
Thesis presented in fulfillment of the requirements for the degree of Master of Management, specialization Strategy and Innovation Management

SUPERVISOR :
Prof. dr. Wim VANHAVERBEKE

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www.uhasselt.be
Universiteit Hasselt
Campus Hasselt:
Martelarenlaan 42 | 3500 Hasselt
Campus Diepenbeek:
Agoralaan Gebouw D | 3590 Diepenbeek

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DISCLAIMER ABOUT THE COVID-19 CRISIS

This master thesis was written during the COVID-19 crisis in 2020. This global health crisis might have had an impact on the (writing) process, the research activities and the research results that are at the basis of this thesis.

PREFACE

This thesis is written as partial fulfillment for the Master of Management, Strategy and Innovation at University of Hasselt. My interest in this topic stemmed from my passion in technology and a career dream of becoming a strategic consultant. As a strategic consultant, I will be tasked with the work of advising organisations from different industries on high-level decision making by analysing knowledge and helping them to deliver best results. This is why I challenged myself to write a thesis that focuses on agriculture. I have worked on this thesis with pleasure despite the challenges caused by COVID-19 and enjoyed carrying out research that has enabled me to complete this thesis.

Agriculture is an industry that affects everyone because we all need to eat. Over the years, this industry is facing numerous challenges that reduce food productivity while the world's population keeps growing. It has been interesting for me to find out how technology can be used to improve yield production while reducing costs and environmental impact through Precision Agriculture. This thesis focuses on how partners in the agriculture value chain can be aligned to adopt precision agriculture. I found out through this research that precision agriculture indeed has a positive impact towards traditional agriculture however there is a need for changes on how different stakeholders within the Agri-value chain engage. From the discussions of this thesis, I believe that it is possible for someone to get a better understanding of precision agriculture and the impact it will have on the agricultural industries if all stakeholders adopt it.

I would like to thank my supervisor, Prof. Wim Vanhaverbeke for the guidance, support and insights while working on this thesis. Furthermore, I acknowledge all the people who made this thesis possible by agreeing to be interviewed for the data collection process. I would like to thank my family for giving me the time to work on my thesis and all support they offered me during these challenging times. Lastly, I would like to thank University of Hasselt for their guidance as we transitioned to working remotely on our thesis due to COVID-19. It has been a huge change for everyone but together we have succeeded.

May this thesis be useful for readers and for future research based on this similar topic or any other related research.

SUMMARY

The world is facing a challenge when it comes to food production and sustainability. Population is increasing, therefore more mouths need to be fed, while the sector at the foundation of food production, the agricultural sector, is facing numerous challenges. Some of these challenges are; climate change pressure, increasing population and the need to protect biodiversity and natural resources from expanding cultivated areas. All these challenges put pressure on agricultural productivity. There is also high demand for agricultural products in new markets such as ethanol production, plant-based proteins and meat replacements. To meet these demands, the agricultural sector needs to take an innovative approach by using technological innovations to improve food production while reducing environmental impact. Digitalization of agriculture focuses on the future of smart farming by using technology tools such as Internet of Things (IoT), robotics, big data and artificial intelligence therefore the introduction of Precision Agriculture (PA). Precision agriculture is an approach to farm management that uses information technology (IT) to ensure that crops and soil receive exactly what they need for optimal health and yield. The goal of PA is to ensure profitability, sustainability and protection of the environment. PA seeks to use new technologies to increase crop yields and profitability while lowering the levels of traditional inputs needed to grow crops; land, water, fertilizer, herbicides and insecticides.

Despite the numerous published benefits of precision agriculture, study shows that adaptation is very slow. A report from ILVO indicated that Flemish farmers are slow in adopting to PA while a focus group of the agricultural European Innovation Partnership also indicated that PA was lagging behind in Europe. This research sought to find out why adaptation of PA is not as rapid as it was expected, and I tried to find possible strategy to align the different actors in the agricultural value chain to speed up the adaptation of PA. The geographical scope of the study was limited to Belgium with a case study in maize farming. The life cycle of maize was studied in order to understand the different actors in the value chain that are involved in the production process. In order to find the challenges that affected the adaptation of PA, I interviewed different players in the agricultural value chain within Belgium. This study uses qualitative research design in order to gain detailed understanding of PA and to answer the research questions. Data was collected, integrated and presented from various respondents in the agricultural sector to find out factors that would align and engage all partners to move the agricultural industry into precision farming. Respondents included representatives from farmers, farmers association, Agri-startups and ILVO. I was not able to interview representatives from the main manufacturers of products and services such as John Deere and Bayer due to time and challenges caused by COVID-19, therefore I collected secondary data for these actors.

From the research, I found out that most of the challenges that slowed down adaptation of PA were not due to the technologies but business models around the technologies. Some of the main challenges were farm data ownership, lack of transparency therefore affecting trust, data structure & compatibility with other systems, data portability, the cost of adopting PA technologies which is very high and the lack of support from PA technology providers. All these challenges are from the farmers and explain why they have mixed feelings about adopting precision agriculture. As a solution, a framework needs to be developed in which all actors can effectively collaborate and co-create value, this will solve the

challenges concerning trust, transparency, data ownership, interoperability and acceleration of innovation in PA. Adopting precision agriculture technologies alone isn't enough to fully leverage the power of digitalization, there is a need for models to enable interoperability and standardization of data within the agricultural ecosystem by creation of integrated scalable platforms that are leveraged across products and industries. It is the responsibility of all actors to come together and create an independent body that will be incharge of creating policies or possibilities of integration within the Agri-value chain.

Farmers lack trust in regard to farm data ownership and feel that there is lack of transparency on how or who uses farm data. Therefore, it is important to create a small regional platform (for instance in Flanders), and let it scale as it creates value and attracts other participants. It is advisable for Djustconnect to set up this platform, centered around the farmer, integrate farm data currently available and create a pull effect by attracting other actors who need access to farm data onto the platform creating network effects. This platform aims to provide an opportunity to all stakeholders in the value chain to jointly work together in identifying, analyzing and overcoming constraints to agricultural development. Data is currently being used as a competitive advantage and revenue source by different actors within the agriculture value chain. The current PA IoT landscape consists of platforms and proprietary systems that are mainly isolated. This leads to a situation where most of the collected data are not exploited while in some cases interoperability and interaction among IoT systems is a mandatory enabler for capturing the maximum potential of digital technologies in PA.

If a framework is created in which different actors can effectively co-create and different platforms are integrated to allow interoperability, data will not be a competitive advantage anymore for an individual actor. Therefore, it is important for the platform to create value for its users in another way. The core value is to align innovation ecosystems within the agricultural industry and to enable system and data integration among different platforms and ecosystems. Integration among systems and data would solve the challenges affecting farmers adaptation to precision agriculture and align the different actors. Issues hindering adoption of precision agriculture such as farm data ownership, farmer lock-in to specific products and services, lack of interoperability among systems, lack of trust, lack of transparency and high cost of precision agriculture technologies can effectively be solved if all actors within the agricultural value chain and external sectors can collectively co-create. Apart from creating value for its users, a platform should be able to create revenue for its operators. There are different revenue streams that can be used in order to make a solid business case, such as a subscription model or a pay per use model for users, where the fees are depending on the data consumption. However, the business case itself requires additional research both on the cost and the revenue side. It is also important that governments set policies and regulations that emphasize on the standardization of systems and other agriculture ecosystems to allow interoperability.

Further study is needed to determine how this ecosystem can be developed to align all the participants, to allow interoperability among systems and to determine whether a sustainable business case can be achieved in practice. Findings from this study can be a foundation and offer insights to future research that will focus on the development of an agriculture ecosystem with an aim align all partners to move into precision farming.

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CHAPTER ONE

INTRODUCTION OF THE STUDY

1.1. Introduction

The Agriculture industry is facing several challenges influenced by a number of global trends. Some of these challenges are: the continuous growth of the world population which is expected to grow at 33% to almost 10 billion by 2050, urbanization, highly degraded natural resources due to excessive use of farm inputs e.g. fertilizers, climate change which reduces productivity in agriculture and food waste due to market inefficiencies (Matthieu D. Clercq et al., 2018). All these trends if not solved will lead to poverty and hunger due to continuous population and depleted resources. Thanks to the dawn of digital transformation which is now being used to disrupt different industries to fully leverage the changes and opportunities of digital technology, the agricultural industry can now embrace precision agriculture.

The introduction of technology is revolutionizing different sectors and the agricultural industry has not been left behind. This industry is being disrupted by the use of science and technology in order to address the challenges that it is facing in a smart, innovative and efficient way. Digitalization of agriculture emphasizes on the future of smart farming by the use of IoT, robotics, Big data and AI. This 'fourth agricultural revolution' (Agriculture 4.0) concentrates on providing the means for observing, assessing and controlling agricultural practices.

The Agricultural industry has gone through previous revolutions that were radical at that time. The first being a movement from hunting and gathering to settled agriculture and farming introduction. The second revolution was related to the British agricultural revolution in the 18th century which led to unprecedented increase in agricultural production due to the adaptation of new agricultural practices. These practices included crop rotation, selective breeding and more productive use of arable land. The third revolution relates to post war productivity increases associated with mechanization and the Green Revolution in the developing worlds (David C Rose and Jason Chilvers, 2018). The fourth revolution of agriculture is influenced by emergent technologies which have the power to disrupt farming beyond recognition. This revolution is aimed at designing innovations to improve agricultural productivity, efficiency and also provide social benefits by meeting human needs. All these are to be achieved by the use of precise and smart farming techniques.

Precision farming is an agricultural concept involving new production and management methods that make intensive use of data about a specific location and crop. Sensor technologies and application methods are used to optimize production processes and growth positions (Simone Giesler, 2018). PA is a whole-farm management approach using technology, satellite positioning (GNSS) data, remote sensing and proximal data gathering. These technologies have the goal of optimizing returns on inputs whilst potentially reducing environmental impacts (JRC 2014-2010). PA aims at increasing long-term, site specific and whole farm production efficiency, productivity and profitability while minimizing unintended impacts on the environment. These may involve the use of: Information technology, satellite positioning data, remote sensing and proximal data gathering. One component of precision agriculture is site specific crop management where decisions on resource application and practices are improved to better match soil and crop requirements as they vary in field. Precision agriculture seeks to use new technologies to increase crop yields and profitability while lowering the levels of traditional inputs needed to grow crops - land, water, fertilizer, herbicides and insecticides (Nicole Rodgers, 2014). Precision farming is a farming concept that uses information management techniques to monitor and optimize agricultural production processes. Rather than applying the same amount of fertilizers over an entire agricultural field, PA will measure variations in conditions within a field and adopt it's fertilizing or harvesting strategy accordingly thereby resulting into production efficiency and a smaller environmental impact (Juan Sagarna, 2019). Figure 1 below illustrates some of the key technologies in precision agriculture.

Through digitalization of agriculture, today farms are generating huge amounts of data and many software-based systems do their service in the farms. However, there is no open platform in place that connects all the players in the agricultural value chain (Christoph Hammerschmid, 2016). The data generated only helps farmers to optimize farm productivity and profitability. Software tools in use in agricultural environments are typically point tools with focus on certain segments in the value chain. They are often not compatible with machinery and software systems of competitors and different players in the industry. There is a need for the agricultural industry to push for open source standards other than proprietary standards being used now. For instance, In Information Technology we also see a push towards open source and open standard technologies, whilst traditionally proprietary protocols and standards aimed at protecting the market, inhibited development of an ecosystem as a whole.

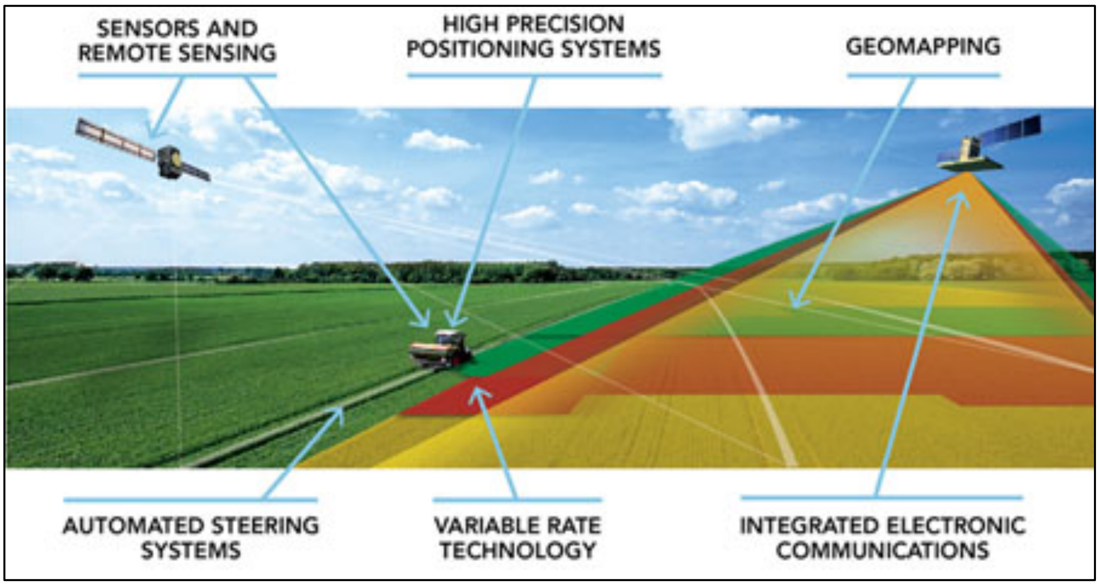


Figure 1; Illustration of some key technologies in precision agriculture

Source: CEMA- https://www.ogc.org/projects/initiatives/agripilot2018

A platform is a business based on enabling value-creating interactions between external producers and consumers. The platform provides an open, participative infrastructure for these interactions and sets of governance conditions for the different actors. The purpose of the platform is to consummate matches among users and facilitate the exchange of goods, services, social currency and information thereby enabling value creation for all participants (Geoffrey G. Parker et. al, 2016). A digital platform is a set of components used in common across a product family whose functionality can be extended by third parties and which is characterized by network effects for instance Airbnb or Facebook. As digital technologies lead to benefits of digital transformation, a platform enables value creation among all the participants therefore facilitating the exchange of goods, services and knowledge. In order to provide knowledge and support innovation in agriculture, various actors (farmers, companies that produce farming equipment, companies that make fertilizers and crop protection, regulators, agricultural educators, researchers, supply chain actors and others) must connect, communicate and cooperate. Together they can amass new information and create input for the agricultural community which is beneficial for all the players in the industry (Barbara Kielbasa, 2015). An open platform connecting all the different players in the agricultural sector would reduce information asymmetry and increase the impact of digitalization in agriculture by enabling efficient, reliable and cost-effective communication among the various partners. The platform is a simple yet transformative concept that is radically changing businesses, the economy and society at large. Any business or industry where access to information about customer needs, price fluctuations and market trends has value can be transformed by the power of a platform.

1.2. Challenges facing digitalization of Agriculture

Digital technology is data driven and what is important is how to get the relevant information and analyze it for future use. Information processing is increasingly taking place via the cloud where data is automatically collected, analyzed and stored. This data can later be retrieved by service providers or on the farmers phone through APPs or API's with different applications giving extensive recommendations for action. The impact of Big Data in agriculture is however still limited because different players in the ecosystem have the ability to collect data pertaining only to their own operation through the growth of technologies and techniques. Farmers use information technologies to conduct their own on-farm experiments, document yield or negotiate crop share agreements using their data collected. Pooling together these datasets of thousands of fields could hold a much greater value both for the farmers and the whole agricultural industry.

In order for Big Data to be effective in agriculture, models should be put in place that allow farmer driven participation in the data value chain. Farmers, Agri-industry and agro-ICT companies should collaborate on data rich services inclusive of the farmers interests and not just themselves. Currently, only limited quantitative evidence exists regarding the assembly of data from precision agriculture technology into a community where all the different actors are present. The importance of an agricultural community is for the market participants to collaborate and obtain information that can benefit everybody in the value chain. Big Data has the potential of achieving this, however models need to be implemented in order to collect relevant information from the actors in the ecosystem (Keith H. Coble et al, 2017). Big Data requires a set of techniques and technologies with new forms of integration to reveal insights from datasets that are diverse, complex and of massive scale (Hashem et al., 2015).

Despite information technologies providing new and useful data for decision making and analysis there are many new challenges that face the agricultural ecosystem. Here are a few issues that appear imminent.

- Farmer adaptation to Precision Agriculture Technologies (PAT) and participation in the data value chain.

According to a report by the 'Flemish government, Department of Agriculture and Fisheries', there is a low adaptation of PAT in Flanders. This is after a focus group of the European Innovation Partnership (EIP-AGRI, 2015) also indicated that the adoption of precision agriculture technologies in Europe is lacking behind. Recently ABN AMRO concluded that everybody is doing smart farming except farmers. On the other hand, farmers that do adapt to smart farming only use the data for their farms. There is no step taken in using the data generated for data driven management decisions.

Big Data is often equated to the big Agri-industry and agro-ICT companies and there is considerable anxiety with farmers across Europe that data on their farming operations is legally captured from them and put in use, for example policy monitoring and pricing negotiations with suppliers. Farming industry at the same time is maneuvering to get access to data and concerned with competitive advantage if data is shared among competitors. Farmers get the problem of lock-in effects and difficulties in moving from one supplier of machinery or inputs to another as data cannot be easily migrated (Archer, 2017). Issues regarding data ownership, access and use are affecting farmers attitude towards adopting precision agriculture.

To avoid this gridlock situation, sharing models for farmer owned data needs to be developed in which farmers can opt in or out of services with suppliers or can actively decide on the level of sharing information with others and have a personal data wallet that can be linked to different services and potentially be used to generate reports on compliance and quality operation (Archer, 2017). Farmers should actively participate in the data value chain and not just used to collect data that ends up being used by suppliers for their own benefits. The use of combined data from different farmers in a local environment but also in broader areas such as Flanders or adjacent regions is important compared to when data is only used on the farmers own farm. For instance, emergence of diseases in an area or data showing how particular treatments help in getting specific results can be efficiently shared therefore helping other farmers that live within the same locality facing the same challenges.

- Impact of interoperability, big data analytics for beneficiaries in agriculture

Interoperability and standardization of data in agriculture is a huge problem. Big data is often characterized around volume, variety, velocity, variability and veracity. There are millions of farm acres around Europe producing a variety of different crop types, using different machines, technology providers and data formats. Velocity; tractors that are now recording 100's of data points up to 5 times per second throughout the field. Variability refers to the different soil types, rainfall patterns, temperature and any specific needs. Veracity can be poor cell connections, harsh environmental conditions or lots of break points. All this qualifies agriculture as a Big data participant.

Major tractor manufacturers are attaching sensors in their equipment and connecting their machines to the cloud in order to capture data. Many startups are emerging to develop all kinds of in-field sensors to capture soil, moisture and other critical data points while scientific weather researchers have created weather solutions specifically for agriculture. All these efforts result in huge data sets but don't fully illustrate the true value to the grower (the farmer). Collecting data is one thing different from effectively analyzing and putting the data into use not just for the suppliers but the whole Agri ecosystem.

Investments in interoperability, standards and analytics have been lacking behind as the models for collaboration and the impact of adopting standards is often poorly understood. With more and more data available, interoperability is important and appropriate big data analytics techniques should be stressed repeatedly as an enabler for achieving value from the data that is often held by many different actors in agriculture. In order to generate digital next generation services in agriculture, the value of adopting these techniques and collaboration should be well elaborated. It is also important to know the possible negative consequences such as privacy, liability or loss of control issues that may arise and how to mitigate these issues.

- Big data technologies and machine learning with open data in agriculture (agriculture communities)

The challenge of the agricultural sector has been to build a data collection as a resource that can serve as reference datasets for evaluation of developing algorithms. More data is becoming publicly available through government open data policies and open publishing of research data while simultaneously satellite programs such as Copernicus are producing mass data. This is a red flag for all the actors who value data as a source of competitive advantage because in the long run agriculture data will become open source. All these data serve as a great resource for developing new algorithms in machine learning and big data.

An open community for development of analytic methods in agriculture should be created. This community should be open to new entrants and provide common pool resources to farmers, research institutes and all the different actors. This will allow for benchmarking of algorithms and dedicated improvements in performance and therefore new applications. Other than having algorithms developed from a particular dataset, it is highly valuable to develop new learning algorithms that use different distributed data.

1.4. Statement of the problem

Precision agriculture technologies aim to improve yield & productivity, reduce costs and limit the amount of inputs such as fertilizer and pesticides being used in maize production. The use of digital technologies generates a huge amount of data that is analyzed and used to create data driven solutions that improve productivity in Precision agriculture. Despite all these benefits of using digital technologies in agriculture, the adaptation of precision agriculture has been recorded to be lagging behind both in Belgium and the EU as shown in a report by ILVO, 2018.

As more original equipment manufacturers come up with new innovative agriculture IoT (Internet of things) tools and platforms to be used on by farmers on the farm, interoperability is rapidly becoming a point of concern. Interoperability addresses the ability of systems and services that create, exchange and consume data to be able to communicate with other systems by exchanging and consuming data. Lack of interoperability is because various tools and technologies used by the different players do not follow the same technology standards or use different platforms therefore resulting in farm data being fragmented and to some point lost.

The lack of an open environment within the various technologies used in PA to connect and share information results in a lack of uniformity in the final analysis done by end users. This is making precision agriculture to a large extent fragmented with different datasets being offered to a farmer. The aim of this study is to find out how all partners can be aligned and engaged to move the agricultural industry into adopting precision agriculture in maize farming by addressing the challenges that hinder adaptation of precision agriculture and find a possible strategy that is flexible enough to incorporate all the different actors to co-create value.

1.5. Objectives of the study

i. To understand what precision farming is and how it affects actors in the value chain.
ii. To find out how all partners can be aligned and engaged to move the agricultural industry into precision agriculture in maize farming.
iii. To find the variables that contribute to optimal maize crop yield and who are the partners that play a role in it.
iv. To find how to manage innovation ecosystems to successfully introduce digital technology to maize farming.
v. To determine the methods that can be used to collect needed data sets and used to further improve maize crop farming.
vi. To develop a practical guideline how an ecosystem of partners in PA has to be developed to improve the chance of adoption and commercial success for all partners involved.

1.6. Research questions

i. How to align and engage all partners to move the agricultural industry into precision farming in maize farming?

1.6.1. Sub-questions

i. Which variables contribute to optimal crop yield and who are the partners that play a role in it?
ii. How to manage innovation ecosystems to successfully introduce digital technology to maize farming?
iii. Which methods can be used to collect needed data sets and used to further improve crop farming?
iv. How to develop an ecosystem of partners in PA to improve the chance of adoption and commercial success for all partners involved?

1.7. Significance of the study

As agriculture faces significant challenges, there is increasing pressure on profit margins and farmers are trying to produce products in the most sustainable way possible. Furthermore, there is growing pressure from governments and the general public towards the ecological footprint of farming, which triggered recent demonstrations of farmers in The Netherlands after political pressure was exerted concerning their contribution to Nitrogen deposition nature reserves. Precision agriculture will not only help cost saving but also has considerable environmental benefits. Increased efficiency through machinery guidance systems, accurately applying chemicals and fertilizers with a basic goal to optimize yield with minimum input are all ways to reduce environmental pollution. Various researches have reported the impact of precision agriculture technologies and their ability to transform the agricultural sector but there is very little research on Decision Support Systems and strategies that are flexible to incorporate PA practices. The degree of development of PA varies throughout the world and over the years the emphasis has changed from simply ‘‘farming by soil’’ (Robert, 1993), through variable-rate technologies, to vehicle guidance systems and will evolve to product quality and environmental management. When governments and regulators learn about PA, environmental management also becomes a focus, but this is a cumbersome process as it implies changes in the existing policy paradigms and business models within the agriculture value chain (Bouma et al.,2002). There are very few data on the adoption of PA in various countries and worldwide. Zhang et al. (2002) gave a ‘‘worldwide overview’’. Griffin et al. (2004) provided the most recent and comprehensive assessment of uptake. Details of developments in South America can be found at the website www.agriculturadeprecision.org. Dobermann et al. (2002) and Wang et al. (2001) present some developments in Asia and Gandah et al. (2000), Florax et al. (2002) and Voortman et al. (2004) present an African example. It would be fair to say that adoption has not been as rapid as was predicted 5 years ago.

In PA research so far, there is a lot of work on yield monitoring (e.g. Colvin and Arslan, 2000) and some work on quantifying soil variation (e.g. Godwin and Miller, 2003; Adamchuck et al., 2004) for variable-rate application (VRA) of inputs. Most of the focus seems to be on some form of zone management (Whelan and McBratney, 2003), but there are not many formal Decision Support Systems (DSS) and no well-designed strategies that are flexible enough to incorporate these practices and concepts into the range of management processes that operate in the practical world. The true practical applicability of PA technology really remains linked to high-tech agriculture. Vehicle guidance (and auto-steer) systems are being adopted widely because, from a user's point of view, economic benefits are readily achievable without the need for much, or any, added decision support or system component integration.

This study seeks to find why adaptation to PA is not as rapid as it was expected and find a possible strategy that is flexible enough to incorporate all the different actors. The findings of this study will help bridge the gap between the actors in the agricultural ecosystem by suggesting possible ways to align and engage them to move into precision farming and to adopt strategies that are beneficial to everyone within the Agric ecosystem. The aim is to determine a business model that will be viable in order for all the actors in maize farming to benefit from the use of digital technology in agriculture and what can be done to make this ecosystem work together creating interoperability between systems. There are a lot of projects within the EU with regards to PA adaptation and ecosystems, this study can be of help to future researchers that might be working on this same topic. Regulators strive to increase the adaptation of PA techniques within the EU, this study might be important to them as it aims to align and engage all actors into adapting PA.

1.8. Scope of the study

The study will cover the different actors that are involved in the maize farming ecosystem in Belgium with a main focus on the equipment manufacturers, Input (seed & fertilizers), farmers, small high-tech companies that now offer agricultural services to farmers, farmers association and regulators.

CHAPTER TWO

LITERATURE REVIEW

2.1. Introduction

Maize, *Zea mays* (corn) a cereal first grown by people in ancient Central America is the second most abundantly produced cereal in the world. A report by Eurostat shows that in 2018, maize was the second most produced cereal in the EU after wheat. Maize farming is one of the main crops of Belgium with an addition to barley, potatoes, sugar beets and wheat. According to provisional agricultural results by Statbel (the Belgian statistical office) there has been a decline in cereal production with the exception of grain maize and rye. This report also shows that agriculture in general has increased (+1.64%) due to the increase of the area of green fodder and permanent pastures in 2019. Despite being a tropical grass, maize is cultivated on every continent except Antarctica since it requires an average of 20-24°C temperature and this should not sink beyond 14°C during the night. In Belgium, Maize is a summer crop therefore can be observed from March to September. There are numerous varieties of maize but they all draw down to two types; silage maize which is cultivated for animal feed and grain maize which may be used for feed as well (poultry feed), industrial purposes (starch, paper industry) and food (maize meal products, snacks, cornflakes).

Yield and quality of maize has always been at risk due to animal pests, weeds and pathogens (Oerke 2006). This has led to dramatic use of agricultural products such as synthetic fertilizers, herbicides and chemical pesticides over the years in order to increase maize yield. However, the increased use of pesticides in agriculture has resulted in adverse effects on human and animal health, environmental pollution (water and soil) and side effects on beneficial organisms (Metaclif 1968; Pimentel 2005). Intensive and highly productive agriculture is not possible without fertilization, extensive use of fertilizers cause losses or nitrogen and phosphorus to the environment which affect the quality of ground and nitrate concentration on surface water. Despite total emissions of potentially acidifying substances from agriculture having fallen by 6% in 2016 compared to 2007, agriculture still remains the most important source of acidifying emissions in Flanders with a share of about one third (a report from Department of Agriculture & Fisheries).

The report shows that Flanders is facing an increasingly ageing and shrinking farmer population as old farmers retire while the youngsters are more interested with industries other than the farm business. Market mechanisms and power relations in the agri-food supply chain also lead to low income to the farmer (7th edition Flemish Agriculture Report-LARA, 2018). All these challenges emphasize the need to embrace precision agriculture. Generating data via GPS systems on tractors or drones, soil and crop sensors, satellite images has become increasingly important but communication and cooperation between the different systems and devices is crucial in order to exploit the full potential use of the data generated.

2.2. Actors in Agricultural value chain

When looking at the mentioned challenges, it is evident that all of the solutions mentioned need to be pursued in unison thereby involving all the different actors in the value chain. The focus here is on precision farming, which we believe to be essential for the future of all participants in the agricultural value chain. Actors include farmers, input producers, machine manufactures, public and independent private advisors, agricultural educators/researchers and Agri-tech startups that offer precision agriculture consulting to farmers. Figure 2 below illustrates the various stakeholders in the context of PA with a focus on inputs, tillage, machineries and the farming process. There is a lack of general data regarding PA and the business organization because manufacturers and dealers rarely reveal sales data. In Europe, there are 4,500 manufacturers with a mix of large multinational companies and numerous SMEs producing 450 different machine types with an annual turnover of €26 billion and employing 135,000 people directly and a further 125,000 in the distribution and service network (CEMA 2014b). Input suppliers specialize in distributing genetic materials used to produce crops for instance seeds or protective additives such as herbicides, fungicides and insecticides. Research and development are significant in this stage in order to produce seeds with high yield and to prevent excessive use of protective additives. The government, regulators and public and private sector are also involved in this stage to ensure that practices are adhered to that protect the environment.

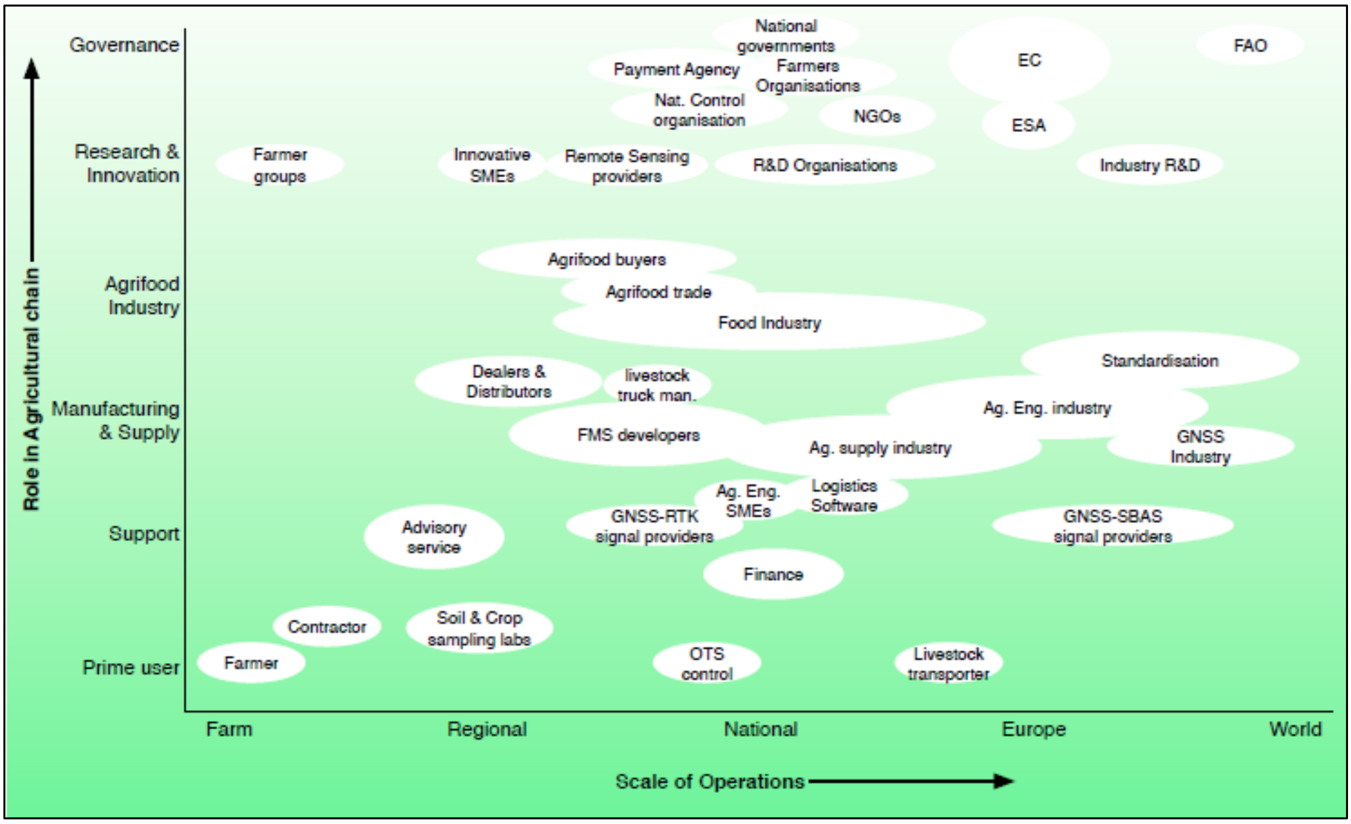


Figure 2: An overview of the stakeholders in the context of Precision Agriculture

Source: Roland Berger Focus – Farming 4.0

Technology solutions include a vast range of applications such as the management of fleets, drones and data, farm management (soil, seed, crop health and pest monitoring), prescriptive seeding and spraying, implement and row guidance systems, vertical farming, and hydro-/aerophonics. Some of the most promising technologies being adopted and used by Agro-chemical companies, original equipment manufacturers, suppliers, technology providers, and select startups are imagery & sensors, robotics & automation, digitalization & big data, as well as biologicals. Players leverage these four major technologies to drive improvements in the farm economy and to shape a new agriculture ecosystem. Three of these technologies work closely together, namely; sensors, robotic automation, and digital data, and are enabled by adequate connectivity as well as the improvements in edge computing and the cloud. Smart farming has led to Agri-Tech startups providing farm management services and solutions to farmers through IoT and IT infrastructure. For instance, In Belgium we have Smart Digital Farming (SDF) and Arvesta which collaborates with Cegeka that help farmers adopt precision farming. Machine manufacturers such as John Deere and New Holland are also not just providing machinery but have their tractors fit with smart sensors to provide productivity in precision agriculture.

2.3. Maize cultivation in Belgium

Maize cultivation in Belgium has grown significantly in the last few decades making it one of the most commonly grown crops. However, maize production fluctuated substantially in recent years, it tended to decrease through the 2004-2018 period ending at 608671 tonnes in 2017 and 442,995 tonnes (a recording of -27.22%) in 2018 as presented on Figure 3 below. Silage maize is primarily cultivated for animal feed but there has been a rise in grain maize that is cultivated for human consumption and to a lesser extent as a source of biofuels.

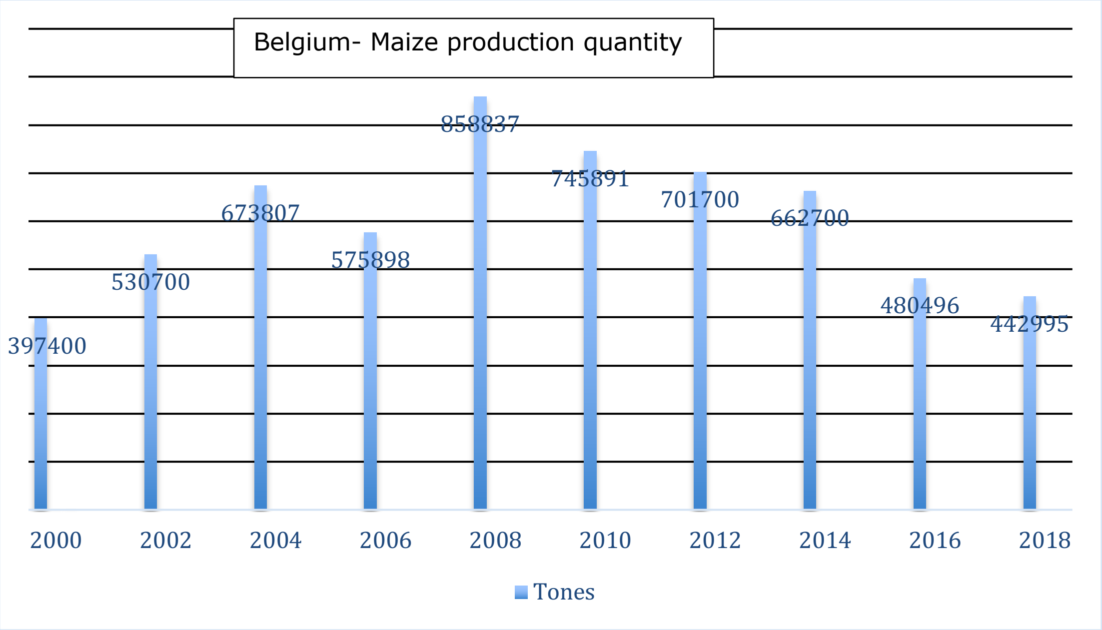


Figure 3: Maize production quantity in Belgium from 2001-2018

Source :https://knoema.com/FAOPRDSC2020

Figure 4 below illustrates an overview of cereals produced in the EU. The EU supports farmers with income support, market intervention and trade policy through the common agricultural policy (CAP). More of the cereals grown in the EU are wheat. The remaining 50% is composed of maize and barley each representing about one third (18% and 16% respectively. The last third includes cereals grown in smaller quantities such as rye, oats and spelt. Cereals in the EU are usually used for animal feed (nearly two thirds); one third directed at human consumption, while only 3% is used for biofuels.

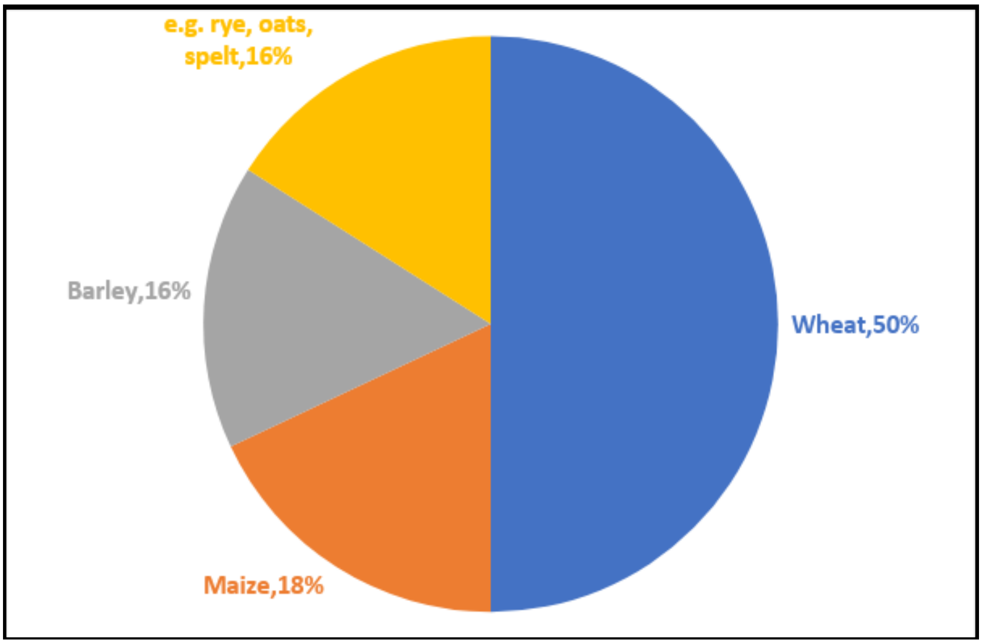


Figure 4: Cereals production in EU

Source: European Commission- https://ec.europa.eu/info/food-farming-fisheries/plants-and-plant-products/plant-products/cereals_en, 2018

2.3.1. Preparation of maize seeds, treatment and soil preparation

Belgian seed companies differ greatly in nature and structure with more than a half of the companies being part of an international seed company. The remaining companies are locally anchored between either family or corporate structure. In April 2019 Seed@Bel was born after a merger of SEMZABEL (the seed sector) and ASSINSEL (the breeders). Seed@Bel represents more than 90% of the Belgian seed sector. Therefore, the seed industry in general can be described as a two-stage industry: breeding and commercial production of the seeds. Breeders attempt to develop new varieties with desirable characteristics of low production cost, high yield, low impurities and resistance to disease, (Van Laecke, 2019). Belgium has been on the forefront of research with an attempt to increase plant growth and seed yield in maize. Researchers from VUB-UGent discovered a gene in maize named PLA1, which would significantly increase plant growth and the size of plant organs such as leaves. By selecting growth enhancing genes, breeders can develop improved agricultural crops which offer harvest security even in challenging climates (Inze, 2017). Despite there being two main types of maize production; grain and silage, the basis of which the two types of seeds are bred are identical. Furthermore, the same climate conditions allow farmers to grow both types of maize seeds and sometimes having an overlap regarding its end use.

Seed treatment is the dressing of seeds before they are planted with specific formulations in order to protect them in the early stages of their development. This treatment targets seed or soil borne diseases, soil dwelling or early season insects. The treatment consists of either fungicides, pesticides or a combination of both. Seed treatment producers such as Syngenta and Monsanto sell their products to seed companies such as Advanta, wholesalers, dealers/ cooperatives or directly to large farmers. Monsanto has invested in modern European maize seed plants which take field maize from local growers and prepare them into seeds for the farmers who will plant the following year's crop under the DEKLAB brand. Traditionally farmers prepared seeds for the following seasons themselves. This was done by selecting the best corn from the current harvest. Technology has made the process of choosing the best seed easier either through genetic modification or convectional crossbreeding. Maize requires dry soil in Spring for sowing therefore farms with heavy soil are often ploughed in winter in order to achieve the correct seed bed by spring. The aim is to achieve a deep, loose seed bead since maize is a free rooting plant which needs no restriction during root development. Crumblers and tractors are used to cultivate the ground in order to achieve the openness required for sowing.

2.3.2. Sowing of Maize

Sowing of maize seeds begins from the end April to May depending on the climate since maize requires an average of 8°C to germinate after being planted. Planting should begin a few days after the onset of rains when the soil is moist. A seed planter for instance the John Deere MaxEmerge XP planter is used to drill seeds into the soil in rows and uniform depth. The recommended spacing is 75cm between rows and 25cm between plants in a row. The planter can be connected to a tractor and driven by the farmer or farmers can use precision planters with auto-steers using GPS which will automatically plant the seeds over an area already prepared. In March 2017, the European Commission submitted proposals to ban all outdoor uses of neonicotinoid seed treatments for all crops outside greenhouses which means that from 2020 farmers will have to drill deeper to at least 7-8cm while sowing maize compared to the current 5cm deep. A view from Cropmap which shows the agricultural landscape of Belgium on a map indicates that more maize is cultivated in Flanders compared to Wallonia. Cropmap combines data from satellite imagery and artificial intelligence to farmers with insights to improve yield like knowing which crop to plant where depending on the soil analysis. See figure 5 below.

Maize requires nitrogen for growth and development since it is the most important primary nutrient. Application of fertilizer nitrate-nitrogen (N) is added at different stages of the maize growth cycle depending on the need. High nitrate-N accumulation in the soil profile from over application is a continuing concern for maize production, especially in intensive agriculture systems. For environmentally friendly crop production, residual soil nitrate-N content should be minimized. However it is impossible to achieve high maize yields if nitrate-N in the root is too low therefore it is important to find the most suitable level of N levels where the lower limit does not restrict grain yield, and the upper limit does not lead to unacceptable N losses to the environment. As the EU tries to cut on Nitrogen emissions, farmers have to adapt to precision farming in order to efficiently use N fertilizer because most nitrogen that ends up in the environment comes from farms. The agricultural origin of these nitrogen (N) fluxes accounts for 50-80% of total N inputs to EU waters (European Commission, 2002). Legislative measures adopted to comply with the Directive 91/676/EEC concerning "Protection of Waters against Pollution caused by Nitrates from Agricultural sources," in some areas did not obtain expected results and are not always complied to by farmers (MacGregor and Warren, 2006; Mouratiadou et al.,2010). Optimum rate and time of N application can enhance yield productivity and nutrient use efficiencies while reducing the environmental pollution.

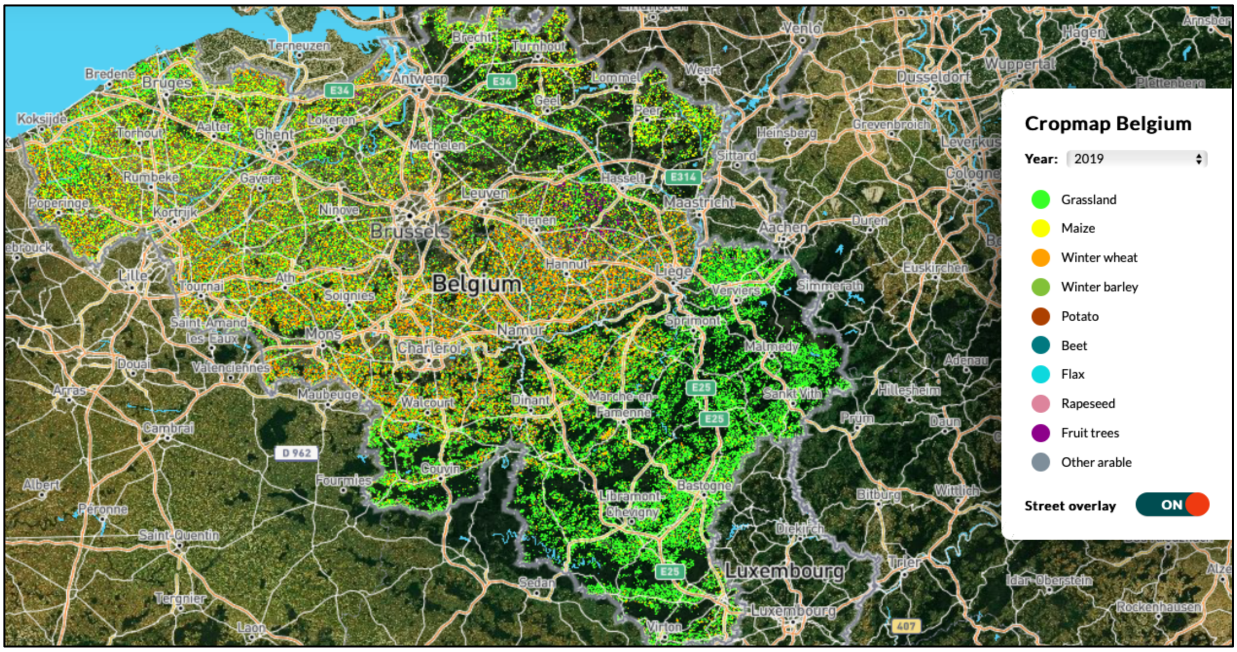


Figure 5: Crop map view giving an early estimate of the 2019 Agriculture landscape in Belgium

Source: Crop map in Belgium, Year 2019

A promising alternative solution relies on Precision Agriculture for efficient N management methods by exploiting the impressive recent technological advancement in the fields of IoT, remote sensing, ecophysiology and geo-spatial data management. Precision nitrogen management aims at optimizing fertilizer nitrogen inputs for high yields and minimizing losses to the environment. Accurate fertilizer requirements by the crop must be predicted to reduce minimum or excessive use of N to the environment. Different approaches have been proposed for the management of N fertilization in the context of precision agriculture. They span from "on-the-go" methods, in which the fertilizer dose to be applied is determined instantaneously, by taking into account crop status as detected for example by tractor-mounted sensors (Tremblay *et al.*,2009) to methods based on the definition of N prescription maps built on spatial information layers (Long et al., 2000).Two main strategies exist for the definition of N prescription maps. The first assumes the possibility of continuous regulation of N spreading, leading to the drawing of prescription maps fully reflecting the spatial variability of crop production factors. A second strategy consists in identifying, within a field, relatively homogeneous areas for which prescribed fertilization rates are constant (uniform management zones, UMZ) (Koch et al., 2004; Basso et al., 2007; Casa and Castrignanò, 2008). N supply varies from soil and weather parameters between years and site therefore yield maps create yield patterns on the farm with zones depending on the amount of nitrogen required in the soil.

2.3.3. Weed, pest and disease management

Insect pests directly damage crops causing significant losses, and pest control has always been considered the most difficult challenge to overcome. The main reason is that the dynamics of the pest population density in the field cannot be accurately monitored. Monitoring of pests have been used on manual methods that do not lend themselves well to automation and digital software solutions. Furthermore, regular monitoring of fields is labor intensive, time consuming and costly especially in large farms. Once drilled into the soil, all fields receive a pre-emergent herbicide to combat weeds since maize is poor at competing with weeds in its earlier stages of development. During the early stages of maize development, most of the seedbed remains bare, offering conducive conditions for rapid development and growth of weeds. Weeds are controlled by herbicides in all European regions on more than 90% of the maize production area. The most important monocotyledonous weeds are Poaceae such as *Echinochloa cru-galli* and *Setaria viridis* which cause problems in all European countries (Patrick L.J, 2011). Precision farming techniques can be used in managing weeds and reduce the amount of herbicide used by effectively spraying only areas that have weed infestation. A site-specific herbicide application technology or precision weeding robots can be used to detect and manage weeds. The system discriminates the different weeds from maize crops which generates weed maps automatically therefore reducing the number of herbicides used.

Although maize is relatively a pest free crop, there can be pest problems like corn earworm *helivoverpa armigera*. Precision pest and disease management can be used to save time, money and excessive use of pesticides to the environment. Spraying specific areas where pests are prevalent is more efficient and environmentally friendly. Unmanned aircraft systems for agricultural sensing such as drones are not just used to collect data in precision agriculture but have the ability to carry payload of spray and efficiently only spray damaged or affected crops. The Belgian Research Institute for Agriculture, Fishery and Food ILVO, conducted their first exploratory research with crop measurements by drones in mid 2018 in cooperation with Noordzee drones and fellow researching company Inagro. DJI Agras MG1 drones were used for the research. Since then various projects such as ICARES have been developed to demonstrate to farmers how drones can contribute to growing and caring for crops (René Koerhuis, 2018). There are various startups offering precision farming technology to farmers such as SmartAgriHubs which was launched in November 2018 and Smart Farmers in 2015. Farmers are using drones to count stalks of maize, monitor plant stress and manage the nutrients of corn fields. Farmers can fly drones throughout the corn life cycle; Early growth stages, from emergence (VE) through four-leaf growth stages (V5), are particularly valuable times for growers to collect aerial imagery. Farmers can use drone imagery and Precision analytics agriculture to conduct emergence and stand evaluations. This will highlight areas where the planter might have failed or indicate where conditions such as dampness might be preventing seeds from germinating. Farmers can use drone technology throughout the season to collect corn crop imagery to evaluate plant vigor or access storm damage after bad weather.

In 2016, Bayer and FaunaPhotonics entered a three-year research collaboration in order to develop new sensor solutions that would improve monitoring of insect pests in agriculture. New sensor solutions can deliver data directly to Bayer's digital farming software and will enable farmers to make faster and better decisions in relation to more targeted use of herbicides and pesticides thereby increasing yield, saving money and reducing excessive use of products. Pests control has always been a challenge since the data present is not exact and hard to monitor. Unlike the present method where farmers have to set traps and capture the pests that will be checked, the new sensors by FaunaPhotonics will automatically record the insects and where they are. The digital sensors will ensure effective and accurate monitoring of insects. The principle of the instrument is based on the fact that a laser beam is transmitted to the atmosphere and when it hits an insect, some of the light will be returned to the laser radar where it can be picked up by a telescope and projected onto a sensor. Analysis of the backlit light can provide a wealth of information about the insect - for example, about its body and wing size and color, whether it is luminous or glossy, how fast it fades with the wings and flare. This means that you can decide which insects, for example, float around on the farmer's land or in the backyard without having to deal with time-consuming capture and investigations of insects under a microscope which are otherwise standard measures to that kind.

2.3.4. Harvest of Grain maize and Silage

Crop harvesting extensively uses devices such as GPS, GIS, a computer and sensor technologies to accurately measure the amount of crop to be harvested at a specific location. Farmers are increasingly adopting advanced harvesting systems and equipment such as steering and guidance systems, sensors, display devices and harvesting management software. The key player in precision harvesting equipment in Belgium is John Deere who offer combine harvesters, harvesting robots and self-propelled forage harvesters for maize silage. A combine harvester combines several jobs into a single machine, combining cutting the crop and separating the grain from the plant while processing and spreading the remaining material over the field. The standard moisture for corn is 15.5%, drying maize with moisture above the standard can be costly to farmers therefore it is important for harvesting to be done at the right time.

2.4. Innovation ecosystems

Adner (2017) defines the innovation ecosystem as "the alignment structure of a multilateral set of partners that need to interact in order for a focal value proposition to materialize" (p,40). Innovative ecosystems play increasingly important roles in competition and the construction of a business ecosystem has become a corporate strategy. Adner defined the ecosystem strategy as the way in which a focal firm approaches the alignment of partners and secures its role in a competitive ecosystem. The ecosystem strategy strives to retain the value of members, align direction with vision, build common goals so that all members in the ecosystem have clearly defined roles to play, cooperate with each other and compete healthily. The aim of the ecosystem is to create and maintain the sustainable competitive advantages for all its members. The implementation of an ecosystem strategy, ecosystem construction and development can help the agriculture sector move towards sustainable development and achieve performance through precision agriculture (Adner, 2016). A business ecosystem is defined as the set of actors- producers, suppliers, service providers, end users, regulators, civil society organizations – that contribute to collective outcome (Jacobides el at.,2018).This will therefore include all the actors present in the agriculture value chain who will ensure that precision agriculture is a success. Innovation ecosystems seeks to change how a set of actors collaborate and relate to each other to contribute to a collective outcome.

Platform businesses are disrupting the traditional business landscape not only by displacing some of the world's biggest incumbent firms, but also transforming familiar business processes like value creation and consumer behavior as well as altering the structure of major industries. Platforms are also creating new efficiencies by aggregating unorganized markets in for instance the agriculture sector. Market aggregation is the process whereby platforms provide centralized markets to serve widely dispersed individuals and organizations within the value chain (Geoffrey G. Parker et. al, 2016). Platform ecosystems describe how actors organize themselves around common technological or market-oriented platforms (Jacobides et al, 2018). Platforms organize data streams, interactions and social exchanges across users. The platform concept has gradually broadened its scope from internal platforms that consist of one firm, supply chain platforms (that consist of a focal firm, suppliers and assemblers, selectively open interfaces, conceptual relations among actors) to industry platforms (that consist of industry ecosystems, a platform leader, complementors, open interfaces and an ecosystem governance structure) (Gawer, 2014). Common examples of industry platforms are Apple, Google, Facebook and Amazon. Platforms aim to create value and therefore seek for network effects. The more actors that join, the more attractive and valuable it becomes for the actors which in turn attracts new actors. In the long run platforms are useful in facilitating innovation activities (Gomes et al, 2018). Platforms help to manage complexity by breaking up a complex system in discrete components and to encourage division of innovation labor (Konietzko et al, 2020).

Digital technologies enable collaboration platforms and collaboration platforms enable ecosystems that bring together a group of organizations to build new capabilities, products or service offerings. Currently, the world's most valuable companies operate with platform business models while more businesses and sectors are moving from traditional pipeline business models to platform-based models. In pipeline businesses, companies create value through a linear value creation process in which products / services are developed inhouse. In platform business models, value is created through connecting diverse partners and enabling them to interact and transact, which relocates the innovation outside the organizational boundaries and allows the creation of completely new markets. Value creation shifts from relying on a company's internal resources to harnessing ecosystems of resources through a connected platform user (Parker, Van Alstyne & Choudary, 2016: Sangeet Choudary, 2015). Apple and Google are good examples of companies that have succeeded in the creation of active ecosystems of third-party developers that create complementary innovations on top of their platforms (Ulriikka J. & Smeds Riita, 2018). The difference between an ecosystem and a platform is that; an ecosystem is a community of interacting entities. The members of the ecosystem can be organizations, businesses and individuals, all creating value for one another in some way; mostly by producing or consuming goods and services while a platform is the way a particular community or ecosystem is organized to interact with one another and to create value. A platform typically is focused on bringing the ecosystem together and reducing friction for interactions to take place.

Farmers face “dystopian future” without EU rules on digitalization and data (Devuyst, 2020). Dystopian means foreseeing a state where there is great suffering or injustice, in this case for the farmers being used by big companies as data harvesters. Campaigners are urging the EU to regulate the use of digital technologies in agriculture to prevent farmers from becoming “data harvesters''. The report also criticizes the hyping of technologies as a quick fix to environmental problems without regulations or governance set that ensure that all actors involved benefit from PA. The digitalization of agriculture is based on a number of technologies outside the agricultural sector like global positioning systems, cloud computing, drones, IoT. In essence, technologies support very detailed data capturing that in principle can easily be shared (cloud technology) and interpreted with big data techniques.

2.4.1. Capabilities and enablers of smart farming

Precision agriculture (PA) describes a suite of IT based tools which allow farmers to electronically monitor soil and crop conditions and analyze treatment options. There are two current difficulties affecting PA technology adoption; One being the rate of technology acceptance and diffusion of innovation while the second one is, compatibility among technology components which impacts PA adaptation. It is important to have compatibility among PA technology components. Precision Agriculture (PA) is a farming management concept based upon observing, measuring and responding to inter- and intra-field variability in crops, or to aspects of animal rearing. The benefits to be obtained are chiefly due to increased yields and/or increased profitability of production to the farmer. Other benefits come from better working conditions, increased animal welfare and the potential to improve various aspects of environmental stewardship. Thus, PA contributes to the wider goal concerning sustainability of agricultural production (Zarco-Tejada et al., 2014). The description underlines capabilities that smart farming performs. The technology leads to much more and better data capturing leading to better control of biological productions processes that take place under unpredictable influences like the weather. Better control can of course lead to better optimization, or even to self-managing of processes as the software algorithm can deal itself with variations in conditions. Capabilities can be sketched into four sections; Monitoring (Understanding the location, ownership, history, destination, quality conditions and other functional properties of products and other objects by means of sensors and external data sources), Controlling (Intelligence is added in order to take corrective measures), Optimizing (The performances of the food supply chain are improved by applying advanced algorithms and analytics for simulation and support of the decision making based on optimization models and predictive activities) and self-managing (through combining monitoring, control and optimization objects can operate independently (autonomous) during their way through the food supply chain without human intervention, either on the spot or remotely. Autonomous objects can also become self-adaptive systems which are able to learn about their environment, make a diagnosis of their needs, and adapt to the preferences of the users, (LEI,T&U Board, 2016)

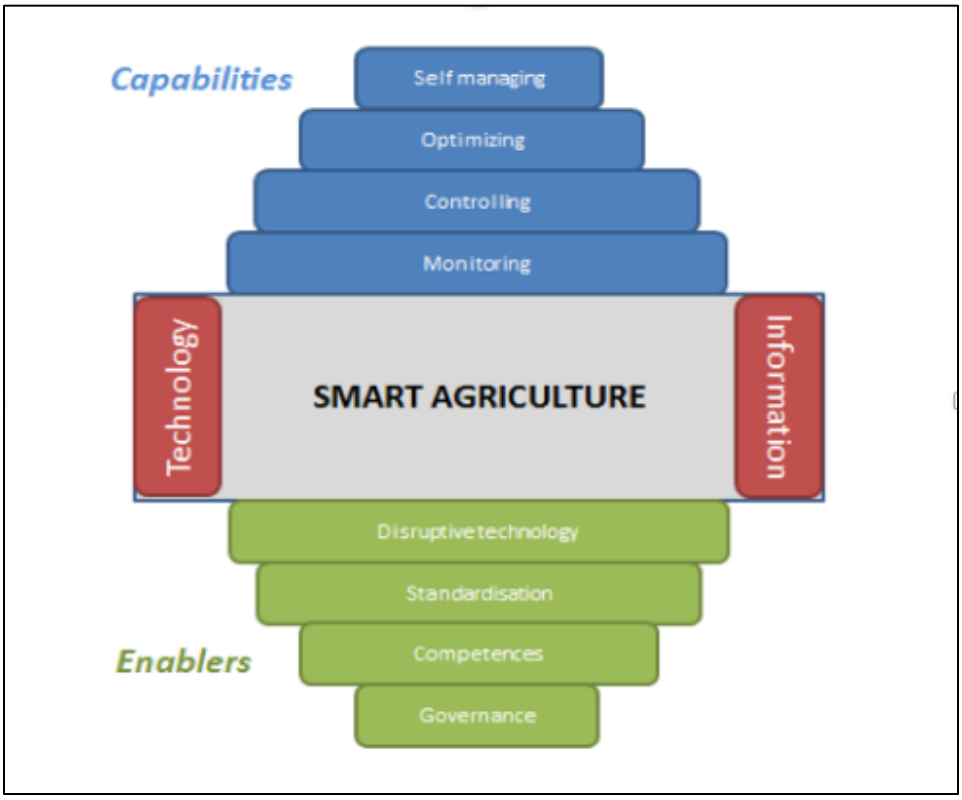


Figure 6: Capabilities and enablers in Smart farming
Source: LEI, T&U Board, 2016

The development of smart farming is based on a number of enablers, important conditions for smart agriculture and supply chains. Some of the enablers are shown in figure 6 above are disruptive technologies (hardware for mechanization, RFID, sensors, wireless networks, web service technologies, cloud computing, big data and predictive analytic tools), standardization (fast, error free and efficient exchange of digital data within and between companies based on information and standards), competencies (awareness, adaptation and knowledge of digital information systems, standards and the skills to use them) and governance (organizational implementation and business models, including agreements on ownership rights, decision rights, remuneration and risk management) (LEI,T&U Board, 2016).

2.4.2. Effects of ICT on business models in Agriculture

The effect of ICT on farm management has great implications on the way farming is currently done. Some forms of labor on the farm are being replaced by machines and software therefore farming is becoming more capital intensive and less labor intensive. Farming being taken over by machines and software implies less work in agriculture and a shift in decision making because some of the decisions move from the farm (farmers) to experts that provide their services remotely. The fact that agriculture is more capital intensive, implies that not all farmers (especially the small ones) are capable of investing in machinery. Most of these farmers use "loon bedrijven / -werkers" (these are people that do contractual work on the farms using their own machinery), because the farmers cannot afford the machinery. Because it is the loon werkers machines that's being used on the farm, it is hard to determine whether the data collected belongs to the farmer or contractors. The most important actor in the adoption of Precision Agriculture technology is the farmer. PA adaptation started in the early 90’s by the most business-oriented farmers with an initial enthusiasm followed by a certain level of discouragement due to the lack of support and the relatively low profitability obtained. The adoption of PA relies currently almost entirely on the private sector offering devices, products and services to the farmers. Public service advice and support is generally very limited. The costs associated with PA implementation are information costs, expenses involving data processing, software and hardware, and learning costs for the farmer to develop management schemes and calibrate the machinery which make adoption very expensive for an average farmer. High investment costs on inputs and machinery accompanied with low profitability prevents farmers from fully adopting PA.

Another effect on management is that the risk of moral hazard issues that exist in agriculture can be reduced or disappear. This risk of moral hazard occurs because the production process is not easy to monitor. That means that an investor or a manager (in economic theory labelled as ‘the principal’) cannot easily control the worker (‘the agent’). How should an investor learn if his farm manager is doing his utmost best, as if he was the owner himself, and is not incorrectly blaming his mediocre results to bad luck in weather or diseases? Such agency problems lead to transaction costs (for the principal to control the agent). ICT reduces this risk and associated costs considerably. This could have big implications for the future of the family farm (LEI, T&U Board, 2016).

The wide adoption of PA within the EU territory would enable the possibility to solicit contributions from a large number of farms and organize annually (through a common methodology) the production of statistics from data recorded and from data produced by these farms. The issue of property rights and of who owns, and controls farm-level data needs to be addressed. Data collected and shared from PA may constitute a new information source on the spatial variability of crop performance and thus contribute to a better understanding of the impacts of soil properties, fertilisers/pesticides efficiency, topography, climate and other factors. These elements would provide a better understanding or fine-tuning of crop yield components, improving accordingly yield forecasting models. In addition, data from PA farms could contribute to improving the crop yield forecast system at a wider scale (Europe) in providing ‘real time’ adjustment of the model, during the crop cycle (e.g. soil status, crop status).

Digitalisation of farming processes continues to expand and intensify. The supply and demand of farming data is rapidly growing. There is a surge of data-tools in the market and even more in the making. Data-driven initiatives are steadily increasing in agri-food chains. Farming is becoming a booming data harvesting business where many players are taking bites into data generated by farming. Many data-driven initiatives are still exploring viable business models to capture the value of data. A variety of business models are being used and developed with different value propositions to different stakeholders (Ge and Bogaardt, 2015). The variety of business models of those data-driven initiatives (e.g. data exchange platforms) present in the agrifood sector, can be illustrated by examples of the five typical business models according to Spijker (2014) in which value is created from data: by selling data, by innovating products through data, by swapping commodity offerings into value-added services, by creating interaction in the value chain, and by creating a network of value based on data exchange (LEI,T&U Board, 2016). An example of value creation website is the EU project FISpace (Future Internet

Business Collaboration Network) which is now available for commercial exploiting by offering a business-to-business collaboration platform that could link platforms like MyDeere.com, 365Farmnet, Akkerweb, Agriplace and others via a Linux-like Open Source model.

Amazon is a good example of business model change. Amazon started off as an online bookstore, focusing on the transactional business and using the internet and web servers as a tool for their business. They quickly realized that that infrastructure was something that for most companies would have to be bought and invested in, lacking flexibility and scalability. Amazon decided they would, apart from their (transactional) marketplace, also offer a scalable and flexible subscription-based cloud solution to companies: Amazon Web Services (AWS). AWS clients can in a ‘pay-as-you-use’ model take up server space for compute or storage for their needs. This is an example of both diversification and business model change.

2.5. Critique on existing literature

A report by Kielbasa (2015) on project AKIS (Agricultural Knowledge and Information System) recommended that in order for change and innovation in agriculture to be fully attained, all actors including farmers, farm workers, agricultural educators, researchers, public and independent private advisors, supply chain and others should connect, cooperate and communicate. Together they can amass information and create input for the agricultural community, which is necessary for farmers to meet new challenges. Innovation platforms are increasingly being proposed in precision agriculture research for development projects and programs since they provide an opportunity to farmers, agricultural service providers, researchers, public and private sector and other stakeholders to jointly work together in identifying, analyzing and overcoming constraints to agricultural development. Existing literature emphasizes the importance of adopting precision agriculture and how digital technology is changing agriculture. Therefore, there is a need for research on how to align the actors in agriculture to collectively collaborate and communicate. Reflecting on the interests and objectives of these actors and finding favorable conditions that will foster collective action and development of agricultural platforms.

2.6. Research gap

Precision agriculture technologies are developing at a breathtaking speed, but it requires integrated, scalable platforms that are leveraged across products and industries. Collaboration and data exchange are needed to fully achieve the power of digitalization in the agricultural sector. While digital solutions have been widely embraced and implemented into smart farming, each piece of software operates on its own ecosystem preventing interoperability of data. This lack of interoperability is not only obstructing the adaptation of new IoT technologies and slowing digitalization, it also inhibits the gain of production efficiency through smart farming. There is a need for further studies to be done in order to come up with new business models that will aim at aligning and integrating different machine communication standards and data sharing between machines and management information systems among the different actors. These conclusions are in line with Aubert et al. (2012), who also pointed out the importance to coordinate all stakeholders (farmers, input suppliers, equipment manufacturers and dealers) in order to improve adoption of the technology. Such coordination could be organized by co-operatives or farmers associations (Aubert et al., 2012).

Current limitations are the lack of standards, limitations on the exchange of data between systems, a lack of independent advisory / consultancy services, a lack of guidance or quantification concerning environmental benefits and a need for better knowledge on the casualties and determinants of yield. There are still obstacles to the adoption of precision agriculture by farmers as they face several challenges. These challenges include cultural perception, lack of local technical expertise, infrastructure and institutional constraints, knowledge and technical gaps and high start-up costs within some cases a risk of insufficient return on the investment. Up to now, the private sector suppliers have been the clear driver of PA development and adoption. The support from governments and other public institutions can play an important role in a wider adoption of PA.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1. Introduction

This chapter involves a blueprint for research methodology which presents the research design, population and nature of data that was used for the study, the data collection tools and data analysis. Therefore, this section is set to answer the research question raised in the study and show a clear path through which the problems and objectives will be solved.

3.2. Research design

Research design is a strategic framework for action that serves as a bridge between research questions and the execution of the research strategy (Durrheim, 2004). Research design aims to provide an appropriate framework for the study; these include what techniques and tools will be used for data collection. This study uses a qualitative research design in order to gain a detailed understanding of precision agriculture and to answer the research questions. I aimed to collect, integrate and present data from a variety of respondents in the agricultural sector to find out factors that would align and engage all partners to move the agricultural industry into precision farming. In-depth face to face interviews and observation methods were to be used in collecting data from the participants who represented different actors in the agriculture value chain. Findings from these interviews were transcribed due to the different nature of data collected, common categories from the data were to be identified during the analysis and used for the conclusion.

3.3. Site and participation selection

The study population consisted of different actors involved in the agricultural value chain in Belgium with a focus on maize production. I sent emails to different target participants requesting them for an interview regarding the research question. I targeted diverse interviewees with an aim to have at least one respondent per actor in the agricultural landscape in Belgium. Positive respondents included participants from farmer communities (majority being farmers), farmers association (Boerenbond), Institute of agriculture and fisheries (ILVO) and an agricultural drone startup that provides drone technology to farmers. Because I couldn’t get participants from the whole agricultural value chain, the study included secondary data collection from other actors like regulators such as CAP (Common Agriculture Policy) and manufactures of products and services like John Deere (manufacture machinery equipment) and Bayer (manufacture of seeds, pesticides and herbicides) to be able to understand what inhibited adaptation of precision agriculture and how to align all actors to engage into precision farming.

3.4. Data collection

I intended to conduct face to face interviews with the respondents but due to COVID-19, the interviews were conducted online. Data was collected using unstructured questions as the researcher steered the research questions in a particular direction depending on the story of the respondent. Data was collected through listening, observing and taking notes as the participants spoke their thoughts concerning the research question. This was done in order to encourage the respondent to expand and go into greater details answering the research questions. The study also employed secondary data from recent publications, journals and news articles in order to find information concerning the other actors that the researcher couldn’t interview. Findings from the interview were gathered in a written format during the interviews and due to the different nature of data collected, common categories from the data were also identified during the analysis.

3.5. Data analysis

Data collected was analyzed by comparing data from different sources and looking for matching patterns. I identified patterns of themes in the interviews, reviewed the themes and created a report focusing on the most important patterns across the diverse interviews. The analysis includes data from all the respondents respecting the credibility and trustworthiness of the participants.

3.6. Ethical considerations

The researcher requested to obtain permission and consent from the interviewees for their data input to be used for the purpose of this study. Participants were treated with full anonymity and confidentiality as all the data was compiled and common partners used for the conclusion of this study. The researcher had full responsibility in obtaining and analyzing data solely for the purpose of this study.

CHAPTER FOUR

CHALLENGES FACING THE AGRICULTURAL ECOSYSTEMS AND ADAPTATION TO PA

Technological development and digitization of agriculture creates a possible improvement in resource efficiency, increased yield and reduction of environmental pollution. Smart agriculture reduces the environmental/climate impact of farming, increases resilience and soil health and aims at decreasing costs for farmers. However, the uptake of new technologies in farming remains below expectations and is unevenly spread throughout the EU. Precision agriculture technologies are meant to decrease costs for farmers however the cost of these technologies is one of the reasons that prevents some farmers from adopting PA. Various research shows that farming results are better when precision agriculture techniques are used. The use of water, seeds and fertilizers have been greatly reduced and farms operate more efficiently on the limited available land by using the exact amount of inputs at the right place and right time.

4.1. The Business models used in Precision agriculture technologies

The issue in precision agriculture is not related to the technologies but rather the business models behind them. The technologies are working but mostly in areas where farmers can afford and pay for them. Precision agriculture technologies do not come with very affordable prices to a point that some farmers are forced to use third parties (loon werkers) to work on their farms. Innovators of machinery sell them at high prices to recover development costs. Moreover, these technologies are not straightforward to operate or service. Farmers need specific education or rely on third parties thereby creating costs upon costs. This also means that small scale farmers or farmers in rural / poor areas where farm inputs and resources are scarce will shy away from precision agriculture. It is important that farmers are able to afford the products / services of precision agriculture technology in order to increase the adoptation rate of precision agriculture.

Digital technologies and open innovation data revolution promise a radical change in the agricultural industry and business models. As advancement in products and software massively increases the ability to access, analyze and recombine big data sets, platforms create the rapid exchange of information and experience. It is important that platforms should be established that will enable open data sharing among participating actors, thus increasing trust. There is currently no national or EU legal framework to control the use of data collected and assessed by agri-business companies. The lack of substantial public debate and political intervention leaves the technology in the hands of a few global corporations who are able to collect, analyse, and monetise the data however they like, whilst consolidating their dominance in the farm sector and food chain. This is already happening as we see few major services / products dominating the agricultural industry. Without intervention, those few who control the data will end up controlling our food and farmers. The EU should create policies that enable sharing of data between different partners in the agriculture chain and this must be conducted in a fair and transparent manner. Every stakeholder in the whole ecosystem has a piece of the puzzle but not everybody in this way is capable of benefiting. The current business models are fragmented preventing data sharing. This prevents optimum use of digitalization and big data in precision agriculture. What needs to be developed is a model where everybody benefits in some way from the benefits of sharing data.

4.2. Challenges in farm data ownership

The absence of legal and regulatory framework around data collection, sharing and use of agricultural data in Precision agriculture contributes to a range of challenges being faced by farmers. This to some point prevents farmers from adopting precision agriculture. The lack of transparency and clarity around issues such as data ownership, portability, privacy, trust and liability in the commercial relationships governing smart farming contribute to the farmers reluctance to engage in widespread sharing of their farm data. The main concern is lack of trust between the farmers as data contributors, and those third parties who collect, aggregate and share their data. Farmers feel like they are left out when it comes to decision making about precision agriculture technologies, yet it is data from their farms that is being used for research and development. Farmers have mixed feelings about adopting precision agriculture because there is no equitable sharing of benefits of digitalization and data collection.

Agricultural technology providers, coming from industries outside the agricultural community, have introduced lengthy and complex software licence agreements that govern the way that farmers' data will be collected, managed and shared with their smart farming technology providers. The scope and extent of the terms of the software licences embedded into farming equipment (e.g. the sensors, robotics, drones, tractors and the agricultural machinery) are rarely discussed or even mentioned at the point of sale. Many farmers have even been surprised that only by turning on their machinery or downloading the technology means that they have agreed to a broad range of terms that regulate who can access and use the data generated on their farms. Farmers who have equipment from different manufacturers end up having fragmented data sets that they cannot even use while others find themselves in lock-in situations since they cannot buy equipment from other manufacturers. This can be frustrating because farmers have been the epicenter of agriculture since its introduction and they've made advancements that ensured there was enough produce for the earth's population. Digital technologies have currently shifted power from the farmers to few commercial manufacturers and industries that are benefiting on the expense of farmers.

The farmers that were interviewed did not know much about the terms and conditions relating to data collection agreement with their service providers. One stated that currently he gets few benefits from the data collected from his farm because they were very segmented. Farmers feel like service and technology providers use their data to make profits for themselves. Where possible, farmers actually prefer not to share their data due to lack of trust on how their data will be used. Willingness to share data is linked to more knowledge of terms and conditions. Farmers also want to be able to choose whom they can share data with, the type of data and the ability to transfer data on different systems. However, a discussion will always remain on who owns the data in precision agriculture unless a business model is developed that ensures all actors benefit from the data collected or a regulatory framework is set up to decide upon it.

A coalition of associations in the agri-food value chain signed a joint EU Code of Conduct on Agriculture Data Sharing of agriculture. The code promotes benefits of sharing data and enables agri-business models to swiftly move into an era of digitally enhanced farming. The code sheds greater light on contractual relationships and provides guidance on the use of agricultural data. In particular the rights to access and to use data. This code of conduct was agreed by Copa and Cogeca, CEMA, Fertilizers Europe, CEETTAR, CEJA, ECPA, EEFFAB, FEFAC and ESA. The objective of this initiative was to create a framework of cooperation among agri-food chain operators in order to make the best use of data in a constantly digitizing farming sector. The code aims to set transparent principles, clarifying responsibilities and creating trust among partners. It set out key guidelines for operators to follow to enable access to necessary data that will facilitate and accelerate data driven business models. Through the Common Agricultural Policy (CAP), the EU is aware that farmers need data in order to fully benefit from Precision agriculture. It is important to protect and involve farmers in the data they generate and make sure that everybody benefits / participates and not only big companies. The Code recognises the need to grant the data originator (the one who has created and/ or collected the data), a leading role in controlling the access to and use of data from their business and to benefit from sharing the data with any partner that wishes to use it. Agricultural data is of high economic importance for both farmers and the entire value chain therefore it is important for all actors to be involved.

4.3. Lack of transparency

Trust is a major issue that affects the adaptation of precision agriculture. The fact that farmers are unaware of the terms and conditions that govern the ownership, use and access to their data indicates that there seems to be very little involvement of farmers in decision making within the agriculture ecosystem. Issues relating to data ownership or access prior to entering a contract for agricultural technologies or services have been neglected. The lack of transparency in legal contracts affects trust and leads to dissatisfaction. If farmers do not understand the implications of what they are signing, they are often unaware of how much control the agricultural service provider is asserting over their data or the extent to which their farm data is being shared and traded. This has a significant consequence to the adaptation of precision agriculture and the whole agriculture industry as it forms the basis of lack of trust that farmers have towards some of the new digital technologies and services. PA might lead to development of digital technologies / services that optimize yield and efficiency in farms but in the long run farmers must be willing to adopt and use these technologies.

4.4. Challenges in data structure and compatibility with other based systems

Among the most important challenges towards the digitalization of agriculture is not only the high cost of technical equipment but also the lack of smart farming solutions capability to interoperate. Farms are islands of information and this slows down the efficiency of precision agriculture technologies. For instance, for a single farm to collect enough information to measure the value created by a new farming practice or a particular seed hybrid would take many years compared to when data from various farms can be analyzed together. A single farm cannot produce enough data to provide meaningful statistical significance. Improvement in data analysis will be possible if information can be distributed across many farms within a region. Wireless data connection and software tools can be used to enable analysis across systems in the farms. The value of precision farming will become clearer to growers and adaptation will increase once information from farms can be connected (bridging the many islands) and be used on a wide scale level. Technological and economical drawbacks caused by the lack of interoperability are the difficulties in integration of heterogeneous IoT devices into platforms, difficulties in the development of applications exploiting data from multiple IoT platforms, obstacles of big data utilization at a large scale, increased costs and discouragement in adopting to precision agriculture due to overall dissatisfaction. Farmers use different products and systems that aren't integrated or do not automatically allow data sharing, they are forced to enter data manually into their personal computers which isn't efficient as some data can be lost due to human error. Having fragmented data in different systems is difficult to fully analyze therefore most farmers find it meaningless due to frustrations.

The current precision agriculture IoT landscape consists of platforms and proprietary systems that are mainly isolated and act as vertical silos. These silos impede the creation of cross domain, cross platform and cross organizational services due to their lack of interoperability and openness. This leads to a situation where most of the collected data are not exploited while in some cases interoperability and interaction among IoT systems is a mandatory enabler for capturing the maximum potential of digital technologies in PA. Technological and economical drawbacks caused by the lack of platform interoperability are; difficulties regarding integration of heterogeneous IoT devices into platforms, difficulties regarding the development of applications exploiting data from multiple IoT platforms, obstacles of IoT technology utilisation at a large-scale, increased costs and discouragement in adopting IoT technologies, and overall user dissatisfaction.

4.5. Challenges in data portability

As part of their smart farming businesses, farmers enter numerous contracts with different parties for products and services. Some of the contractual relationships that farmers enter into that involve the collection and collation of agricultural data include contracts with chemical/fertiliser suppliers, broader service providers (e.g. telecommunications, sensors, soil testing, drones, etc., agri-technology/agri-business providers), and third parties and professional advisers (e.g. agronomists, contractors and advisers). Most data licenses involve a click wrap agreement where clicking on 'I agree' icon signifies consent to the terms of a software license. Data licences that are embedded in digital agricultural technologies are usually complex standard form licence agreements that are generally non-negotiable and presented on a 'take it or leave it' basis when the technology is adopted. The farmer is given no option other than to accept. Often a data licence will also provide links to other policy documents such as the agricultural technology provider's privacy policy. In some cases, it is the privacy policy rather than the terms of use of the data licence that outlines who may have access to the data generated under the agreement. Each different agricultural sector has an industry-focused range of commercial relationships. The more vertically integrated the industry, the tighter the contractual relationships tend to be. This clearly indicates that a farmer is forced to operate with other technologies (within the vertical integration) compatible with his current products / services.

4.6. Challenges in cost of adopting to Precision agriculture

An average farmer cannot afford new applications and technology. Tractors, sprayers, seeders and all other equipment with onboard computers can cost hundreds of thousands of euros. Field analysis and commercial online platforms start from 2 euros per hectare, and to conduct an agrochemical analysis of the soil sample costs around 10-20 euros per soil sample. There are high investment costs in machinery, yet some unmanned aerial vehicles are still relatively unsteady, especially during bad weather conditions resulting in poor quality images. Farmers are forced to buy upgraded equipment that they do not even need at times and manufacturers / developers know that their products are unique therefore the farmers will end up buying anyway. Another major problem is the incompetence of dealers, their main goal is to sell machinery and do not care about the farmers needs or how he will use it.

Farmers are not able to confidently establish at what point would they breakeven and surpass their costs of investment in precision agriculture technologies. It is hard for them to determine they will get a payoff from adopting precision agriculture. Data collected from farms might end up being too large and sophisticated for farmers therefore increasing the costs of either hiring experts or tools for data analysis and interpretation. Technologies, for instance software, develop very fast. This may be a challenge to users, especially farmers who have a lot to catch up with or upgrade. The costs that come along with such developments or upgrades might be too high for the farmers.

CHAPTER FIVE

ANALYSIS AND RECOMMENDATION

5.1. How to align and engage all partners to move the agricultural industry into precision farming in maize farming?

As observed in chapter four, the issue slowing the adaptation of precision agriculture is not the technologies but rather the business models of actors in them. Different actors in the value chain have stand-alone ecosystems that prevent interoperability between systems and value is created on a personal basis and not for all the value chain. Farmers on the other hand feel neglected in the advancement of precision agriculture technologies as they are forced to enter contractual relationships with service and product providers without transparency, with high costs involved and no clear way to determine their return of investment in precision agriculture technologies. Innovation in precision agriculture will be accelerated by creating a framework in which farmers, cooperatives, extension professionals, scientists and the private sector can effectively collaborate and co-create knowledge. Farmers are essential participants in the research process, to identify research priorities, to collaborate with scientists in conducting research, and to adopt and disseminate the results of research. Technical solutions should allow farmers to produce more efficiently, leaving more time for managing, for instance through technical solutions for monitoring and controlling emissions. These solutions should enable farmers to show the quality, the sustainability and the safety of their product to consumers and policy makers, unlike the situation now that it’s service and equipment providers who can answer these questions. Precision agriculture technologies can continue advancing but will never reach their full potential if farmers have mixed feelings about adopting precision agriculture.

The creation of a framework in which different actors can effectively collaborate and co-create knowledge implies some companies will disappear, and the rest will learn to make simple and useful applications that can communicate with other systems. Data is currently being used as a competitive advantage and that is why there is little transparency on the data collected from farms which in turn leads to lack of trust among farmers and willingness to share data. This is because farmers do not see tangible benefits of the data that is collected on their farms. If all data sets created could be put in a platform and openly accessed by different participants within the value chain, everyone will be able to benefit from the big data available. Farmers might have their trust issues solved as they have a clear view on how their data is collected, what data is collected, who uses their data and how beneficial is the data not just to them but the whole value chain. Collaborating and co-creating among different actors in the ecosystem might solve the issue of lack of interoperability in systems and data being fragmented or lost during manual transfer by farmers. It is important that all decisions that are made have the farmer in mind and how the technology is going to benefit them because it is quite clear that everyone is adopting precision agriculture except the farmers, which threatens both the benefit and the development of PA.

The cost of precision agriculture technologies is another aspect that slows down the adoption of precision agriculture. Product and service providers can argue that the cost of research and development of sensors, systems and input is high, but they should keep in mind that farmers should be able to afford these technologies. A framework where actors can effectively collaborate and co-create would reduce the research and development time and costs because data will be shared among different industries within the value chain where some actors can benefit from the experience of other actors. Some actors like software companies are realizing the need of their products to communicate with other products and that there is no future in stand-alone products. There are API's that allow one to work with data in different formats, for example, Trimble and John Deere announced an integration between their services in 2016 which was really good news for farmers. It is very clear from the interviews carried out that farmers are frustrated with data fragmentation which leads to loss of data due to manual data transfer or meaningless data in the long run. This calls out for the need to create agriculture ecosystems which every participant benefits through co-creation of value and products that communicate to allow integration of data or government policies and regulations that will ensure that every party benefits from the big data collected in agriculture to speed up adaptation of precision agriculture.

5.2. Which variables contribute to optimal crop yield and who are the partners that play a role in it?

With an ever-growing global population and rising food prices, the task of feeding the world is going to become more challenging and is just one reason to capitalize on the benefits of precision agriculture. There are a variety of factors that contribute to crop yield in maize farming. Figure 7 below shows the factors which affect yield in crop production. Crop yield factors have been divided into internal and external factors. Internal factors are related to the genetic abilities of the plant. These abilities include a plant (the seed) high yielding ability, early maturity, resistance to lodging, drought /flood and salinity resistance, tolerance to insects and pests and the quality of the grain (protein content).

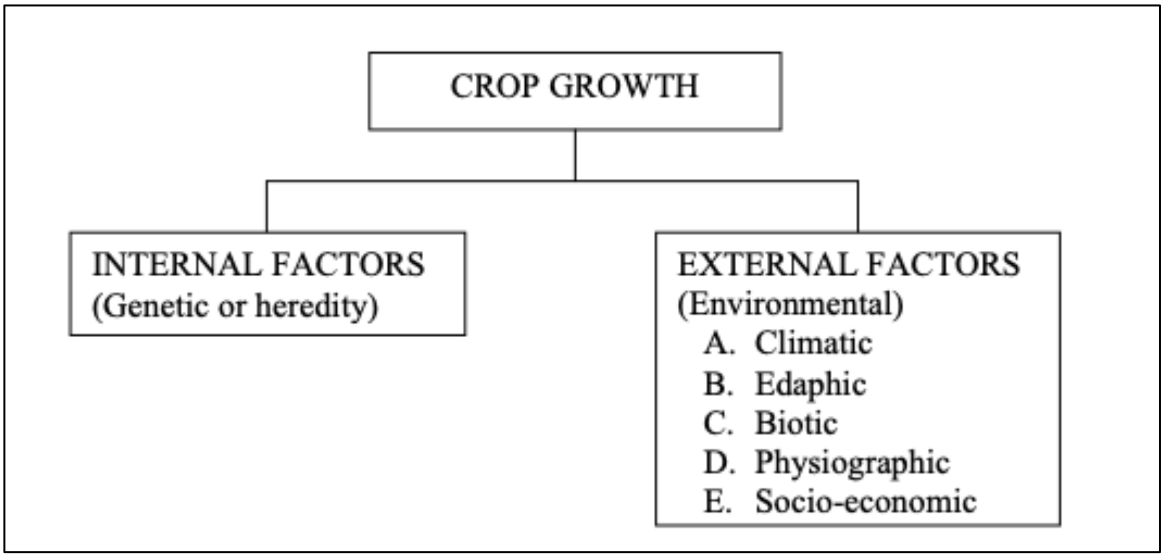


Figure 7: Factors affecting crop production.

Source: http://eagri.org/eagri50/AGRO101/lec09.pdf

Before digitalization of agriculture, farmers could choose the best crops from the farm and use them as seeds for the next season. Seed selection has now been made easier since there are various researchers that aim to discover new genes that could increase plant growth and seed yield in maize. Bayer uses both breeding and biotechnology to produce seeds, the breeding of seeds allows them to use the best line of current seeds to produce a next generation of seeds that are better compared to traditional breeding methods. Modern food biotechnology increases the speed and precision with which scientists can improve food traits and production practices. For centuries prior to the development of biotechnology, farmers have spent generations crossbreeding plants or animals to obtain the specific beneficial traits they were looking for and avoid the traits they did not want. The process not only took a lot of time and effort, but the final outcome was far from guaranteed. Today, food biotechnology utilizes the knowledge of plant science and genetics to further and speed up this tradition. Scientists can move genes for valuable traits from one plant to another resulting in a seed that stands all the external factors. Biotechnology aims to benefit the environment by reducing the amount of chemicals used to protect the seed on the farm. Biotech seeds are designed to be resistant to pests and diseases therefore allowing farmers to use less pesticides and herbicides while still maintaining healthy, high yielding crops. Reduction of chemical usage is beneficial to the water and wildlife. In order to get their seeds, Bayer works together with a number of farmers who plant the seeds for them until they are ready for harvesting and then taken back to the factory.

External factors are divided into five; climate, edaphic (soil factors), biotic, physiographic and socio-economic. Nearly 50% of yield is attributed to the influence of climate factors. Extreme weather events such as droughts have become increasingly common affecting agriculture and have several economic consequences. Climate conditions extend beyond ‘wet and dry’ and predicting weather patterns has become difficult due to global warming. Farmers have experienced cases where the weather patterns shift away from the normal patterns, for instance a dry spell coming at a time when rain is expected. While annual precipitation is an important aspect of climate, there are other aspects to consider such as atmospheric humidity, temperature, wind velocity, increased prevalence of pests during certain climate conditions, solar radiation, atmospheric gases and weather patterns.

Plants grown on land completely depend on soil on which they grow. Soil factors include soil moisture, air, temperature, mineral matter, organic matter, soil organisms and soil reactions. Soil is a principal constituent of growing plants and high moisture capacity can lead to wilting of plants either due to excess or insufficient water. There are numerous nutrients that are essential for proper crop development. Each is equally important to the plant, although they are required in vastly different amounts. The function of nutrients in plants is complex and includes processes like root, shoot, leaf and fruit development, production of proteins, hormones and chlorophyll, photosynthesis, etc. Soil is a major source of these nutrients to plants and soil fertility (or nutrient content) can therefore have a profound impact on crop production. The absence of any one of these nutrients has the potential to decrease crop yield by negatively affecting the associated growth factor. Availability of water has a direct impact on crop yield and profitability can therefore vary widely due to the highly variable nature of precipitation, both in timing and amount. Too little precipitation can cause crops to wither and die, whereas excessive rainfall (especially when it follows irrigation) will also have adverse effects on crop growth. When crops are over-irrigated, water, energy, labour, and fertiliser are wasted and crop production can decrease.

Biotic factors are beneficial and harmful effects caused by other biological organisms (plants and animals) on the crop plants once in the fields. Competition between plants occurs when there is demand for nutrients, moisture and sunlight particularly when they are short in supply. When different crops are grown together (cereals and legumes), mutual benefits result in higher yields. Through precision agriculture machinery providers such as John Deere have developed precision planters like the 'Vacuum planter' which gently pulls and holds individual seeds to individual holes of the seed disk for population control and spacing accuracy. This prevents plants from competing against each other for nutrients as the right spacing is automatically created. Other plants and animals can be harmful for the maize plants in the fields. The traditional use of chemicals for pest prevention wasn't accurate because some good insects like honeybees and wasps which help in cross pollination can be affected as well. Precision farming is a system approach that helps in controlling all the above-mentioned factors by managing soils and crops to reduce decision uncertainty through better understanding and management of digital technologies.

5.3. How to manage innovation ecosystems to successfully introduce digital technology to maize farming?

Innovation matters in data driven businesses because technology advances at a fast pace and change is inevitable. If businesses do not find a way to innovate and keep up with technology, they risk fading away as other agile businesses take over. There are many examples such as Nokia, Blackberry or Kodak who failed by ignoring new innovations and businesses models. Innovation is a survival mechanism and the cost of research comes at a high price unless an organization decides to open up and leverage outside technology. Innovation ecosystems are basically a large number of diverse participants that come together to co-create value. Innovation ecosystems is a network of interconnected organizations that are organized around a focal firm (the orchestrator) or a platform and focuses on new value development through innovation. In a new knowledge intensive economic landscape, closed innovation doesn't work anymore. Firms need to access knowledge sources from outside the organization due to the inability to generate all necessary knowledge by themselves. The network of linkages in which a firm co-creates value outside its organization is considered as an ecosystem. Dynamic markets, intense competition and shorter product life cycles force companies across different industries to interact with one another in order to co-create value. A firm's abilities to successfully commercialize a new product depends not only on its own technology strategy but its capabilities to manage an innovation ecosystem. For instance, Bayer's open innovation strategy helps the organization leverage knowledge from academia, industry start-ups such as FaunaPhotonics, and various partners across industries.

An innovation ecosystem in precision agriculture would include all the actors in the agri-food industry and others, like startups from different industries that are applying their services to agriculture. Technology giants like Amazon and Microsoft are also showing interest in precision agriculture. Ecosystem management is vital for the success of data driven models by bringing together all partners involved in order to help them deliver solutions to each other. The objective of these ecosystems is to create value for users by increasing productivity in agriculture and reducing service/ product cost through co-creation in research & development. Innovation ecosystems have the power to disrupt the agriculture landscape if partners create frameworks in which they can co-create. Different actors in the value chain are developing innovation ecosystems that encompasses all their farming solutions, for instance Xarvio by Bayer and myjohndeere.com by John Deere. However, these ecosystems created by Bayer, BASF or John Deere create lock-in effects for other players like farmers, technology developers in platforms that are too small due to lack of compatibility.

One of the main challenges towards digitalization of agriculture is the lack of smart farming systems capability to interoperate. Interoperability is the ability of computer systems or software to exchange and make use of information. This is mainly because devices are made by different manufacturers who use data collected as an asset towards future innovations. Big data creates a very valuable source of information which can be utilized to sustainably improve planning, implementation and evaluation of communication activities therefore transforming business processes and models. Lack of interoperability among systems however slows down the impact of digitalization in the agricultural sector. If a single farmer is frustrated because he cannot make clear farm decisions due to his data being fragmented, imagine this challenge at a large scale and the impact it has on agricultural data. This means that some data is lost that could be beneficial for precision agriculture. The impact of digitalization in the agriculture sector will reach full potential if data sets can be integrated in order to make intelligent analysis and find solutions to problems that affect agriculture as a whole. All actors in the agricultural value chain, no matter how big or small, should benefit from digital innovations to be able to upgrade their products, services, improve processes and adopt its business models to the digital change.

The challenge to manage innovation ecosystems is attracting and making the platform interesting for all partners through co-creation of value. The core value is to align innovation ecosystems within the agricultural industry and to enable system and data integration among different platforms and ecosystems. Integration among systems and data would solve the challenges affecting farmers adaptation to precision agriculture. Farmers remain at the heart of digitalization of agriculture, their needs are the main driver for setting innovation priorities therefore it is necessary to align the focus of technology according to the needs of farmer communities. Farmers' frustration towards the use of digital technologies inhibits them to adopt the technology because they don't observe tangible benefits of using precision agriculture technologies keeping in mind the costs of investing in these technologies. Issues hindering adoption of precision agriculture such as farm data ownership, farmer lock-in to specific manufactures of products and services, lack of interoperability among systems, lack of trust, lack of transparency and high cost of precision agriculture technologies can effectively be solved if all actors within the agricultural value chain and external sectors can collectively co-create.

Agriculture ecosystems have a great variation in structure and function because they are designed by actors in the agricultural value chain. Policies and regulations promoting agriculture ecosystems should be set in place in order to encourage partners to connect different agriculture ecosystems and platforms. Value created through integration of systems and data will benefit the whole ecosystem by solving the challenges mentioned in chapter four; farm data ownership, business models around precision agriculture technologies, lack of transparency and trust, data portability and systems interoperability and the high costs of precision agriculture technologies. The benefits of integrating systems and data within the agriculture ecosystem will increase the adaptation of precision agriculture.

The development of an ecosystem that offers integration of systems and data as a focal value proposition will lead to a change of business models across the agricultural industry. There will be a shift from product to data driven business models. John Deere is a good example of who had a shift in not only selling machinery but software solutions on a subscription basis. Sensors mounted on John Deere’s tractors collect data which is stored in myjohndeerecom cloud and can be accessed by farmers. However, as farmers become more aware of the importance of farm data and as they are not able to transfer data from one system to another, they get frustrated and a discussion emerges about data ownership. One can argue that farm data belongs to the farmers or the owners of precision agriculture technologies which collect the data, but what is apparent, all actors in the agriculture value chain need each other in order to succeed. If standards that allow interoperability among systems are set, actors will be forced to collaborate and create innovative ideas. For instance, Bayer manufactures pesticides while John Deere manufactures spraying machinery which is used by farmers for field spraying. If both Bayer and John Deere collect data separately as the farmer works on the field and this data cannot be integrated, then it is difficult to get better analysis compared to when the systems information can be integrated. Digital technologies only have transformational impact if businesses processes can be changed to allow collaborative innovation. Most standards are voluntary formulated by members within the value chain. They are offered for adoption by people or industries without being mandated by law. For example, the joint EU Code of Conduct on agriculture data sharing which is a coalition formed by association in the Agri-value chain. Actors in the value chain may come together and as a group decide that there's a need for standardization.

Collaboration enhances creation and implementation of new ideas by creating joint ownership and spreading risks to a larger group of actors. When actors in the agricultural value chain come together to co-create, the issue of farm data ownership can be solved because data collected is analyzed and used to the benefit of all the actors in the ecosystem. The issues concerning transparency and lack of trust among farmers will be solved as well because all the actors, both big and small will be involved and benefit from the ecosystem. If all actors are willing to share their knowledge and expertise, the time and costs spent on research and development of innovative ideas will reduce. This will make it possible for manufacturers to sell their products and services at an affordable price that all farmers regardless of their size can afford to pay or farmers will feel involved in the agricultural ecosystem and as a result fully adapt to PA. If farmers are willing to share their data and manufactures products and software adhere to interoperability standards, farmers will be able to make use of their whole data and optimally increase yield while reducing costs. Recorded profits in agriculture will allow farmers to afford purchasing and using precision agriculture technology tools. The ecosystem can also be used to share knowledge and educate farmers on how to use PA technologies and the benefits. This will help farmers better understand how their technologies work and use them to their best advantage.

5.4. Which methods can be used to collect needed data sets and used to further improve crop farming?

Data is collected from the farm by the use of Precision agriculture technologies equipped on the machines and in the soil. In order to maximize yield potential, farmers must consider many variables including weather, timing, soil quality, moisture, nutrients level, seed placement and frequency and dosage of fertilizer / pesticide application. Machineries equipped with IoT such as sensors are an intricate ecosystem of data flows across machines, farmers, John Deere, external partners and the technological infrastructure to facilitate them. Farms are full of valuable data that if connected to PA technologies, enables farmers to improve productivity, increase efficiency and reduce costs to ultimately maximize profitability. Figure 8 below shows how data is collected using different systems and analyzed to improve farm decisions through PA in a specific farm.

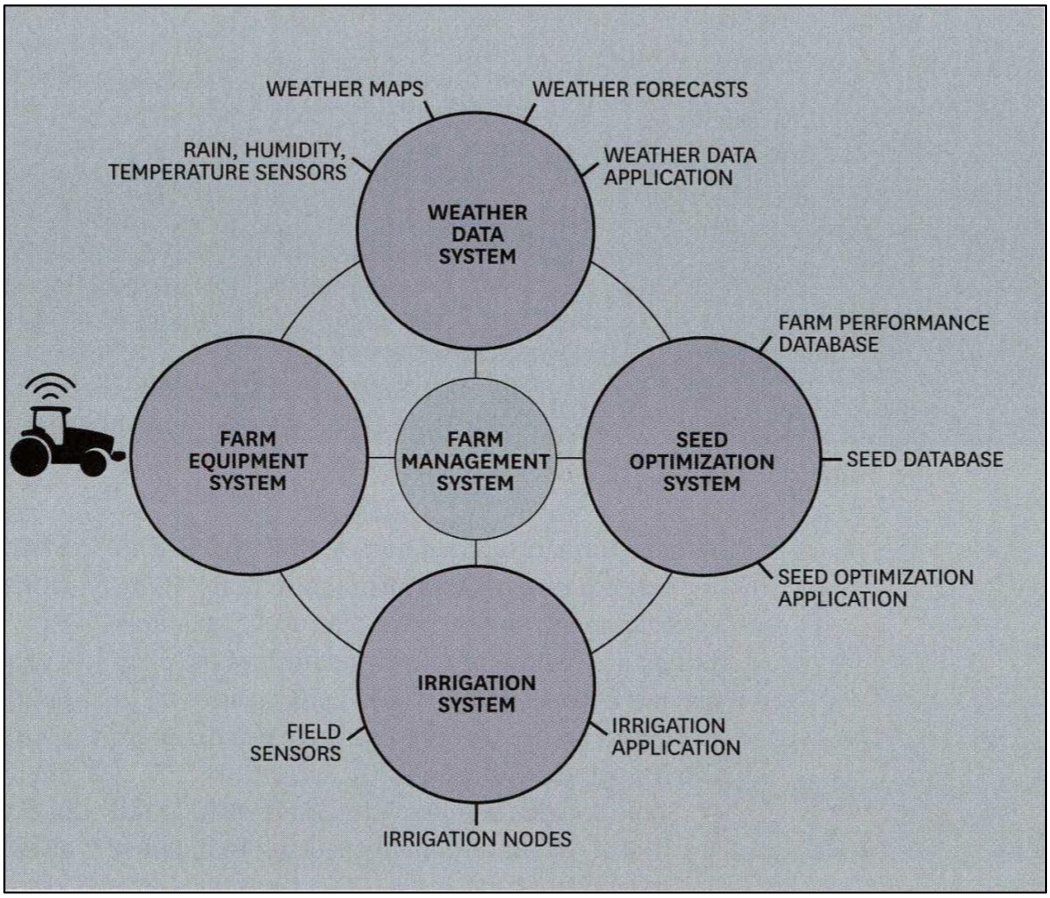


Figure 8: John Deere farm management data

Source: Michael E. Porter and James E. Heppelmann, "How Smart, Connected Products Are Transforming Competition," Harvard Business Review, November 2014.

Data including crop management, and machine operation (fuel level, location, machine hours) is collected primarily by sensors embedded both in machines and in the soil. More data is pulled from external sources such as weather stations for weather prediction data or commodity pricing. The data is automatically uploaded onto the cloud and farmers can access it through the 'myjohndeere.com' portal. Farmers can monitor activities real-time, analyze performance and determine decisions that will improve yield production. MyJohnDeere.com is an open platform thereby enabling farmers to share their data with apps created by third party Agriculture software providers leveraging John Deere APIs only. Satellites like Sentinel-2 of the European Union's Copernicus programme collect images shot in visible infrared ranges. Satellites are equipped with capabilities to easily monitor large areas. Earth observation data collected by the satellites can help farmers increase agricultural productivity and sustainability in precision farming. Images from the satellite can show a farmer where crops need more attention preventing him from either spraying the whole field with pesticide. Satellite data is free for everyone and the data is being used extensively to improve precision agriculture. This is a clear indicator that PA will have more innovation potential if all the actors agree to co-create and use data for the benefit of all participants in the ecosystem.

Despite all the benefits of PA on farm management, there is greater potential if these data can be used across farms within a locality. For instance; farmers can learn from each other by querying the database to seek optimal mixtures of knowledge to increase yield in their own farms or farmers can also be alerted early on pests in their region and carry preventive measures. Like this, third parties will be able to develop services and reports based on this information to assist farmers who are less tech-savvy, also addressing the issue of the smaller and less developed farms. Farmers on the other hand want to be able to move their data from their machines to other preferred systems other than only those connected to 'myjohndeere.com'. In 2019, John Deere partnered with CLASS, CNH industrial and 365FarmNet to create DataConnect just like ISOBUS (physical connection between hardware), a cloud to cloud solution to record on-farm data with a mixed brand fleet. By connecting to DataConnect, farmers can choose their preferred data platform through Deere, CLASS, New Holland or Case IH brand equipment. This is a clear example that data sets can be collected from different service / product providers and accessed on a common platform however it doesn't clear farmers frustration on the use of precision agriculture technologies and data transparency. Farmers are frequently given a take it or leave it technological package based on experimental research managed by researchers and big corporations with farmers excluded. Farmers would prefer to discuss their recommendations and make their own decisions suited for their particular conditions rather than being told what to do.

ISOBUS is a standard protocol which makes communication possible between hardware devices such as tractors, software and equipment of major manufacturers. This allows the exchange of data and information with universal language through a single control in the tractors cab. The use of ISOBUS protocol is an agreement between main manufacturers of agricultural equipment to solve compatibility problems, standardizing communication among different implements from different manufacturers or a of a different hardware level. If such a standard could be adopted by all hardware/software to allow communication and collaboration in PA, the impact would be overwhelming. Most hardware providers have chosen to adopt the ISOBUS standard by joining the AEF (Agricultural Industry Electronics Foundation) which promotes the ISOBUS standard to ensure interoperability of different hardware manufacturers equipment. It however does not address the portability of data between the different cloud environments. Enabling this would solve the issue of fragmented data, creating value by combining information often held by different actors in agriculture. Big data in agriculture will reach its full potential once all data within the agri-food value chain can be analyzed for better farm management and decision making. It is also important to know the possible negative consequences such as privacy, liability and loss of control issues that may arise when interoperability of data is standardized and how to mitigate these issues.

5.5. How to develop an ecosystem of partners in PA to improve the chance of adoption and commercial success for all partners involved?

Since data ownership is one of the main reasons that affects trust and willingness of farmers to adopt precision agriculture, all actors should benefit from open agriculture data movement. An open innovation ecosystem would ensure that all participants benefit through value creation on the data collected. The aim of innovation ecosystems enables value creation not just for big commercial players but also small-scale producers. As systems evolve, they need primary data from farmers. Agri-food chain actors could benefit from open sharing and exchange of farm data. If all overlapping data sets used by small scale farmers concerning agriculture law and regulations, development projects in precision agriculture, land use, data productivity, soil management, pest management, market and price data could be accessed in an ecosystem, we would see an acceleration in the adoption and an increase in the success of precision agriculture. It is important that governments set regulations that ensure transparency in data and interoperability among systems. Open data approaches will help solve the data ownership, accessibility and sharing problems in precision agriculture. Just like any user platform, there should be regulations in place to ensure that open data provided is not exploited in unanticipated and inappropriate ways. Participants should be given access to data that only benefits them in the value chain in order to reduce the risks of monopoly therefore data being ‘as open as possible’ and ‘as closed as necessary’ at the same time.

There are various research projects established on creating innovative ecosystems that can bridge the gap between multiple partners in complex agriculture ecosystems within precision agriculture. Examples include; Smart Agri Hubs, a project dedicated to accelerating digital transformation of the European agri-food sector with an aim to build an ecosystem that will enable integration of technology and business support among various players in Europe. Another example is DJustconnect, a platform launched by ILVO in partnership with Boerenbond (farmers’ association), AVEVE, CRV, dgz and Milcobel which enables data sharing in an advanced way within the agri-food chain and builds around the farmer. Another approach of a data exchange platform is DKE Agrirouter from Germany. DKE is in joint ownership of the following farm machine manufacturers: SDF, Raunch, Pottinger, Lemken, Kuhn, Krone, Horsch, Grimmie, Excel Industries, Amazone and AGCO. Interestingly enough, some of these companies are also member of the AEF. The Agrirouter intends to serve as a neutral instance that enables farmers and agriculture contractors to exchange data between machinery and agricultural software applications from a wide variety of vendors. Users set their personal Agrirouter and only need to use the control center to set the routes to be used for transferring their data. Agrirouter doesnt establish standards for data exchange but serves as a translator of several different IOSXML dialects and other standards (Figure 9 below). The platform translates the data passing through it to a service provider that the farmer intended to receive the data. the farmer is allowed to keep full control of the data flow towards third-party applications and only machines authorized by the farmer exchange information. the farmer can cancel the subscription whenever he feels like, however, this is not the same for the data that flows to the OEM cloud of the machine manufacturer (IoF2020)

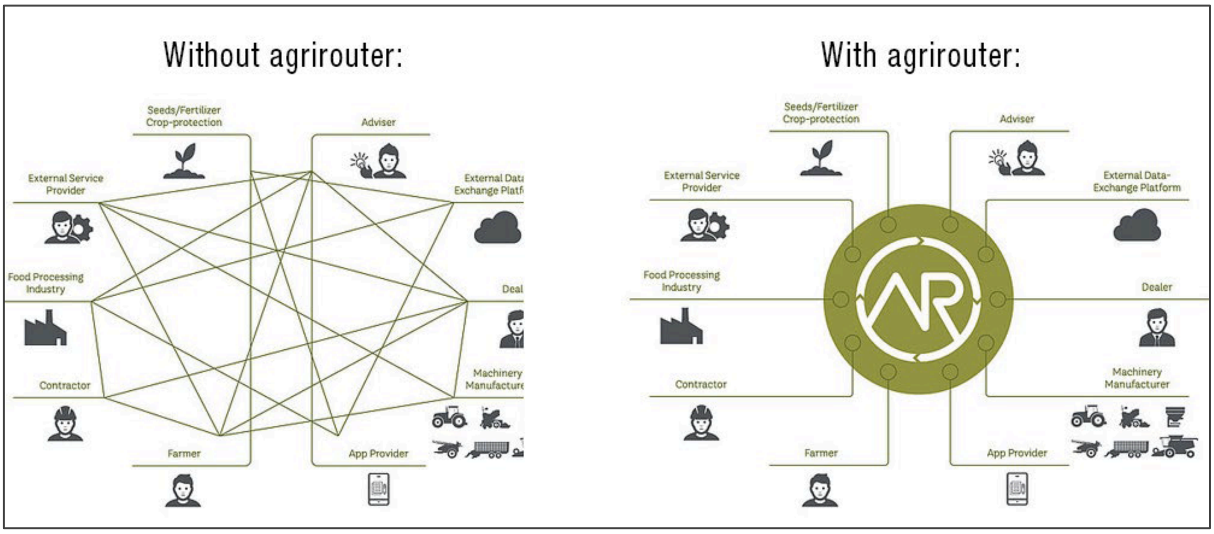


Figure 9: Agrirouter- Data routing approach
Source: IoF2020-Use-Case Business Models

5.5.1. Integration across the agriculture value chain

Creating sustainable business models is a solution to most of the challenges that precision agriculture faces. Business models have the power of disrupting and transforming industries, for instance the case of John Deere. John Deere initially a tractor company announced in 2014 that it was laying off 600 workers due to less demand of its products yet in 2018, it employed 67,000 people worldwide. In 2017, John Deere acquired Blue River Technology, a leader in applying machine learning to agriculture. John Deere is no longer just selling tractors (product) but also a software service for the use of the tractors on a subscription basis. John Deere further prevented the repair of their tractors by other dealers thereby locking farmers to their products and to John Deer dealerships. John Deere used the power of digitalization to transform their products into a continuous source of income through service subscription while at the same time obtaining valuable data. John Deere also launched data enabled services that let farmers benefit from monitoring real-time data. The ‘myjohndeere.com’ online portal enabled farmers to access data gathered by sensors attached to their machinery as they work in fields, as well as aggregated data from other users around the world. This platform will however only work on John Deere products / services. Farmers can access and see it but are not able to export the data to other applications used to analyze and make decisions in farming. One farmer was frustrated that he couldn’t connect his John Deere data to AgroVision, a platform that helps him analyze data and overall farm management.

Digital technologies evolve faster and the time for monopoly in precision agriculture is coming to an end. Other actors like famers are becoming aware and feel exploited by big corporations who benefit from data collected on their farms. While one would expect big companies to already act as orchestrators, most are buying startups and merging or acquiring other companies in order to increase their service portfolio while at the same using data for competitive advantage. On the other hand, farmers are an important player in the ecosystem but currently do not have the power to demand for changes on how data is captured and used unless they all decide to stop using precision agriculture technologies until they are heard. Individual actions by smallholders will have little impact in this data-driven environment. Joint action by smallholders offers ways to jointly safeguard their own data, maximize returns in value chains, and best exploit the potential of third-party services and data offerings. From one interview, a farmer stated that at times services / products that they don't even need are forced on them at a higher price, yet they do not see the benefits of these upgraded technologies. Farmers are frustrated because they can't interoperate the fragmented layers of data on their farms. This affects the overall decision making in the farms because use of farm data is not maximised.

In a digital ecosystem, participants act collectively to create new markets, deliver new forms of value and build new engaging experiences. Uber leverages its platform business model to drive a successful mobility ecosystem. When a product / service is delivered digitally, dominating the supply chain is no longer a guarantee of market success. Nokia failed to see the power of ecosystems which led to their failure despite being an industry leader at that time. Ecosystem orchestrators connect stakeholders, creating value for all the ecosystem therefore expanding value from physical assets to data assets and shared resources.

5.5.2. The platform architecture framework

Through platforms, businesses are powered with the ability to leverage and orchestrate a connected ecosystem of producers and consumers towards efficient value creation and exchange. Many businesses leverage platform thinking as companies across industries are actively building platforms in order to benefit from knowledge and expertise outside of their organizations. Most of these business models function as plug-and-play to facilitate interactions within the platforms while at the same time protecting core values that organizations wouldn't want to share. Across all platforms, three distinct layers emerge; the network/ marketplace community, the infrastructure layer and the data layer.

- The network community layer

The network or community layer comprises all the participants on a platform and their relationships. Social networks require users to connect with each other explicitly while marketplaces may not require users to form explicit connections but may regularly match buyers and sellers, allowing them to interact. Users in an agricultural platform do not necessarily have to connect with each other as every user will implicitly benefit from the community without the requirement to connect with others explicitly. It is important that all users are treated neutral to prevent the case of monopoly in the ecosystem and the platform should be managed in such a way that it is affordable for farmers and SMEs to participate. External network producers create value in the network layer, to enable value creation of external network platforms need a second layer (Infrastructure layer)

- Infrastructure layer

The infrastructure layer consists of the tools, services and rules that enable the plug in and play nature of a platform business. It has little value unless partners start creating value on the platform. This layer provides the infrastructure on which value can be created. The core value of this platform is creation of data. A common open platform is needed to facilitate the various actors using ICT components and application services. It is important that rules of interaction are created that provide consistent standards for this collaboration that in the future will not create restrictions for exploitation (backwards- and forwards compatibility) so that multiple ecosystems around the same platform are possible.

- Data platform layer

Every platform uses data and the value of this platform is enabling data capturing through system and data integration. Data allows the platform to match supply with demand depending on the party that needs to access data thereby matching the most relevant content with the right users. For instance, Nest thermostat and IoT data platform, the thermostat uses a data platform to aggregate data from multiple thermostats. This aggregation of data enables analytics for thermostat users and powers services to the city's utilities board. Just like Nest thermostat or Airbnb using data to match hosts to travelers, this platform can benefit through creation and integration of data which will be beneficial to all users. The system & data integration module must provide API to enable smooth data exchange between Application Components and enables access to distributed data. To enable smooth data exchange the platform should contain mechanisms for data mediation to be able to handle heterogeneous data from various sources. Additionally, Payment of Application Services should be handled within this module.

5.5.3. The ecosystem players and co-creation

Figure 9 below shows a sketch of an overview in the agricultural ecosystem, in terms of actors involved and who play different roles. The core value of the platform is to enable system and data integration. It is important to understand the issues faced by these actors and provide solutions by matching issues to opportunities across the ecosystem. An ecosystem analyzes and establishes networks through network effects by creating profiles and matchmaking problems to solutions. When these actors co-create value together, they do not just share experience but also develop a common vision that benefits the whole value chain. Clearly defined roles, processes and transparency builds trust among members solving issues regarding data ownership which is a hindrance to precision agriculture adaptation. An ecosystem of all players involved will refine innovative ideas through co-creation therefore continuously innovating the agricultural industry. The core value of the platform is system and data integration from all other agriculture related ecosystems. The platform should enable the creation, curation and consumption of value (data) among the users. Users will not only be in the business of creating products / services anymore but enabling interaction. However, the challenge is how to effectively set up and manage ecosystems and use them strategically to create value. Co-creation is the collaborative development of new value among businesses, customers, suppliers and even competitors. It is a form of collaborative open innovation in which knowledge and expertise are shared and improved together.

Figure 10: An ecosystem sample framework that could be used to share information and expertise to help co-create in agriculture through system and data integration as the focal value proposition.

Each agriculture sub sector has its own specificities therefore it is important that a platform starts in a small scale, for instance a region, then let it scale as more networks join due to the network effect and more value is created. An ecosystem orchestrator is the actor that connects companies in a value chain by setting up strategic partnerships and alliances mainly through digital means. Orchestrators offer products and services that are limited to their original product range and share customers and data with their partners in the ecosystem. An example of an orchestrator in Belgium could be Djustconnet. Djustconnect is an independent project by ILVO in partnership with AVEVE, Boerenbond, CRV, DGZ and Milcobel. Djustconnect is a platform that enables data to be exchanged in a regulated way within the Flemish agro food chain. A report by ILVO indicated that farmers are slow in adopting precision agriculture therefore understanding that the reason for low adaptation to PA lies with the farmers. From an Interview with Djustconnect, it was clear that farmers are frustrated and lack trust due to the issue of data ownership. Djustconnect aims at ensuring equal benefits from agricultural data throughout the value chain and centered around farmers. Farmers decide which data they want to share and with whom. Other actors who want to access the data collected on the platform must get approval from the farmers. The reason that Djustconnect could be the orchestrator is because they have gained farmers' trust in Flanders. Lack of trust affects farmers willingness to share data. However, the disadvantage of Djustconnect being an orchestrator is that it has very little power to attract other actors into the ecosystem. A platform is successful and able to scale when it creates value, and a critical mass is essential for its survival. Value is determined by network effects and the larger the network, the more service providers will join. If value is created, it will greatly facilitate this process.

Farmers remain at the heart of digitalization of agriculture, their needs are the main driver for setting innovation priorities therefore it is necessary to align the focus of technology according to the needs of farmer communities. This should be done in a bottom up approach and not top down the way innovations are done at the moment. Currently, farmers are offered products / services on a take it or leave it basis without any options. Farmers should be included, together with Agri-cooperatives in testing and assessing the effectiveness of a variety of tools and business models. Farmer inclusion in such decision making will help in educating them on the use of precision agriculture technologies. Farmer involvement will also help in creating trust and transparency among partners. As much as farmers are important, they do need all the other parties in the value chain to succeed in precision farming. Platforms create value through network effects, and it starts by pulling participants into the ecosystem. If enough farmers are using a platform for their data storage and sharing, the platform will be able to pull other participants who are in need of the farmers data to join. Seed and supply companies can access continuous data of plant growth information thereby helping them to further improve their seeds while in return farmers get more information on how to improve yield.

Governments and regulators play an important role in enabling policies that call for simple and easy adoptable standards. Governments create policies that ensure equal and fair treatment of all actors in the value chain. These policies might include standardization of systems to encourage interoperability of data. Without policies that encourage data interoperability being implemented, it will be a challenge to get valuable information from all the agriculture data being collected with huge differences in the types of datasets and levels of quality. Efficient planning of agriculture production requires thorough information about measures and events in the past, all this relies on data collected in the farm. Farmers have the electronic equipment to collect and record production data. However, the required data has to be manually transferred from one software package to another. A standard system for electronic data exchanges offers new possibilities for information directed agricultural production increasing sustainability and keeping adverse effects on the environment to a minimum.

Precision Agriculture aims at producing more food crops with lesser inputs by reducing the application of seeds, fertilizer and pesticides. This impacts companies that produce pesticides and herbicides because they benefit from higher sales of these products. The impact of PA on crop protection companies is important from a business model perspective as their primary objective is to sell seeds and chemicals on a repeated basis to farmers. Monsanto (which was acquired by Bayer) is under a high amount of scrutiny right now for a number of herbicides / pesticides which are believed to have had a negative impact to the environment (for instance, Glyphosate which has a lot of resistance around it and linked to the killing of bees). Both introduction of PA technologies that enabled optimal usage of inputs and growing knowledge among users on the harmful effects of certain inputs is a threat to input producers. In 2016, Bayer entered a collaboration with Fauna photonics to develop new sensor solutions to improve insect monitoring, this was a move to help farmers effectively control harmful insect pests while at the same time protecting beneficial insects such as pollen bees. This collaboration gives insights on how co-creation is important in sphere heading advancement and innovation in the agricultural sector. Co-creation within the Agri-value chain will benefit input producers and give them a positive face, away from the scrutiny as they try to help farmers use less fertilizer, herbicides and pesticides.

Most farmers, especially small-scale ones find the cost of precision agriculture equipment very high and they can’t fully account for the return of investing in these technologies. These costs include purchase of equipment, software subscriptions and repair. Unlike old tractors, farmers are prevented from repairing their tractors unless it’s done by specific dealers (who are very expensive). This is a costly investment for farmers and the fact that despite all these investments their data is still fragmented in different systems frustrates them. Frustration is a negative emotion and explains why farmers' adaptation to PA is low. Equipment providers need to find a way in which farmers benefit from the use of PA technologies. If farmers can have access to their data, clear the trust issues and get knowledge & support from product / service providers, adaptation to PA will increase as well as purchase of precision agriculture technologies. Co-creation will increase innovative ideas through sharing of knowledge and experience therefore reducing the time and cost for research in manufacturing PA technologies. Reduced costs result in reduced prices in PA technologies therefore increasing the number of farmers who can afford this equipment.

In 2019, John Deere also entered a collaboration with Faunaphotonics with an aim to find how Faunaphotonics technology can be connected to John Deere technology. Faunaphotonics is a start-up that is quickly innovating precision agriculture and collaborating with big agriculture incumbents in order to better their technology. This emphasizes the fact that collaboration / co-creation will increase innovation in PA and the risk incumbents face of losing their market leadership to agriculture start-ups who might come up with easy solutions to the challenges that hinder PA adaptation. Other technology giants out of the agriculture landscape such as IBM, Amazon and Microsoft are showing their interest in precision agriculture. These are companies that have proved success in leveraging the power of ecosystems and platforms. Microsoft recently leased a platform called “FarmBeats'' that intends to solve the farm connectivity problems by using TV white space- the frequency of unused TV channels- to connect the farm to the cloud. Based on Azure platform, Farmbeats will offer a ready to use form of algorithms, including sensor fusions, machine learning and edge computing that can easily be accessed by application developers through API’s (application programming interface). Microsoft's data is also intended to be publicly available to members in its open ecosystem, this might turn out to be the Linux of precision agriculture. Data will remain to be the property of the application developer or the farmer which resonates well with data ownership issues in precision agriculture. Such advances from non-agricultural companies and tech giants’ interest in PA clearly indicates that the agricultural industry is undergoing a major disruption and the incumbents within the Agri-sector should focus on value co-creation especially with the farmers needs at heart.

An example of an ecosystem is illustrated in figure 10 above. If farmers produce farm data, all this data can be collected on a platform orchestrated by Djustconnect. Loonwerkers, who are contracted by farmers who lack machinery should add their data per job on the database. This platform can be used to attract all the other network communities (as illustrated in Figure 8) attracting users in the ecosystem who will create value for each other through co-creation. Farmers are used to pull other users from the communities into the platform in order for them to access farm data. Data collected is used for analysis on a larger scale by all participants in the value chain. Government publications, latest agriculture innovations and information can also be published on the platform as value in order to attract more users. Data can also be provided to research centers and universities for free on conditions that participants within the ecosystem benefit from the results or external users can be charged to access high quality data. Adds can be placed on the platform for instance; contractors advertising their services, start-ups advertising their new technologies, farmers advertising their products or farmland for lease or any other transaction that happens within the agri-food value chain and paid per view. This is just a simple example on how all actors within the Agri ecosystem can co-create value and innovation in precision agriculture. Further study is however needed to determine how this ecosystem can be developed to align all the participants, to allow interoperability among systems and to determine whether a sustainable business case can be achieved in practice.

CHAPTER SIX

IMPLICATIONS OF NEW BUSINESS MODELS IN PRECISION AGRICULTURE

6.1. Open data sharing

In the previous chapters, I have shown the need for interoperability among precision agriculture technologies. The current agricultural landscape is very fragmented with many service providers. Larger companies are not offering open data ecosystems keeping the current impact of technology in precision agriculture rather low. Actors in the value chain invest in digital technologies in order to benefit from big data and make accurate future decisions. In other words, data is being used as a competitive asset. However, there is greater potential in integrating data throughout the value chain. Some benefits of open data sharing within the agriculture value chain are; more insights from a huge database since all data sets are combined, better algorithms, better understanding of data and decision making to deliver value. It is important to define a solution on how value can be captured to benefit participants if data is not used as a competitive advantage anymore. Data should be collected and structured in a way that it has all the valuable information necessary for users.

A negative implication of open data sharing is that data will not deliver a competitive advantage anymore for a single actor in the value chain. The value will be created on the ability of interpretation and analysis of the data and develop services for farmers based on these data-based insights. Therefore, value creation stems from the accessibility, analysis and usability of the data. If leveraged correctly, data from the agricultural sector has the power to increase yields. This in turn will spur adoption of precision agriculture among farmers. Another challenge of open data sharing is the risk associated with personal information and, therefore, every platform agriculture needs to ensure GDPR compliance.

6.2. The network effects

The core building blocks of a future data economy are interconnected platforms that standardize the information exchange and centralize/structure the services offered by a fragmented market of application providers. The farmer clearly wishes to have one major service platform on the farm that manages the farm master data and offers all relevant services around it. This distribution infrastructure is a driver for quick take-up of smart services and a faster validation of new solutions in practice on the farm. The ability of a platform to thrive depends on network effects. The network effect is a phenomenon whereby increased numbers of participants improve the value of a product or service. The larger the network of users, for instance more farmers on a platform, the more service providers and equipment manufactures will join. This in turn will make the platform more attractive for farmers and increase the number of farmers buying these services. When network effects are strong, the value provided by a platform continues to rise.

In this study Djustconnect is used as an example of an ecosystem orchestrator in Belgium. A negative implication of Djustconnect or any other regional agriculture platform being an orchestrator is the lack of power to attract network effects. This is because these platforms are covering only a region or a country, which is small for such a network. It is important that a platform is integrated at a European level. Local platforms should collaborate with others, for instance Djustconnect collaborating with a German platform therefore scaling at an international level. If these platforms can scale by integrating services for the farmers at a European level, other actors within the value chain will be attracted to join.

Small networks cannot survive because operating system costs and the app developing costs are very expensive. This might explain why the prices of precision agriculture technologies are costly. The cost of these technologies is one of the reasons that hinders farmers from adopting precision agriculture. Costs can be reduced if there are more players on a platform sharing expenses and co-creating value. Having more people on the platform will also reduce the costs per user and time taken by individuals in research and development. It would be effective if established companies find ways to engage broader ecosystems in order to leverage market development.

6.3. Suitable business models and how to monetize the platforms

Finding a suitable business model revolves around the question of how to create, deliver and capture value to all the stakeholders. Identifying a suitable business model within the agri-value chain requires continuous discussions among service providers, equipment providers and farmers to find a win-win solution for all the parties involved. It is important that all the parties benefit from the digitalization of agriculture and make data exchange possible. IOF2020 proposes a business model that foresees the formation of an independent company that acts as a collection agency on behalf of its stakeholders. This independent agency will act as an intermediary among the different actors within the value chain. The sole purpose of the agency is to manage, store and share data in a transparent way in order to benefit all the actors in the value chain. Actors within the value chain can partner to form this independent company, as we have seen the case of DK Agrirouter or Djustconnect in the previous chapters. Manufacturers and service providers sign up on the platform and register all their connectable devices to the platform catalogue. If the farmers wish to connect any of their machines there are two options.

- Option one: Monetize data and share with third party services (Data Marketplace)

In this option, the farmer simply wants to monetize or share part of the farm data through the data marketplace of the platform. The farmer will define the sharing criteria that will be part of the license under which the data is offered. The data flows in return for a regular fee or one-time payment by a third-party service or can be offered for free by the farmer. if there is money flowing back to the platform again 50% of the revenue flows to the platform, while 50% are equally shared between the farmer and the manufacturer.

- Option two: Connect the machine to specific service (Data Subscription plan)

In this model, the farmer subscribes for the service that he needs at a specific time. For instance, if the farmer wants to use a disease detection system, he simply registers to the service. He connects all the necessary machines and sensors requested by the service to work properly. The farmer also gives the service permission to use data for this specific purpose. In return, the farmer pays the fee for this particular service to the service provider. There is no contractual relationship with the farmer. One challenge that we saw in the previous chapters is that farmers were finding themselves in a lock-in situation for subscriptions that they did not need. Farmers also have less influence on deciding the type of data being taken from their firms. This model creates transparency and gives the farmer authority on dividing which farm data to share. It also reduces the cost that farmers have to pay on monthly/ yearly subscriptions because he will only subscribe to a specific service that is needed.

Once the farmer subscribes for a specific service, the service provider automatically signs a subscription plan for the farmer with the amount of data to transfer per month or year. Once the farmer pays the subscription, the service provider transfers the data subscription fee to the platform. The contractual relationship between the service provider and the platform stays active as long as the farmer keeps the machines registered and the data flowing. This implies that the farmer is at liberty to unsubscribe any moment once the service does not benefit him anymore. Half of the subscription fee remains with the platform to cover its running costs and further development. The other 50% flows to the manufactures of the connected machines and sensors. the share would be divided by manufacturers of the devices registered by the farmers either equally by the number of connected devices, the amount of data transferred or the quality of the offered data. Figure 10 below shows an overview of 4 different data approaches.

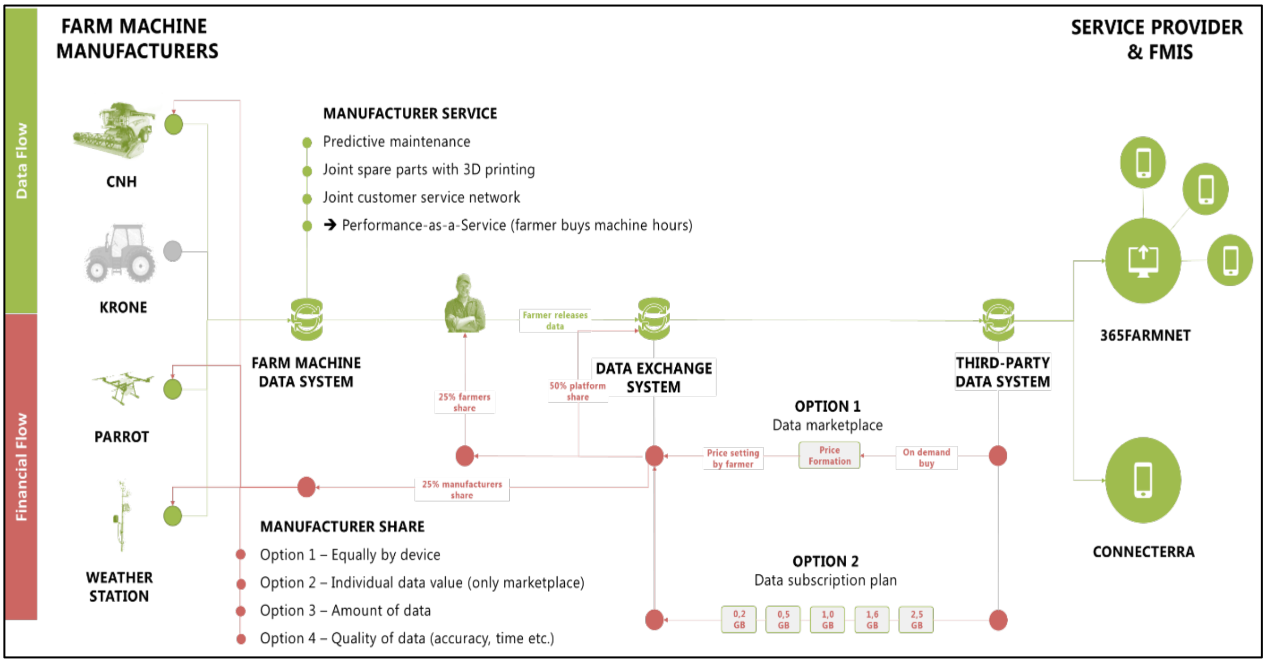


Figure 11: Showing an overview of different data exchange approaches

Source: IoF2020_WP4_Deliverable_4.9_Business_models_M24_Final.docx

Many activities performed on a farm have to be carried out to comply to many regional, national or European regulations that are constantly changing due to environmental or safety constraints. These regulations contain for example the maximum amount of manure to be brought out per hectare or the distance that a sprayer has to respect from surrounding nature or housing when applying pesticides on the field. Currently, these regulations are published in many different standards reaching from simple PDF documents available for download on a website to web services.

If a software or platform provider would like to gain access to farm machine data and gain the ability to directly communicate with farm machines of their clients, they need to agree to the terms of the farm machine manufacturer platform. Some of them will ask the software companies a data access fee, some of them are integrating it in services sold to the farmer, and others consider data streams a product feature for which no additional fees should be charged.

6.4. Revenue models

- Subscription model

In this model, customers pay a regular fee, either on a monthly or an annual basis in order to gain access to the product or service. Most farmers' IoT devices have a fulltime connection. This enables service providers to leverage that connectivity and to develop a recurring-revenue business model. Instead of offering a one-time license deal, service providers offer a subscription model to the farmer. the farmer doesn't become the owner of the hardware but simply pays a subscription fee for its usage. This model offers a farmer an easy entry for temporarily trying out a potential solution on the farm with an opportunity to terminate the service subscription if it doesn't provide expected benefits. Subscription model can address the situation where farmers find themselves in a lock-in situation for services that they do not need or benefit from. This model can also reduce the entry barrier by reducing the cost of precision agriculture technologies investments because the products belong to the service providers. Service providers can introduce "as a service" business model for a system that includes both hardware and software.

- Output or performance-based model

This model offers customers to pay for the actual output or benefit a product or service provides. The hardware manufacturers and service providers could offer machine-based performance and take over the risks of maintenance and servicing of the machines to assure the performance is guaranteed. This business model is only practicable when manufacturers have sufficient predictive insights in their machinery and the machinery can be offered to several farmers at similar usage times. The advantage of this model is that it can reduce the farmer's objection to buying expensive equipment and enable a more sustainable usage of PA equipment. The industry could become more efficient in making use of the same machines for different farmers.

- Asset sharing model

The cost of buying expensive farm equipment is a big challenge for farmers. Another concern when buying expensive precision agriculture equipment is whether the farmer will be able to utilize the equipment to its maximum capacity. The objective of this model is to share overcapacities of machinery, equipment or IT resources to either afford high-tech solutions or minimize the trade-off if the ideal size that you need is not available in the market. This business model revolves around selling your extra capacity back into the market. The goal is to maximize the utilization of your IoT product across multiple customers. In that way, each customer pays a reduced price and you are able to get faster market penetration, compared to when a single customer has to pay for your complete product.

CONCLUSION

Digitalization involves the impacts of digital technology in our societies transforming our way of work by converting information from a physical format into Big data. Digital technologies are successfully transforming various industries. For instance, the health sector (through home monitoring of patients using wearables, electronic health records, application of computer aided visualization and decision support systems). Digitalization of agriculture emphasizes on the future of smart farming by the use of digital technologies such as IoT, robotics, Big data and AI in order to efficiently increase productivity. Precision agriculture is a site-specific management strategy that gathers, processes and analyzes farm data to support management decisions for improved resource use, efficiency, productivity, profitability and sustainability of crop production. PA seeks to use new technologies to increase crop yields and profitability while lowering the levels of traditional inputs needed to grow crops; land, water, fertilizer, herbicides and insecticides. Smart farming reduces the environmental impact of farming, increases resilience and soil health and decreases costs for farmers. However, the uptake of new technologies in farming remains below expectations and unevenly spread throughout the EU and in Belgium. This research aimed to find out how all partners in the agriculture value chain can be aligned and engaged in order to move the agricultural industry into adopting precision farming in Belgium.

The study found out that the main challenges affecting adaptation of precision agriculture were not due to the technologies but the business models around the technologies. The challenges associated with smart farming range across various agricultural production systems and infrastructural limitations apply when it comes to IoT implementation. Some of the main challenges are related to farm data ownership, lack of transparency on how data is used or shared therefore affecting trust, data structure & compatibility with other systems, data portability, the cost of adopting PA technologies which is very high and the lack of support from PA technology providers. All these challenges affect farmers perception negatively towards adopting precision agriculture. These challenges can be solved by creating a framework in which farmers, cooperatives, professionals, scientists and the private sector can effectively collaborate and co-create knowledge.

Through digitalization of agriculture, farms are generating huge amounts of data and many software-based systems do their service in the farms. However, farmers get frustrated because they cannot transfer data from the different systems into one platform or personal computers so that proper analysis can be done. Farm data is fragmented and lost because systems do not communicate to each other. The lack of interoperability among systems raises the issue of data ownership and lack of trust. The lack of different systems to integrate forces farmers to be locked-in to one product or software provider no matter the cost associated. For instance, farmers that use John Deere have their farm data collected by sensors mounted on the tractors, stored and accessed at myjohndeere.com cloud. If the farmer is using services from various providers, he cannot integrate data from his John Deere with the other platforms thereby making data fragmented and overall data analysis for better farm decision making incomplete. It is hard to argue whether farm data belongs to the farm owners or to the product and service manufacturers that own sensors which collect data, one thing that’s clear is that all these actors need each other in order to fully benefit from the digitalization of agriculture.

The capacity to create value throughout the agricultural chain and increasing the adaptation of Precision agriculture depends on connectivity of infrastructure. Data infrastructure is the system enabling and governing collection, access and transfer of data in a transparent way, as well as storage and analysis to produce knowledge and drive innovative insights within the agriculture value chain. Precision agriculture solutions require integrated, scalable platforms that are leveraged across products and systems. Actors within the value chain need to come up with solutions that allow interoperability of data. In order for Big Data to be effective in agriculture, models should be put in place that allow data interoperability and farmer driven participation in the data value chain. Both farmers, Agri-industry and agro-ICT companies should collaborate on data rich services inclusive of the farmers interests and not just themselves. Actors within the value chain need to come up with these solutions that allow interoperability of data or else players outside the industry will come up with new solutions that will challenge incumbents. Technology giants such as Amazon and Microsoft are already developing cloud solutions for agriculture data. Governments and regulators also have a role to play by emphasizing the importance of interoperability and setting policies that will enable standardization of data for interoperability.

It is recommended that actors in the value chain create a framework for co-creation with system and data integration as the focal value proposition. This will solve data ownership issues as all participants will benefit from the ecosystem. Farmers are faced with trust issues when it comes to data ownership therefore it is important that a platform to align all participants is developed at a small (for instance in Flanders) and let it scale as it creates value and attracts more participants. The challenge of local platforms is that they scale slowly. It is advised that local platforms collaborate with other platforms (for instance co-creation of local platforms in Belgium and those in the Netherlands) in order to increase participants, network effects and to scale at a European level. A platform scaling at a European level will attract more users than a local platform.

Identifying a suitable business model within the agri-value chain requires continuous discussions among service providers, equipment providers and farmers to find a win-win solution for all the parties involved. This study further tries to find a suitable business model that could create, deliver and capture value to all the stakeholders. Independent agencies should be formed by stakeholders to act as intermediaries among the different actors within the value chain. For instance, I will use Djustconnect as an orchestrator in Belgium. Djustconnect is a unique data sharing platform for advanced data sharing in the Flemish agri-food chain. It is a collaboration between ILVO, AVEVE, Boerenbond, CRV, DGZ and Milcobel. Dustconnect aims to ensure fair and transparent data sharing throughout the value chain and it is centered around the farmers. Farmers produce farm data and all this data is collected on the platform. However, the challenge that Djustconnect faces is finding a suitable way to create value and to monetize the platform. A platform creates value depending on the number of users and network effects and users join a platform when they see benefits. In chapter six, this study identifies a suitable business model that can be used to attract other actors to a platform in order to create value and how to monetize a platform. The first option is monetizing data and sharing it with third party services (marketplace) and the second option is connecting the machines to a specific service (data subscription plan. Value is created on the platform through integration of data from sensors, input by farmers and farm equipment. Loon werkers, who are contracted by farmers who lack machinery could add up their data per job done on the database. Other users who require data or information can be pulled on the platform eventually scaling the platform and increasing value creation. Government publications, latest agriculture innovations and information could also be published on the platform in order to attract more users.

The cost of operating a platform largely depends on two factors; the amount of data storage needed, and the amount of computing power needed for analysis. The amount of storage needed depends on the amount of data that the platform holds, which is partially depending on the number of users of the platform as well as the amount of data per user which is uploaded. Data structure and availability (immediately or with a delay) also plays a role in the data storage cost. All these costs do not incorporate the development and maintenance of the platform. Many platforms fail because they can’t create value due to lack of network effects and money to run the platform. Therefore, it is important to identify the revenue streams on business models. The platform can be monetized by letting one part pay for accessing information for the other side. Data can also be accessible to external users for instance, start-ups, research centers or universities for free on conditions that participants within the ecosystem benefit from the results or external users can be charged to access high quality data. Adds can be placed on the platform for instance, contractors advertising their services, start-ups advertising their new technologies, farmers advertising their products or farmland for lease or any other transaction that happens within the agri-food value chain. Advertisements and fees charged on external users (pay per view for data) can be a revenue model for the platform. Further study is however needed to determine how this ecosystem can be developed to align all the participants, to allow interoperability among systems and to determine whether a sustainable business case can be achieved in practice.

BIBLIOGRAPHY

Adner, Ron. (2016). Ecosystem as Structure: An Actionable Construct for Strategy. Journal of Management. 43. 10.1177/0149206316678451.

Archer, P. (2017). Six Challenges for Agriculture » Big Data Europe. [online] Big-data-europe.eu. Available at: https://www.big-data-europe.eu/six-challenges-for-agriculture/.

Aubert, Benoit & Schroeder, Andreas & Grimaudo, Jonathan. (2012). IT as enabler of sustainable farming: An empirical analysis of farmers' adoption decision of precision agriculture technology. Decision Support Systems. 54. 510–520. 10.1016/j.dss.2012.07.002.

B. Basso, M. Bertocco, L. Sartori, E.C. Martin. (2007). Analyzing the effects of climate variability on spatial pattern of yield in a maize-wheat-soybean rotation. Eur. J. Agron, 26: 82-91, 2007

B. Koch, R. Khosla, W.M. Frasier, D.G. Westfal, D. Inman. (2004). Economic feasibility of variable-rate nitrogen application utilizing site-specific management zones., Agron. J, 96: 1572-1580

Berlin, A., Verstegen, J., Choucair, N. and Aguado, R., 2020. *Iof2020- Internet Of Food And Farm 2020,* D4.9 IOF2020 Use Case Business Models. 4th ed. IoF2020_WP4_Deliverable_4.9_Business_models_M24_Final.docx.

C.J. MacGregor, C.R. Warren. (2006). Adopting sustainable farm management practices within a Nitrate Vulnerable Zone in Scotland: The view from the farm. Agr. Ecosyst. Environ, 113: 108-119, 2006

Coble, K., Mishra, A., Ferrell, S. and Griffin, T. (2018). Big Data in Agriculture: A Challenge for the Future. Applied Economic Perspectives and Policy, 40(1), pp.79-96.

Copa-cogeca.eu. (2018). [online] Available at: https://copa-cogeca.eu/img/user/files/EU%20CODE/EU_Code_2018_web_version.pdf.

D.S. Long, R.E. Engel, G.R. Carlson. (2000). Method for Precision Nitrogen Management in Spring Wheat: II. Implementation.,Precis. Agric, 2: 25-38,

David Christian Rose, Jason Chilvers. (2018). Agriculture 4.0: Broadening Responsible Innovation in an Era of Smart Farming**.** Frontiers in Sustainable Food Systems, 2018; 2 DOI: 10.3389/fsufs.2018.00087

De Clercq, M., Vats, A. and Biel, A. (2018). AGRICULTURE 4.0: The Future of Farming Technology. [online] Worldgovernmentsummit.org. Available at: https://www.worldgovernmentsummit.org/api/publications/document?id=95df8ac4-e97c-6578-b2f8-ff0000a7ddb6.

Ec.europa.eu. (2018). Shaping the digital (r)evolution in agriculture. [online] Available at: https://ec.europa.eu/eip/agriculture/sites/agrieip/files/eipagri_brochure_digital_revolution_2018_en_web.pdf.

Ec.europa.eu. (2019). [online] Available at: https://ec.europa.eu/eip/agriculture/sites/agri-eip/files/eip-agri_seminar_digital_strategies_final_report_2019_en.pdf.

Ecpa.eu. 2020. [online] Available at: <https://www.ecpa.eu/sites/default/files/documents/AgriDataSharingCoC_2018.pdf> [Accessed 21 May 2020].

Gault, M. (2020). Farmers Are Buying 40-Year-Old Tractors Because They're Actually Repairable. [online] Vice. Available at: https://www.vice.com/en_us/article/bvgx9w/farmers-are-buying-40-year-old-tractors-because-theyre-actually-repairable

Ge, L. and Bogaardt, M. (2015). Bites into The Bits: Governance Of Data Harvesting Initiatives In Agrifood Chains. [online] Library.wur.nl. Available at: <https://library.wur.nl/WebQuery/wurpubs/496505>

Giesler, S. (2018). [online] Biooekonomie-bw.de. Available at: https://www.biooekonomie-bw.de/en/articles/dossiers/digitisation-in-agriculture-from-precision-farming-to-farming-40.

Hammerschimdt, C. (2016). Open software platform to connect agricultural machines and IT systems. [online] Smart2.0. Available at: https://www.smart2zero.com/news/open-software-platform-connect-agricultural-machines-and-it-systems.

Horizon 2020 - European Commission. (2016). Final paper on a strategic approach to EU agricultural research and innovation - Horizon 2020 - European Commission. [online] Available at: https://ec.europa.eu/programmes/horizon2020/en/news/final-paper-strategic-approach-eu-agricultural-research-and-innovation.

Hunt, J. (2016). Step-by-step guide to planting maize - Farmers Weekly. [online] Farmers Weekly. Available at: https://www.fwi.co.uk/livestock/step-step-guide-planting-maize.

I. Mouratiadou, G. Russell, C. Topp, K. Louhichi, D. Moran. (2010). Modelling common agricultural policy–Water Framework Directive interactions and cost-effectiveness of measures to reduce nitrogen pollution. Water Sci. Technol, 61: 2689-2697

I.A.T. Hashem, I. Yaqoob, N.B. Anuar, S. Mokhtar, A. Gani, S. Ullah Khan. (2015). The rise of “Big Data” on cloud computing: Review and open research issues. Inf. Syst., 47 (2015), pp. 98-115

Jacobides, Michael G., Cennamo, C., Gawer, A. (2018). Towards a theory of ecosystems. Strategy. Manag.J. https://doi.org/10.1002/smj.2904

Järvihaavisto, Ulriikka & Riitta, Smeds. (2018). From Technology Platform to Innovation Ecosystem. Academy of Management Proceedings. 2018. 17531. 10.5465/AMBPP.2018.17531abstract.

Keith H Coble, Ashok K Mishra, Shannon Ferrell, Terry Griffin. (2018). Big Data in Agriculture: A Challenge for the Future, Applied Economic Perspectives and Policy, Volume 40, Issue 1, March 2018, Pages 79–96

Kielbasa, B. (2015). Tracking the actors of innovation in agriculture - Horizon 2020 - European Commission. [online] Horizon 2020 - European Commission. Available at: https://ec.europa.eu/programmes/horizon2020/en/news/tracking-actors-innovation-agriculture.

Konietzko, Jan & Bocken, Nancy & Hultink, Erik. (2020). Circular Ecosystem Innovation: An Initial Set of Principles. Journal of Cleaner Production. 253. 119942. 10.1016/j.jclepro.2019.119942.

Lv.vlaanderen.be. (2019). Challenges for Flemish Agriculture And Horticulture. [online] Available at: https://lv.vlaanderen.be/sites/default/files/attachments/gr_201807_lara2018_samenvatting_eng_def_0.pdf.

McBratney, A., Whelan, B., Ancev, T. et al. (2015). Future Directions of Precision Agriculture. Precision Agric **6,** 7–23 (2005). https://doi.org/10.1007/s11119-005-0681-8

Mcbratney, Alex & Whelan, B. & Ancev, Tiho & Bouma, Johan. (2005). Future Directions of Precision Agriculture. Precision Agriculture. 6. 7-23. 10.1007/s11119-005-0681-8.

N. Tremblay, Z. Wang, B.-L. Ma, C. Bélec, P. Vigneault. (2009). A comparison of crop data measured by two commercial sensors for variable-rate nitrogen application., Precis. Agric, 10: 145-161,

Nash, E., Dreger, F., Schwarz, J., Bill, R. and Werner, A. (2009). Development of a model of data-flows for precision agriculture based on a collaborative research project. Computers and Electronics in Agriculture, 66(1), pp.25-37.

Oerke, E.-C. (2006). Crop Losses to Pests. The Journal of Agricultural Science. 144. 31 - 43. 10.1017/S0021859605005708.

Parker, G., Alstyne, M. V., & Choudary, S. P. (2017). Platform revolution: how networked markets are transforming the economy and how to make them work for you. New York: W.W. Norton & Company.

R. Casa, S. Pascucci, A. Palombo, S. Pignatti. (2010). Soil texture and organic matter estimation of an agricultural field from hyperspectral remote sensing., Proc. 4th Global Workshop on Digital Soil Mapping, Roma, Italy

Rogers, N. (2014). What Is Precision Agriculture? [online] Sustainableamerica.org. Available at: https://sustainableamerica.org/blog/what-is-precision-agriculture/

Roland B. Focus. (2019). Farming 4.0: How precision agriculture might save the world Precision farming improves farmer livelihoods and ensures sustainable food production.

Saunders M, Lewis P, Thornhill A. (2009). Research Methods for Business Student. 5th ed. Edinburg Gate: Pearson Education Limited.

Smets, G. and Rüdelsheim, P. (2011). Baseline information on agricultural practices in the EU Maize (Zea mays L.). New Biotechnology.

Turner, P. (2017). Can Big-Data Deliver Big-Returns for Agriculture? [online] Medium. Available at: https://towardsdatascience.com/can-big-data-deliver-big-returns-for-agriculture-8800d31440a.

Van Bogaert, T., Jannsens, R. and Maertens, E. (2018). Adoption of precision farming by Flemish farmers. [online] Departement Landbouw & Visserij. Available at: https://lv.vlaanderen.be/nl/voorlichting-info/publicaties-cijfers/studies/report-summaries/adoption-precision-farming-flemish.

Vib.be. (2017). New plant research leads to the discovery of a gene that significantly increases seed yield in maize. [online] Available at: http://www.vib.be/en/news/Pages/New-plant-research-leads-to-the-discovery-of-a-gene-that-significantly-increases-seed-yield-in-maize.aspx.

Wolfert, S., Ge, L., Verdouw, C. and Bogaardt, M. (2017). Big Data in Smart Farming – A review. Agricultural Systems, 153, pp.69-80.

Www3.weforum.org. (2016). Building Partnerships for Sustainable Agriculture and Food Security- A Guide to Country-Led Action. [online] Available at: http://www3.weforum.org/docs/IP/2016/NVA/NVAGuidetoCountryLevelAction.pdf.

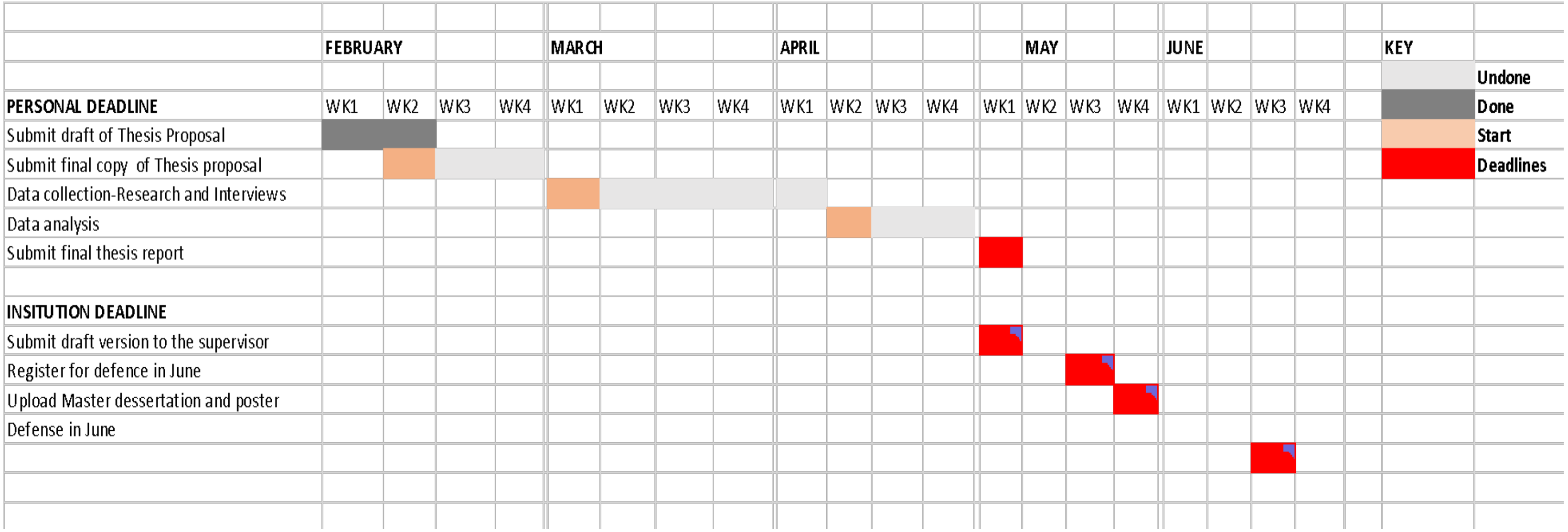
APPENDICES

Appendix 1: List of figures

Appendix 2: Acronyms

PA	Precision Agriculture
PAT	Precision Agriculture Technologies
AI	Artificial Intelligence
GNSS	Global Navigation Satellite System
IoT	Internet of Things
AAPs	Applications
API	Automated Programing Interface
ILVO	Institute of Agriculture, Fisheries and Food in Flanders
N	Nitrogen
CAP	Common Agricultural Policy

Appendix 3: Research Timeline



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