Leveraging Smart Farming Technologies for Enhanced Agricultural Production

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Abstract

Title: Leveraging Smart Farming Technologies for Enhanced Agricultural Production.

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Keywords: Agricultural Innovation, Precision Agriculture (PA), Smart Farming (SF), Internet of Things (IoT), Machine to Machine (M2M), Cloud Computing, Big Data, Artificial Intelligence (AI), Automation, Robotics, Autonomous Driving, Diffusion of Innovations, Resource-Based View (RBV), Maslow's Hierarchy of Needs, SWOT Analysis, Technology Adoption, Data Security, Financial Barriers, Maturity Model Analysis, Environmental Impact

Precision agriculture and smart farming technologies offer significant potential to enhance agricultural productivity and sustainability in Germany. The central issues covered within this thesis are an analysis of the main drivers that contribute to agricultural innovation and a particular look at the determinants influencing technology adoption decision-making among contemporary German agriculturists.

Drawing on a comprehensive literature review, a survey of different farmers and interviews with agricultural professionals, this mixed-methods approach was executed. The data analysis based on the diffusion of innovation theory, the technology acceptance model, resource-based view and SWOT analysis additional to the Maturity Model which compared the results from the PWC results to this survey results.

Major findings include financial barriers such as the upfront costs for new technologies and doubt on how to recover them. Concerns such as technical complexity and data security also mitigate adoption. For instance, innovation can be expedited by policy incentives and subsidies, which often fall short of motivation. Knowledge exchange emerges as crucial for aiding adoption, but German bureaucratical barriers are persistent regarding foreign advancements.

This study is an attempt to bring in more clarity to the multifaceted sphere of innovation processes in German agriculture. The nature of priority areas, such as cost reduction and improved training, are emphasized for stakeholders aimed at promoting adoption in digital-forward productivity technologies. Ultimately, overcoming barriers and realizing the promise of precision agriculture requires a multidimensional strategy.

Sumário

Título: Aproveitamento de tecnologias agrícolas inteligentes para uma melhor produção agrícola

Autor: Caspar von Guionneau

Palavras-chave: Inovação Agrícola, Agricultura de Precisão (AP), Agricultura Inteligente (SF), Internet das Coisas (IoT), Máquina a Máquina (M2M), Computação em Nuvem, Big Data, Inteligência Artificial (IA), Automação, Robótica, Condução Autónoma, Difusão de Inovações, Visão Baseada em Recursos (RBV), Hierarquia de Necessidades de Maslow, Análise SWOT, Adoção de Tecnologia, Segurança de Dados, Barreiras Financeiras, Análise do Modelo de Maturidade, Impacto Ambiental

A agricultura de precisão e as tecnologias de agricultura inteligente oferecem um potencial significativo para melhorar a produtividade e a sustentabilidade agrícola na Alemanha. As questões centrais abordadas nesta tese são uma análise dos principais fatores que contribuem para a inovação agrícola e um olhar particular sobre os determinantes que influenciam a tomada de decisão na adoção de tecnologias entre os agricultores contemporâneos alemães. Baseando-se em uma revisão abrangente da literatura, uma pesquisa com diferentes agricultores e entrevistas com profissionais da agricultura, esta abordagem de métodos mistos foi executada. A análise de dados baseou-se na teoria da difusão da inovação, no modelo de aceitação de tecnologia, na visão baseada em recursos e na análise SWOT, além do Modelo de Maturidade que comparou os resultados da pesquisa da PWC com os resultados desta pesquisa. Os principais achados incluem barreiras financeiras, como os custos iniciais para novas tecnologias e dúvidas sobre como recuperá-los. Preocupações como complexidade técnica e segurança de dados também mitigam a adoção. Por exemplo, a inovação pode ser acelerada por incentivos políticos e subsídios, que muitas vezes são insuficientes para motivar. A troca de conhecimento surge como crucial para auxiliar na adoção, mas as barreiras burocráticas alemãs são persistentes em relação aos avanços estrangeiros. Este estudo é uma tentativa de trazer mais clareza ao campo multifacetado dos processos de inovação na agricultura alemã. A natureza das áreas prioritárias, como a redução de custos e o aprimoramento do treinamento, são enfatizadas para as partes interessadas visando promover a adoção de tecnologias produtivas com foco digital. Em última análise, superar as barreiras e realizar a promessa da agricultura de precisão requer uma estratégia multidimensional.

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List of Abbreviations

AI	Artificial Intelligence
AgTech	Agricultural Technology
GDP	Gross domestic product
GHG	Greenhouse Gas
GIS	Geographic Information System
GPS	Global Positioning System
IoT	Internet of Things
LED	Light Emitting Diode
PA	Precision farming
PWC	Price Waterhouse Coopers
R&D	Research and Development
ROI	Return on Investment
SF	Smart farming

1 Introduction

Agriculture in Germany is historically a key sector that supports the economy through substantial GDP growth and much employment for a greater part of the country's populations. Nevertheless, the 21st century comes with its own challenges affecting the sector such as climate change, population growth and demand for sustainability. In this light, agricultural innovation is essential to address these challenges. This thesis sets out to study the fundamentals of agricultural innovation in Germany, investigating the determinants that influence adoption and implementation of emerging technologies.

The concept of innovation in agriculture is broad and includes crop and livestock management, digital technology applications, and sustainable farming. While the benefits of such innovation are apparent, the forces that promote or prevent its adoption remain poorly defined. This thesis will also address a wide range of accompanying issues, utilizing various data sources and analytic methods for taking a comprehensive look at where Germany's agricultural innovation now stands.

The research will be guided by the following Research Question: **What are the major determinants of agricultural innovation in Germany today?** To respond to this question the thesis will rely on a variety of databanks that will include, academic literature, industry reports, primary data collected in surveys and interviews with farmers and agricultural advisors. A number of theoretical frameworks will be used to underpin the analysis, such as innovation diffusion theory, Resource based view, Maslow´s hierarchy of needs and SWOT analysis.

The research will provide crucial knowledge to policy makers, industry stakeholders and researchers. The study will identify the main determinants of agricultural innovation and, as a result, yield ideas on stimulating progressive practice in farming hence aiding to enhance sustainable and productive farming methods. In addition, the research will make it possible to see where policy measures could be applied to promote adoption of new technologies and practices by revealing the barriers for innovation.

2 Agriculture Industry

Agriculture is a large and diverse sector that includes various activities ranging from organic-growing local farmers to the large-scale enterprises producing grain or livestock for international trade (Biering, 2023). Many companies sell equipment for the agricultural sector, from basic plows to advanced harvesting combines (Biering, 2023). The efficiency of food production is underpinned by this extensive network of manufacturers, producers, and intermediaries (Biering, 2023).

Agriculture accounts for almost 4% of global GDP. In several underdeveloped countries, the informal agricultural sector may account for more than a quarter of GDP. Furthermore agriculture is two to four times more effective for raising incomes of economically disadvantaged individuals than other sectors. Consumer tastes and preferences are changing, raising the demand for higher quality food. Hence, there is increasing investment to improve productivity by deploying new technologies (Syngenta, n.pag).

The future of agriculture is currently shaped by a number of major tech-related trends. Research shows that emerging themes for 2023 are biotechnology, water management, vertical farming and data-driven decision making. The sector is also grappling with problems over rising input forces and lack of labour (Syngenta, n.pag).

Digitalization therefore represents a key transformation in agriculture. Advances include robotic systems, temperature and moisture sensors, and aerial imagery with GPS technology (Oliver Wyman, n.d.). Applications related to high-tech precision agriculture and robotics will modernize farming to enhance profitability, efficiency, and environmental safety (Oliver Wyman n. d.).

2.1 Precision Agriculture (PA)

The term "Precision agriculture" became prevalent in agricultural discourse in the 90s. It refers to digital techniques applied to manage different aspects of farming. Common forms of precision agriculture include Precision Crop Farming, Specific Area Agriculture or Precision farming (*DLG-Merkblatt 447 Digitalisierung in Der Landwirtschaft*, 2019a).

PA focuses on the targeted use of technology in crop cultivation. To implement this, farmers need detailed information about the soil. This data is acquired through soil sampling and lab tests using drones, sensors, and satellites to gather information (Sishodia et al., n.d.). Thus, PA relies on location-specific data to allow farmers to more effectively cultivate land with the goal of optimizing production conditions such as the nutrient content in the soil along with calibrating the amount of pesticides or fertilizers needed (Maffezzoli et al., 2022).

This leads to more efficient use of resources and cost savings compared to traditional methods. At the same time, PA promotes a more environmentally friendly approach. PA was first used for fertiliser application based on soil conditions. Agriculture 4.0 came into being to advance precision farming, facilitated by gathering and analysing data from fields, equipment sensors, and other external sources (Maffezzoli et al., 2022).

However, digital technologies' adoption has lately intensified in Germany's agriculture with would-be adoption rates of about 15-20% within the next five years for "barn robotics," "section control" as well as variable-rate applications and maps from satellite data (Gabriel & Gandorfer, 2023).

This is part of the country's aggressive climate goals aimed at achieving carbon neutrality by 2045 in which for instance the agricultural sector is set to play a major role (Martyniuk & Khodakivska, 2022).

Moreover, precision farming technologies have been tested in small-scale farming and prove to be very promising at this point. Additionally, such findings are of a particular relevance for Germany that experiences the predominance of small- and medium-sized farms (Erasmi & Kappas, 2021). Coupled with, efficient production and lower environment costs by small farmers. In addition, precision farming encourages the use of field-specific management approaches that optimize resource utilization and reduce the danger of environmental pollution (Prause, 2021).

2.2 Smart Farming (SF)

SF is related to PA and includes automatic steering systems for agricultural machines and implements, especially for self-propelled machinery and processes (Shaikh et al., 2022). Precision farming is a predecessor strategy that involves the use of big data and cloud computing in maximizing farming practice while Smart agriculture is a more evolved precision method that combines big data, artificial intelligence, and cloud computing to improve its practices (Nurcahyo et al., 2023). Smart farming incorporates computerized assistance which maximizes the working parameters as well as obtains qualitative indices of lifting, comfort and safety in the course of increased work for a user with low fuel consumption and labour force but low negative impact on environment (ILIE, 2019).

Various terms describe the digitalization phenomenon in agriculture including Precision (Livestock) Farming, Smart Agriculture; Smart (Livestock) Farming Digital Farming; Farming 4.0 and Agriculture 4.0 (*DLG-Merkblatt 447 Digitalisierung in Der Landwirtschaft*, 2019a); Smart Livestock Farming Potential of Digitalization for Global Meat Supply n.d.). In April 2021, the Federal Ministry of Food and Agriculture announced that Germany is one of the leading countries in the world for modern agro technologies (BMEL - Gesetze Und Verordnungen - Rechtsgrundlagen Des BMEL p.18).

2.2.1 Internet of things (IoT) / Machine to Machine (M2M)

The Internet of Things (IoT) refers to an extensive information technology infrastructure enabling automatic communication as well as networking of real and virtual objects. Incorporating data storage capabilities into an IoT network requires ongoing data to support queries which may require access to older site data. Data have to be stored in defined formats for intelligibility and readability in the future (*DLG-Merkblatt 447 Digitalisierung in Der Landwirtschaft*, 2019b).

One notable application of IoT and Machine-to-Machine (M2M) technologies is collecting and storing comprehensive crop data which helps farmers track trends and make comparative analyses of growing patterns (Misra et al., 2022). Another use of IoT and Machine-to-Machine (M2M) technologies is weather data management for particular locations including forecasts by Misra et al. (2022). This data helps farmers determine appropriate planting times, crop varieties, and harvesting and irrigation management (Misra et al., 2022)(Mathan, 2020).

Wireless sensor networks (WSNs) are important in IoT for measuring and processing environmental factors such as soil moisture, temperature, humidity, water pH and wind speed. WSNs comprise multiple nodes with sensing, communication, and computational capabilities, making them ideal for agricultural and greenhouse environment monitoring (Misra et al., 2022).

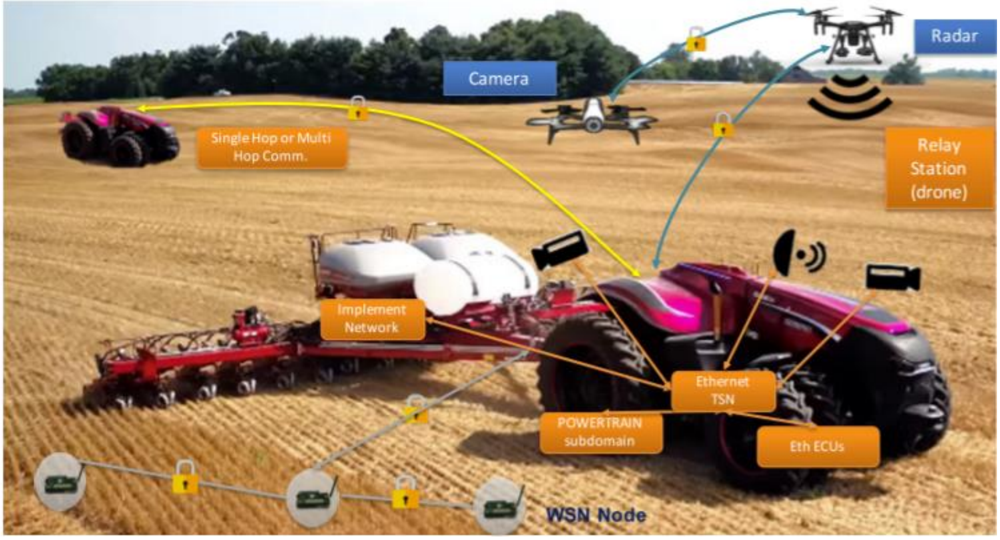

Figure 1: (Bacco et al., n.d.) A real-time, high-throughput, and multi-hop M2M/IoZT wireless communication

To illustrate what is already technologically possible: The tractor no longer has a driver's cabin and is controlled by the farmer sitting at home. The farmer assigns a task to the tractor, which has all the field boundaries stored, allowing it to execute the specific task with the appropriate machinery. The machine is connected to the tractor via an ISOBUS connector. Both the tractor and the attached machinery are equipped with cameras and sensors that send a command to the onboard computer every 2 seconds, which then adjusts the machine or checks if the settings are still correct. Driving is supported by an RTK system. Additionally, the machine can communicate with other operational devices on the farm to optimize its work. This leads us to the next topic.

2.2.2 Cloud Computing

Cloud computing supports the aggregation, analysis, and storage of large amounts of agricultural data which can be accessed remotely to inform decisions (Ees, 2023; Mathan, 2020). This data can also be used for monitoring growth and comparing crop yields with prior trends (Mathan, 2020). Cloud computing also helps farmers to sell directly to consumers or retailers cutting out intermediaries (Ees, 2023), (Mathan, 2020).

Despite obvious benefits, cloud computing and other forms of digitalization have barriers to adoption. Rural farmers are often computer illiterate (Satej & Suresh) and the costs of turning to cloud solutions is a hindrance for small scale farmers. In addition, lack of adequate internet services in most rural regions adversely affects effective implementation (Faster Internet Needed for German Farmers, 2018).

2.2.3 Big Data / Artificial Intelligence

A substantial area of research and development is big data and artificial intelligence (AI). Big data refers to extensive datasets that can be analysed using computational methods to extract patterns, trends and relationships, especially concerning human behaviour and interactions (Rakesh & Ramesh, 2021).

AI strives to give software the ability to scrutinize its environment through a set of identifiable standard rules and search methods, or machine learning models that can detect patterns (Rakesh & Ramesh, 2021). Big data and AI can also help with crop data management, soil data and analysing yields and land use to improve decision-making and resource allocation (Rakesh & Ramesh, 2021).

2.2.4 Automation / Robotics

Automation of processes in crop agriculture is an emerging area where the market for automation and robotics systems in agricultural applications is expected to grow to USD 20.6 billion by the year 2025 (Mahmud et al., 2020). The need to raise the productivity and quality of agricultural products are important factors driving this growth. The automation of agricultural processes can be divided into four main categories: seeding, checking, spraying and collection (Mahmud et al., 2020).

2.2.4.1 Planting

Seed uniformity and detection are the aspects of automation in planting. For example, researchers have developed systems that employ Infrared Light Emitting Diodes (IR LEDs) and photodiodes to calculate sowing rates for different seeds e.g., chickpea, wheat, and alfalfa. The output voltage of the light-receiving sensor is converted into a value, which is brought to a model that calculates the sowing rate. Previous in-situ studies also suggested that sensing-based images can provide reliable information on successful sowing rates for maize, which will be a further step to define suitable precision algorithms for optimized planting processes (Mahmud et al., 2020).

The Danish Institute of Agricultural Science also has a system called the Autonomous Plant Inspection (API) Research Platform. It has the capability to perform operations, spraying, sensing and weeding using a real-time global positioning system. It also provides “weed maps” that direct how to spray herbicides more accurately to account for weed shapes and sizes (Mahmud et al., 2020; Tejaswi, n.d.).

2.2.4.2 Inspection

Agricultural inspection refers to examining plants for diseases or quality problems. Automation removes inefficiencies associated with manual inspection. An autonomous inspection camera is usually either stationary, mounted on a mobile robot platform or placed on a drone. This makes disease prevention and quality checking more precise (Mahmud et al., 2020).

2.2.4.3 Spraying

Automation protects farmers from risky chemicals used in production and spraying operations. Research is still ongoing to develop autonomous systems to help farmers control plant diseases and insect damage (Mahmud et al., 2020; Tejaswi, n.d.).

2.2.4.4 Harvesting

Over the past decades there has been active development of autonomous harvesting systems. The goal is to improve the efficacy of robotic and automation applications in the harvest process, making them similar to or better than manual harvesting (Mahmud et al., 2020).

2.3 Autonomous Driving

John Deere and Case IH Yanmar, major producers of agricultural machinery, have made significant progress in autonomous driving technology. There are more than twenty international projects at present (Han et al., n.d.).

John Deere has an automated system called “Auto Trac Controller” that uses laser scanners that can be adapted to other manufacturer’s tractors (Haverkamp et al., 2013). Case IH uses an autonomous tractor which is equipped with cameras and sensors that can be remotely navigated with a tablet (Pitfalls et al., n.d.).

Yanmar’s self-navigating “Robot Tractor” uses an inertial measurement unit (IMU) and a real-time kinematic (RTK) module from a GNSS system for precision autonomous control (Woods, 2022). The NHDrive autonomous tractor from New Holland employs radar, light detection and ranging (LiDAR) to detect obstacles. The highest inaccuracy in these systems was below 30 cm as reported by Mohr and Kühl (2020)

Agriculture is hampered by an ageing labour force and a lack of skilled workers. This has propelled automation and mechanization aimed at enhancing efficiency and lowering costs. The advent of autonomous agricultural vehicles has been fast-tracked by developments in sensor technology and ICT (Han et al., n.d.).

2.4 Status Quo PWC

The study "Smart Farming: “Digitalisierung in der deutschen Landwirtschaft – Nachhaltigkeit und Effizienz durch den Einsatz digitaler Technologien” details the current status of digitalisation in German agriculture. It shows the prospects of technological change in agriculture and provides for farmers, politicians, society cooperate to face the challenges (PricewaterhouseCoopers, 2016).

Subjects of Precision and Smart Farming have already been dealt with amongst 33% of the typed possibilities. Nevertheless, just 50% are readily informed. Where farmers mostly get their information includes trade journals, internet and speaking with friends (PricewaterhouseCoopers, 2016).

Over 60% of the farms have adopted digital technologies and more than half, that is 62% of these investments, were made in the last four years. The investment ratio is cost of stocks divided by annual turnover and it amounts to 10% on average, which is relatively large as compared for other industries. In addition, 60% of the farmers surveyed who were invested in planning to continue at that rate or level of investment while 28% said they had plans on increasing their investments (PricewaterhouseCoopers, 2016).

Intelligent agricultural machinery is widely adopted, in particular more than of halves (53%) of the respondents already using or intending to use these machines. Such machines enhance efficiency as well as sustainability, by using resources – energy, water, fertilizers and plant protection products and labor optimally. The bigger the area of cultivation, the more benefits are derived from these machines (PricewaterhouseCoopers, 2016).

For example, arable farming has adopted the use of GPS technologies. In particular, they enable precision farming where information technology is used to ensure that the crops and soil receive precisely what is required for optimal health and productivity (PricewaterhouseCoopers, 2016).

Only one in three of the arable farms surveyed currently use Farm-Management-Software. Approximately 50% of the farmers deploy smart agricultural machinery to maximize their usage. These includes the use of drones or robots (PricewaterhouseCoopers, 2016).

For 76%, the high acquisition costs represent the greatest obstacle to their usage in Precision/Smart Farming. Besides, every second farmer does not know whether an investment in the required equipment is reproductive (PricewaterhouseCoopers, 2016).

This study therefore brings out the realization that these digital technologies are not just hype in agriculture but have become “evidence of routine and Workaday Matters” and have ‘turned daily work’ within arable farms. As noted, they play an important role in advancing efficiency of operational procedures and staff allocation. However, there are non-economic aspects, which contribute to the digitalization transition as well. Responsible handling of natural resources is necessary based on legal regulations such as the Fertilizer Ordinance and cultural landscape programs (PricewaterhouseCoopers, 2016).

2.5 Diffusion of Innovations

Everett Rogers formalized this theory in his book; *Diffusion of Innovations* (1962). It presents a number of general notions about the ordinary diffusions of innovations in a social system (Orr, 2010). Such practices are often employed in finding out how emerging ideas, customs, or items take root and circulate through different cultures or societies (Jankovic, 2005).

According to Rogers, adopters of any new innovation or idea can be categorized into five groups based on a normal distribution: They include innovators (2.5%), early adopters (13.5%), early majority (34%), late majority (34%) and laggards (16%) (Marrone, 2013; Scheuer, 2021). The awareness, interest, evaluation, trial and adoption (AIE T- A) of each adopter on the willingness and ability to adopt an innovation (Marrone, 2013; Scheuer, 2021).

The theory also incorporates the tipping point notion, whereby a trend crosses into exponential growth. This points out the homogeneity such that any positive change will easily promote other changes in a social system (Orr, 2010).

The theory of diffusion of innovations has been widely used across different sectors that include public health (Moseley, 2004), rural development (Jankovic, 2005), technology adoption in education (Webster, 2011) and the spread on autonomous vehicles (Umberger, 2016). It has been used to characterize and elaborate the conditions indicating that an innovation is likely to hit the high-point tipping, or develop our abilities for effective directed action aimed at accelerating it (Orr, 2010).

2.6 Resource Based View (RBV)

Resource-Based View (RBV) is one of the leading frameworks which argue that resources and capabilities are at the heart of a firm’s strategy and source of its competitive advantage. The third approach to RBV which is over 20 years old and has been adopted widely and criticized heavily (Chatterjee et al., 2023).

RBV considers firm as a set of resources and capabilities. Resources can be physical (also financial) and intangible which include firm's reputation, skills and experiences, organizational procedures, employee's knowledge; brand name. However, capabilities refer to how a firm uses its resources to achieve an end (Gisip & Harun, 2013).

According to the RBV, firms can attain sustainable competitive advantage through valuable, rare, inimitable and non-substitutable (VRIN) resources and capabilities (Bhyrovabhotla, 2012). They should be firm-specific resources and capabilities associated with its performance (Bhyrovabhotla, 2012).

The RBV has been actuated in different areas. In Thailand, this is demonstrated in an analysis of university business incubators (UBIs), which has identified enabling factors as human, technological, financial and organizational resources (Somsuk et al., 2012). Another study on UK retailing used the framework to analyze competitive advantage in this sector and linked strategic adaptive capabilities to key resources (Canagasuriam, 2002).

The RBV in regards to brand management suggests that increased attention should be paid on internal factors for the better performance of a brand. The model of antecedents and consequences of brand management grounded on the RBV cites top management emphasis on brand, corporate supportive resources, market orientation as key internal enablers for successful execution of the concept (Gisip & Harun, 2013).

To sum up, although it has been criticized for being circular and tautological, the RBV is a strategic management tool for focusing on how firms' resources and capabilities provide for sustainable competitive advantages. It has been used in different spheres and states thus showing the main new information contributing to the success of a firm (Lockett et al., 2009; Priem & Butler, 2001)

2.7 Maslow´s Hierarchy of Needs

Maslow's Hierarchy of Needs is one of the psychological frameworks from Abraham Maslow in his 1943 paper, "A Theory of Human Motivation". According to this, people have a hierarchical set of needs that build upon each other. It is usually represented as a pyramid, with the most rudimentary needs at the base and culminating in more sophisticated wants (Pariyatman et al., 2022).The physiological needs are at the pyramid base and they mean survival to be guaranteed. Such needs include need for food, water, sleep and warmth. No other need is satisfied until these needs are met by the individuals. The fussiness level above is the need for safety and security. After physiological needs are satisfied, people seek physical safety. This middle level of pyramid stands for belongs and love. It involves the need for interpersonal relationships, friendships, family and community (Pariyatman et al., 2022). The esteem also called ego and it includes the self, which is pride and satisfaction with oneself an achievement as well as knowledge. These involve their need of being acknowledged, esteemed, recognized and accomplished (Pariyatman et al., 2022).

Figure 2: (Hopper, 2020) Maslow´s hierarchy of needs

The apex is self-actualization, which implies the necessity of self-fulfillment and growth. This is the ultimate form of psychological development and identity realization. It is worth mentioning that Maslow’s Hierarchy of Needs does not provide strict order (Pariyatman et al., 2022). Several needs may be experienced and paid attention to in different orders, where the stages interact. Moreover, not everyone attains the pinnacle of self-actualization since it includes fulfilment of lower-level needs as well as personal expansion and revelation (Jerome, 2013).

Maslow’s Hierarchy of Needs has found its way into a number of fields including psychology and business among other to comprehend why people behave the way they do. For example, it has been applied in addressing the motivations for adopting particular technologies and to assess conflict resolution. Despite its critics and limitations, it continues to be one of the most acknowledged and influential theories of human motivation (Jerome, 2013).

2.8 SWOT Analysis

Businesses utilize SWOT Analysis as a strategic planning instrument to reveal the Strengths, Weaknesses, Opportunities and Threats. This helps in scrutinizing an organization's internal and external environments, allowing it to build on strengths, remedy weaknesses, seize opportunities and cushion against threats (Benoit, 2012).

Internal environment includes strengths and weaknesses as factors within the control of an organization. Strengths are resources and capabilities that give an organization an upper hand over its rivals, while weaknesses are areas in which the organization may be disadvantaged (Benoit, 2012).

However, opportunities and threats are external forces that result from the environment in which an organization operates. In the external environment opportunities are defined as favouring conditions which an organization can utilize to its benefits while threats are seen as unfavourable conditions which could potentially harm the organization (Benoit, 2012).

The SWOT Analysis in Different Contexts. It has, for example, been used in developing business strategies for a coffee shop in Pekan Baru and identifying the weak points of the model (Musfar et al., 2022). Utilization of this instrument has also been done to develop strategies for channeling regional development planning services in Payakumbuh City and for formulating business strategies in a color crackers industry, Indonesia (Budiman et al., 2018).

Such a SWOT Analysis was conducted on the Kurdistan Regional Government in the work of government readiness for identifying weaknesses and strengths as well as opportunities for development (Abdulla & Sherwani, 2017). Also, it was used in developing marketing plans for firms thus enabling such companies to learn opportunities available in the market as well as threats that may exist together with their strengths and weaknesses (Yu-quan, 2001).

In summary, SWOT Analysis is useful or the strategic planning particularly in helping organizations to understand their internal and external environments and develop effective strategies from this understanding.

3 Methodology

The following chapter details the research methodology, including the research design and the data collection.

3.1 Research Design

The main aim of this section is to elaborate the research method used in this dissertation. It is a qualitive scientific research method called systematic literature analysis. This thesis draws upon the review of the literature. This literature review focuses on the importance of digitization in agriculture, its construction within agricultural sector and possible digital vision. This paper will gather information from both the primary and secondary sources. The interviews are the main source. Secondary sources include relevant journals for the literature, and survey results.

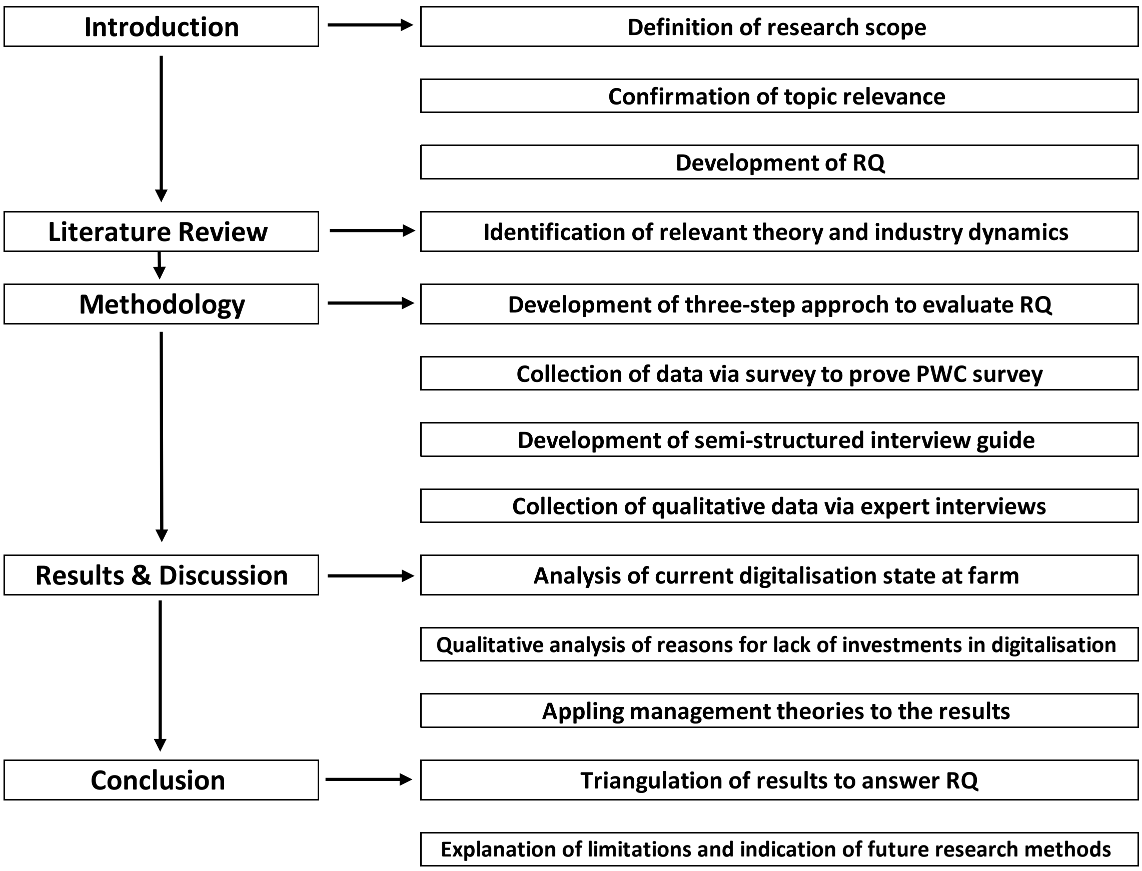

Figure 3: Illustration of research design

The thesis starts with an extensive review of literature that centres on digitalization in the agriculture sector. It is based on academic journals and the 2016 survey questions used by Price

Waterhouse Coopers (PWC). Literature review is used to trace potential drivers of agricultural innovation (Gutiérrez Cano et al., 2023). Afterwards, a similar survey is done which is the one PWC conducted in 2016. The latter is referred to as 'mapping the digitalization of German agriculture'. The survey is carried out via a Survey program and Snowball sampling technique and it focuses on farmers and agricultural advisors. After the survey, there are interviews with farmers and agricultural advisors to go into subject of digitalization of agriculture deeper.

This research applies the so-called triangulation technique to assess the present digitalization level in Germany's agricultural sector. This approach interrelates the results of the literature review, survey, and interviews to present a holistic perspective about the main determinants of agricultural innovation (*Was Sind Die Vorteile Und Herausforderungen Der Mixed-Methods-Forschung?*, n.d.).

3.2 Data Analysis

The type of qualitative content analysis employed here is Mayring and Fenzl, 2014 five step (Elo et al., 2014). This analysis involves three distinct phases:

Open Coding: Textual comparison referred to the process of categorising relevant anti-theme concepts and their raw data into distinct themes and concepts.

Axial Coding: The raw categories developed in the open coding phase are organized, adjusted, and categorized. This stage involves identifying associations among codes as with a view to creating more general coding categories.

Selective Coding: Axial coding assists in categorising the data into narratives to generate a theory that will be holistic in regard to the research question.

The results and discussion part of the thesis involves exploring and comparing the main themes developed out of coding process with the interviews findings.

It is only by employing this comprehensive approach to research and data analysis that one can hope to come to a complete understanding of the principal determinants behind German agricultural innovation these days. Thirdly, mixed methods approach and data is used as a form of enhancing the accuracy and validity of the findings in qualitative research literature from various authors (Le Gal et al., 2011).

Interview Partner	Biography
Enno Wilhelm von Katte (Interviewee 1)	Owner of 2000 hectares, also a test farm for machine manufacturer Horsch. Also known for promoting digitalisation in agriculture in Germany
Johannes Langhans (Interviewee 2)	Owner of 1500 ha in Germany on two different farms. Developer of new technologies in Germany. Co-operation with Dammann (manufacturer of sprayers). Also lobbyist for agriculture in Mecklenburg-Vorpommern.
Henning Heidkamp (Interviewee 3)	Owner of 1000 hectares of farmland in Germany. Additionally 50 horses and foals. Involved in the state trials of Precision Farming and Smart Farming
Julius Marschall (Interviewee 4)	Owner of 1700ha of farmland in the south of Germany. Young team that tries to be innovative and open to new techniques.
Philipp Langels (Interviewee 5)	Owner of 800 hectares of farmland and also 53 horse farms. Experimental farm for AI-supported foal births

Table 1: Interview partners from different agricultural farms

3.3 Maturity Model

To conclude the analysis, we used a Maturity Model of Innovation Levels on Farms which will conduct in a mixed-methods approach combining the data from the surveys from PWC and from this survey for the thesis. The survey will be applied across a wide spectrum of farms to quantify the extent to which these pioneer farms have adopted technology. Specifically, the survey will include questions designed to categorize farms into distinct innovation levels: Analog Farm, Beginners, Expert, Professionals and Leaders. The familiarity and investment of the participants in precision and smart farming technologies, such as the use of GPS + RTK Steering Systems, sensors, robots, drones and intelligent agriculture machines (AI) will be enquired. The interview guide can be found in appendix (chapter 8.2).

The responses will help to understand the percentage of subjects at each maturity level. In addition, selected experts in agricultural technology will be interviewed in-depth to support the surveys result. Current technology adoption on farms will be further explored via interviews to determine the barriers and advantages of these integrations as well as the possibilities for future advances in technology to answer the research question properly.

The combination of the two surveys will allow us to provide a complete picture of the state of innovation on farms compared to each other in order to outline the trends, main difficulties, and possibilities. This combination approach guarantees a comprehensive and complex comprehension of the innovation ecosystem in agriculture, which in its turn provides detailed maturity model embracing both numeric parameters and quality dimensions.

4 Results & Discussion

In the following the results of the quantitative survey are being displayed. The aim is to show the distribution of maturity according to the 5 innovation levels after showing an overview of the survey's results.

4.1 Maturity Model Analysis of Survey

After examination of the survey data and literature review, it becomes evident that multiple factors contribute to the digitalization in agriculture. With this foundational knowledge, we plan to consult industry experts to gain deeper insights into the underlying reasons for these challenges. The research primarily focuses on the question, "What are the major determinants of agricultural innovation in Germany today?" We analysed the findings based on the survey results and information gathered from the literature review, aiming to uncover significant insights into the dynamics of innovation in the agricultural sector.

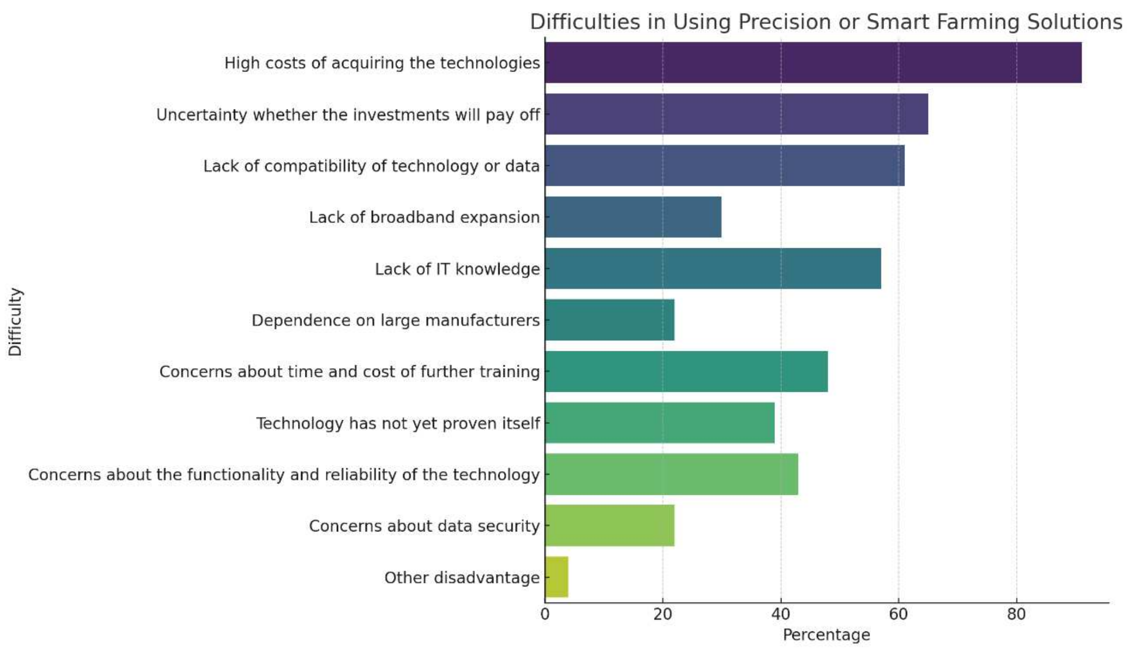

Figure 4: Difficulties in Using Precision or Smart Farming Solutions

The major challenge is the high costs with 91% of the respondents, which means financial challenges were a major concern. The other main challenge is uncertainty regarding return on investment with 63% of respondents unsure about the financial benefits of these technologies. An equal number of respondents mention problems related to technology or data compatibility, making it difficult for many people to assimilate a new system with an old one. Thirty two percent of the respondents are affected by lack of broadband expansion, these issues stem from infrastructural limitations where internet connection is poor or non-existent especially in the rural regions. Over 20% of the respondents also reported problems like lack of IT expertise, relying on big vendors and time and expense issues with training. One other radical barrier is mistrust regarding the functionality, reliability as well as data security. Other disadvantages were mentioned by a smaller percentage of respondents, and an insignificant part (5%) said they do not experience any difficulties. The graph highlights various obstacles associated with the cost of new technology, lack of knowledge relating to its application as well as inadequate infrastructure for prompt development that is necessary in driving up acceptance of smart and breakthrough farming practices.

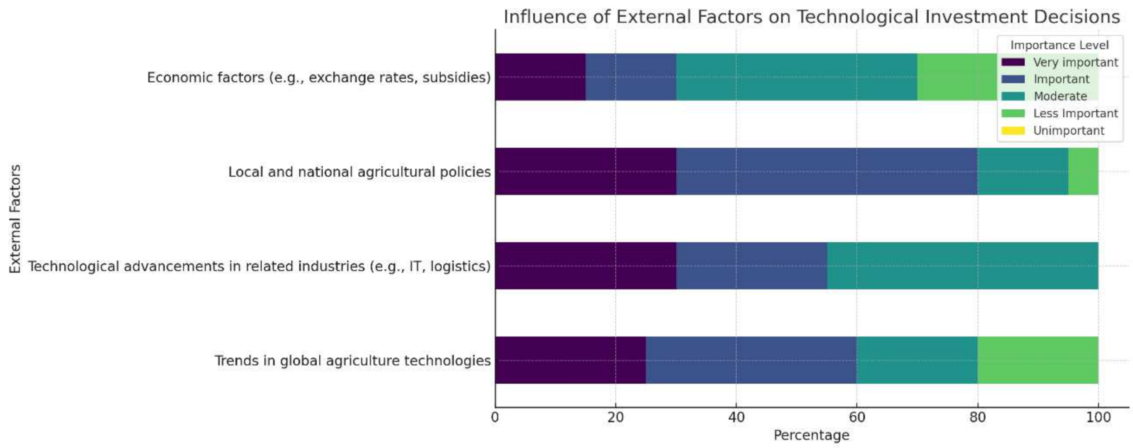

Figure 5: Influence of External Factors on Technological Investment Decisions

According to the survey, 96% of respondents are aware of Precision or Smart Farming with 63% feeling “well-informed” about the concept. This indicated that the majority of respondents were very aware and knowledgeable about these advanced farming practices. This serves to underscore the importance of training and knowledge in personnel as 44% of respondents identified increased or improved resource on training and skill development of personnel.

Strategic Planning and Vision

While the survey does not specifically address strategic planning and vision, it is apparent that 67% of respondents had already begun to invest in new technologies and plan further investments; a clear indication that these farmers have well developed current strategic plans or future farm directions.

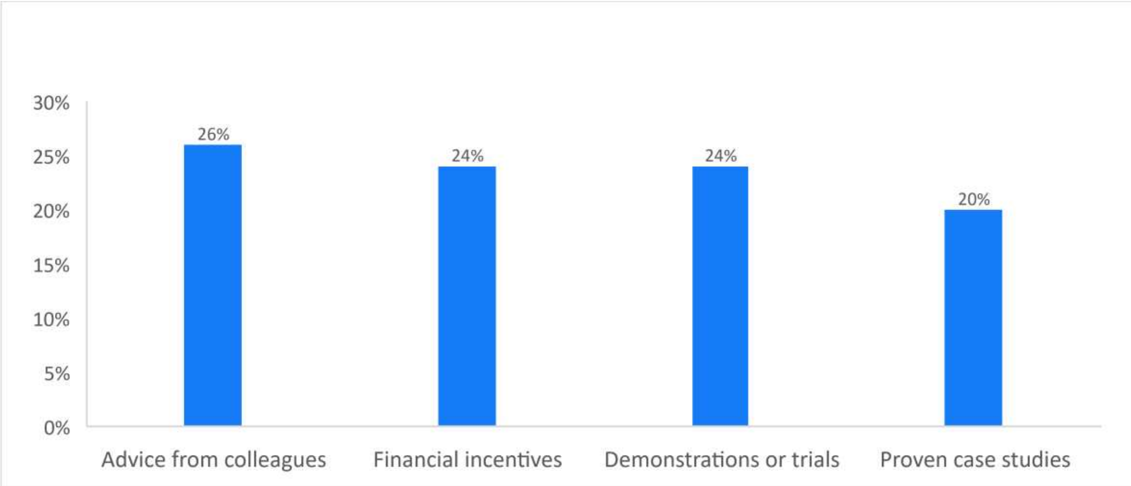

Figure 6: Factors encouraging adoption of Precision / Smart farming technologies

Infrastructure and Equipment

It is only around quarter of respondents (26%) who use machinery rings that implies majority of farmers prefer to possess and operate their own machinery. The availability and quality of infrastructure and equipment is also an important determinant for new technology adoption.

Financial Resources and Budget Allocation

According to the survey, 67% of respondents have invested in new technologies and are planning more investments. Nonetheless, 11% of the respondents are however invested but do not intend to invest any further while another 11% have no investment intentions. This can be due to a number of reasons including scarcity funds, insignificance benefits or contentment with existing technologies.

Global Agriculture Technology Trends

About 20% of respondents know information about Precision or Smart Farming only from talking to colleagues, 19% of their knowledge has been gained by their own as well as in the internet and trade journals (15%) indicating that they are aware of global agricultural technologies.

Progress Made in Related Industries.

The survey does not refer to the technological development in other related industries. The variations in technology already used by respondents in their agricultural operations include; Use of GPS Steering Systems (19%), Apps to assist on documenting work processes and farming data (17%) and Application of Sensors (14%), suggesting influence related industries such as IT technology driving decisions on investments in an agricultural technology.

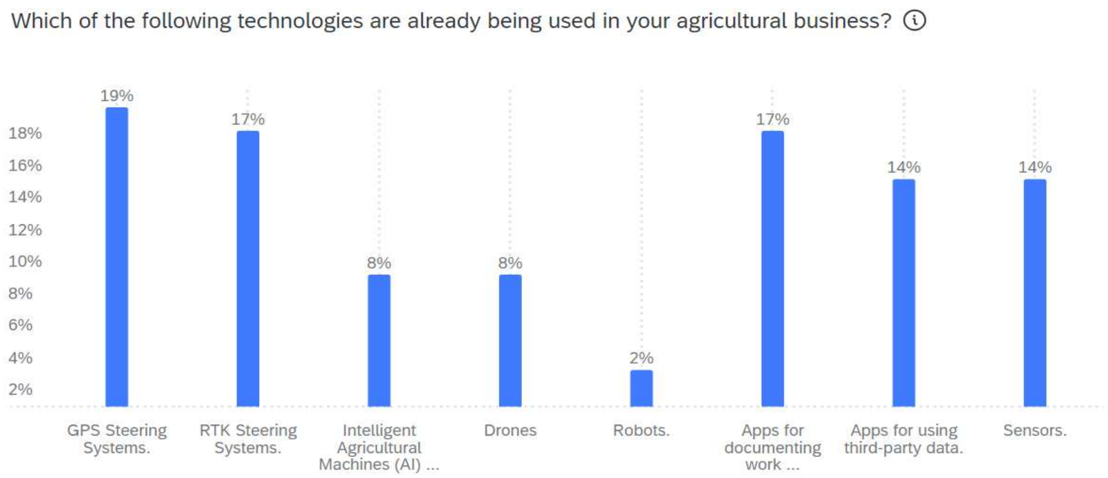

Figure 7: Already existing technologies in survey agricultural businesses

Economic Factors

The fact that 25% of respondents hold that financial incentives or subsidies represent an opportunity for increasing rates of adoption in innovative technologies means that either local or national policies may facilitate the process. The survey indicates that 91% of the respondents consider expensive technology acquisition to be a major problem that hinders the adoption of Precision/Smart Farming solutions. Another case in point is 65% who talk of lacking confidence in the rate of return.

Incompatibility and Technical Standards

Respondents identified lack of compatibility nature of technology/systems (61%) and absence of technical standards as significant hindrances.

However, the survey does not give the comprehensive view of no expanse situation and gaps in IT field. Nevertheless, this reveals the necessity of increasing IT facilities and knowledge among farm workers as only 19% respondents inform about Precision or Smart Farming mainly via Internet, and their counterparts percentage is slightly lower than 20%.

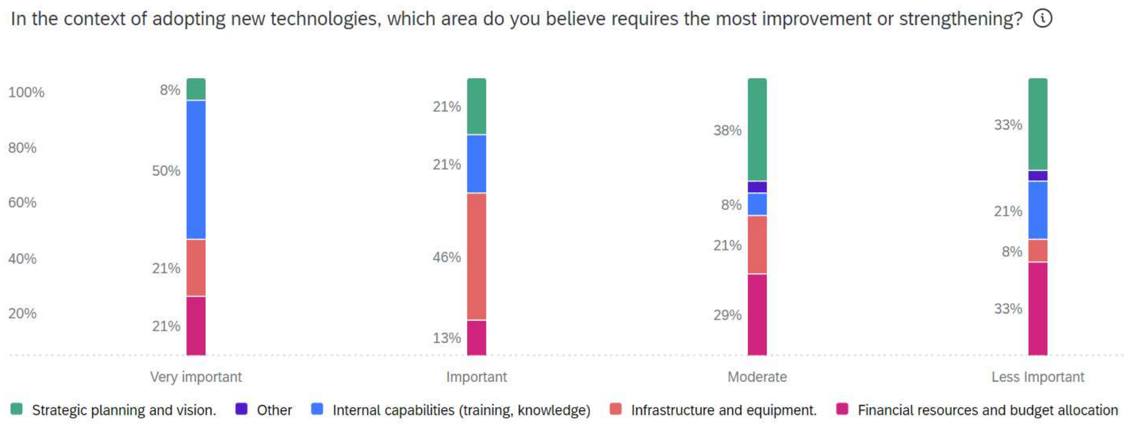

Figure 8: Areas of improvement for adopting new technologies

High Training Costs

On the other hand, it is surprising that 50% of people suggest that training and skill development would have the biggest impact if improved or increased for adopting innovative technologies means that the human resources face significant challenges with regard to these costs and is often limited to the education level from the workers.

Data Security

Respondents highlighted the doubts about technology utility, dependability (43%) and fears over data safety. In the interview with Interviewee 2, this was also confirmed. He would be willing to create 'Big Data' to advance in cultivation methods. However, due to the risk that the data might not remain on his private server but instead be analysed by external providers and made accessible to other farmers, there is no further interest."

To sum up, the survey answers some pressing questions regarding what propels agricultural innovation. Some internal enablers that influence adoption of new technologies include training and knowledge, strategic planning and vision, infrastructure/equipment, financial resources/budgeting. Other external factors that determine investment in technology include international trends on agricultural technologies, other relevant sector revolutions, and the broader local or national policies to promote agriculture as well as worldwide economic issues. Nevertheless, to foster the adoption of innovative technologies in agriculture challenges and barriers should be overcome: high costs and investment uncertainty, compatibility issues and lack of technical standards, absence of broadband expansion and IT knowledge, dependence on big producers as well as training costs make farmers hesitate with respect to functionality reliability or data security.

Innovation is essential for growth and competitiveness, especially in technology. Nonetheless, there are a number of forces that may prevent people from being innovative and limit the level of innovation.

The main takeaway from the survey is the maturity model which categorizes the surveyed farms into the 5 stages of maturity according to their level of innovation. In this model, the progression from Analog Farm stage to Leaders depicts a perfect maturity process where in initial awareness and basic technology use leads into fully-integrated data-driven approach signifying comprehensive smart farming practice.

Analog Farm (13%): In this category, farms have not incorporated any digital related technology. It becomes known to the farmers as Precision Farming or Smart Farming but which they indicate having limited information about it. Some would want to get more information about these issues in the near future. Typically, these farms have made no investments in new technologies such as the Internet of Things, Cloud Computing, AI / Big Data or Robotics/Automation nor pursued any related training/recruitment.

Beginners (35%): In this class of farms, lavish use of basic digital technologies has emerged. Their primary technological adoption stage is the use of GPS and RTK Steering Systems. Such technologies are implemented to make farming operations more precise however they frequently do not become an integral part of the farm's strategic management.

Experts (27%): Adopting AgTech goes beyond the initial adoption where expert-level farms are using more advanced technologies. This reflects the company's drive towards effective farm management by integrating technology such as sensors, robots and drones into their activities. Increased data generation and operational visibility are provided through these technologies that can result in better decisions.

Professionals (8%): Precision farming is deeply integrated into the processes and IT infrastructure of professional farms. They use intelligent agricultural machines with AI or systems that can self-improve over time. This presents a greater advancement in empowering technology towards maximization of farm activities and resource utilization.

Leaders (31%): Leader category – this represents the highest stage of technology integration in farming. In addition to documenting work processes and managing farming data, these farms deploy applications that can leverage third-party data. Digital technologies are used in their full integration into the business model to integrate processes driven by real-time information and smart farming as a key element of operation.

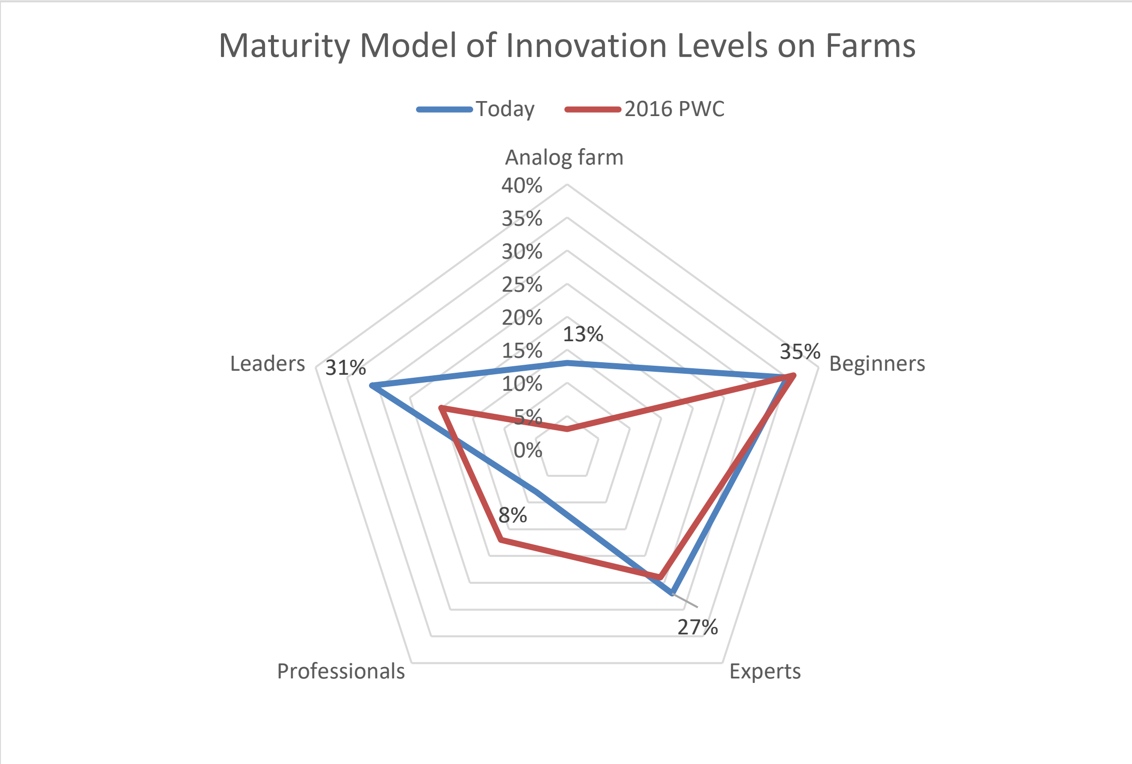

Figure 9: Distribution of level of innovation in Maturity Model

The Maturity model shows that only a small number of farms does not use any kind of technology. Meaning a certain level of innovation has been established in German agriculture. The vast majority of the farms survey are Beginners and experts which make up 52% of the surveyed farms. There is only a very small percentage of Professionals which use precision farming as a integrated tool in their daily operations. It is interesting in that not less but 31 percent of the farms can been categorized as leaders in the maturity model. This leads to the assumption that farms do not stop at the level of a Professional, but strive to achieve a high level of digitalization once they have integrated Precision Farming technologies or they stop at a basic level of Ag-Tech integration.

4.2 Diffusion of Innovation

In applying the "Diffusion of Innovations" framework to the adoption of new agricultural technologies, individuals can self-categorize based on the adoption curve shown in the graph. The percentages indicate how early or late they are in adopting new technologies compared to others in their community or sector.

Innovators (11% on the graph): These farmers are the earliest to adopt new technologies. They take risks and are eager to experiment with novel agricultural methods or equipment, often leading the way for others.

Early Adopters (41% on the graph): Farmers in this group quickly follow the innovators. They adopt new technologies early but after careful consideration. Their adoption decisions are respected by their peers, which often encourages wider adoption.

Early Majority (33% on the graph): This group adopts new technologies before the average farmer but not as quickly as the early adopters. They typically need to see that the technology has been successful for the innovators and early adopters before they commit.

Late Majority (11% on the graph): These farmers are more sceptical and will adopt new technology only after a majority of their peers have done so. They often need support and evidence of the technology's effectiveness before making a decision.

Laggards (4% on the graph): This group is slow to adopt new technology, often due to limited resources or an inherent resistance to change. They may adopt new methods only when necessary or when external pressures make it unavoidable.

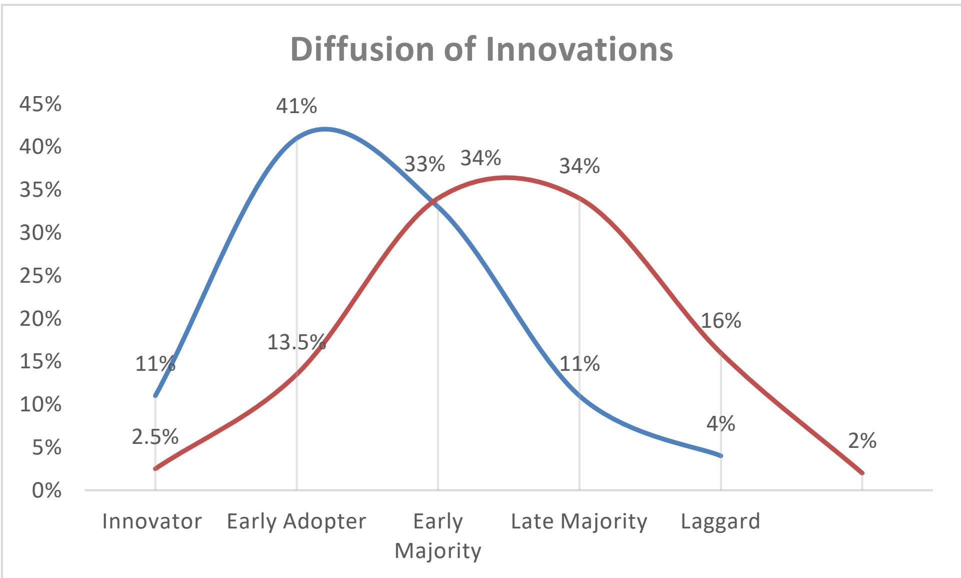

Figure 10: Normal Distribution (red); Survey results (blue)

These categories are useful for self-assessment within the agricultural sector to understand one's typical response to new technologies. This can help in strategizing how to approach new innovations, whether one is looking to be a leader in adopting new methods or more cautious, waiting for clear benefits before investing. The graph indicates a community with a higher-than-average rate of innovators and early adopters, which could be indicative of a dynamic agricultural sector that is open to new technologies and quick to implement them.

4.3 Resource Based View (RBV)

Drawing on the survey results and using the Resource-Based View (RBV) framework, a number of key resources and capabilities that add to the competitive advantage of farms can be identified. Thereafter, these resources and capabilities can be grouped into tangible and intangible assets.

Tangible Resources:

Technological Infrastructure: According to survey results, the farms are in different technology adoption stages such as the Analog, Developments and Leaders. The role of technology as a resource, including use of GPS and RTK Steering Systems; sensors, robots, drones and AI must not be neglected.

Financial Resources: Sixty-seven percent of respondents in the survey already invested in new technology, and are intending to invest further. This is an important resource since it provides financial capability to invest into new technologies.

Infrastructure and Equipment: This is expressed in the manner that 74% of respondents preferable own and operate their machinery, meaning that the infrastructure and equipment quality resource is key.

Intangible Resources:

Knowledge and Skills: Of those surveyed, 63% responded that they felt well-informed about Precision or Smart Farming, and 44% identified more training/skill development of personnel as a valuable resource. This implies that the intangible resource of knowledge and skills with regard to new technologies is vital.

Strategic Planning and Vision: The fact that 67% of respondents invested in new technologies and plan further investments means that in the long term productions will become more efficient. Therefore the future for these farms looks promising related sustainability and profit , which is an intangible resource of special weight.

Trust and Security: This survey established that there is mistrust concerning the capability, dependability and even the observation of higher stages of expertise. Therefore, trust and security are among the crucial intangible resources affecting the adoption of new technologies.

With respect to resource heterogeneity, the survey findings indicate that there is considerable disparity in technological adoption, knowledge and skill fidelity, and strategic planning among farms. This difference, in turn, might promote the variance of competitive advantage.

Regarding resource immobility, the findings show that certain resources especially knowledge and skills, trust and safety might be hard to move from one farming system to another. Such a firm might gain immobility that potentially leads to sustainable competitive advantage. The survey results add value to our understanding of the resources and capabilities that are relevant for farms' competitive advantage. Such insights help in strategic management decisions and opportunities for future research.

4.4 Maslow´s Hierarchy of Needs

Based on the survey results, the respondents appear to be beginner, evolving or leader technology users in their farming practices. This could be interpreted in the context of Maslow's hierarchy as follows:

Physiological Needs: Both the farmers who are adopters of technology and those who have not adopted technology need to fulfil their physiological needs as humans. The Maasai indulge in farming practices that are necessary for acquiring of food and water.

Safety Needs: Beginners are farmers that have turned to the most basic digital technologies in their farms maybe for the sake of improving their safety and security. One such case is the employment of GPS and RTK steering Systems which provide guidelines for more accurate farming exercises hence safety.

Love and Belonging Needs: Expert farmers' needs may revolve around social identity and cut across, say, wanting to feel part and parcel of the farming community. For example, they may be depicting their 'in-group' role by incorporating advanced technologies like sensors, robots and drones into their practices.

Esteem Needs: The deep integration of precision farming into their processes and IT infrastructure may mean that farmers who have deeply integrated precision farming into their processes and IT infrastructure (professionals) are trying to make a reputation or be respected by fellow farmers. They may want to elevate their status and or esteem among farmers by employing AI intelligent agricultural machines or self-improving over time kind of systems.

Self-Actualization Needs: By contrast, farmers at the leader stage of technological adoption where digital technologies have been fully integrated into their business model, may be geared towards self-actualization. They may be attempting to actualize themselves and grow by using third-party data and adopting processes based on current information.

To sum it up, Maslow's Hierarchy of Needs offers a workable basis for analysing the factors that motivate respondents' behaviour and attitudes toward technology adoption in farming. Such information can help you understand the reasons advancing or inhibiting adoption of technology with respect to the needs that are being served, or underserved by the technology on them.

4.5 SWOT Analysis

The SWOT analysis of the survey results can be summarized as follows:

Strengths:

High Awareness: According to the survey, 96 percent of respondents are aware of Precision or Smart Farming, with 63 percent claiming that they feel "well informed" about the concept. This implies that the awareness and intellect on advanced farming systems are relatively significant.

Investment in Technology: 67% of respondents report that they invested in new technologies and plan to invest more. This signifies the willingness to utilize innovative technology and readiness to embrace innovation.

Variety of Crops: These respondents crop grains, corn, rapeseed, sugar beet, fruits and potatoes. Such diversity might have enabled it to cope with market fluctuations and diversify.

Weaknesses:

High Costs: Respondents identified that a significant challenge was the high costs of new technologies, as 89% of respondents was concerned. This may act as a barrier for the uptake of new technologies.

Uncertainty about ROI: The return on investment from these technologies was unclear to 63% of respondents. They may eventually discourage additional investment and impede the uptake of new technology.

Lack of IT Expertise: More than 20% of the respondents identified issues such as lack of IT knowledge that could stand in the way of the application of advanced technology.

Opportunities:

Training and Skill Development: An opportunity was the increased or better resource on training and skill development of personnel as identified by 44% of the respondents. This indicates a need for more education and training on advanced farming technology.

Financial Incentives: One quarter of the respondents feel that financial stimuli or grants could help in adoption of innovative technologies. This indicates that policy interventions may have a substantial impact on the level of acceptance of new technology.

Threats:

Data Security: The respondents were concerned with the new technologies' functionality, reliability, and especially with the data security. That could impede the growth of new technologies and present a substantial threat to farms that have already done so.

Dependence on Large Manufacturers: Dependence on the large manufacturers was a concern from most of the respondents. This can restrict the selection of technologies and therefore increase costs.

Lack of Broadband Expansion: 32% of the respondents have not seen any expansion. This can limit adoption of such technologies that need constant broadband service especially via internet services.

To summarize, despite the high awareness and willingness to adopt IT items, there exist important determinants of the non-adoption including costs, return on investment uncertainty and IT expertise. These would involve better and more training, if necessary with part of that training cost shifting to the initiated technical change, and some financial rewards. Nevertheless, some obstacles such as issues about data protection and reliance on specific big producers may restrict the acceptance of a new innovation.

4.6 Qualitative Interviews Analysis – Encoding Key

This coding should provide a structured overview of the main themes and relationships in the narrative interviews. It aims to help develop a deeper understanding of the dynamics of technology adoption in agriculture and its associated influences.

4.6.1 Open Coding

In Open Coding, key concepts and categories were identified directly from the transcripts of the interviews.

Technological Advancement:

- Digital Technologies: Mentions of IoT, AI, Big Data.

- Innovative Practices: Discussions about precision agriculture.

- Technology Adoption: Barriers and successes in the introduction of new technologies.

- Technology Impacts: Efficiency, productivity.

Policy Influence:

- Government Policy: Subsidies, research funding.

- Regulatory Framework: Environmental regulations.

- Political Support: Support programs.

- Policy Obstacles: Legislative gaps, bureaucracy.

Climate Adaptation:

- Climate Change Awareness: Perceptions, concerns.

- Adaptation Strategies: Resilient practices.

- Environmental Impacts: Soil condition, weather changes.

- Sustainable Agriculture: Eco-solutions, resource conservation.

Knowledge Exchange:

- Educational Resources: Training, workshops.

- Information Exchange: Networks, cooperations.

- Research Contribution: Universities, research institutions.

- Practice-Oriented Learning: Experience sharing, case studies.

4.6.2 Axial Coding

In Axial Coding, I connect the identified codes from Open Coding to recognize relationships and patterns.

Technology and Policy: How does government policy influence the introduction and use of digital technologies in agriculture?

Technological Barriers and Climate Adaptation: What role does technology play in adapting to climate change, and what are the barriers to its introduction?

Knowledge Exchange and Technology Adoption: How does the exchange of knowledge and experience affect the willingness and ability to adopt new technologies?

4.6.3 Selective Coding: Technology Adoption and its Influences

Finally, the Selective Coding, focuses on the specific topic of "Technology Adoption and key determinants.

- **Obstacles to Technology Adoption:** Costs, lack of clear ROI, complexity of technologies.

- **Influence of Policy on Technology Adoption:** Subsidies and support programs as motivators or obstacles.

- **Influence of Knowledge Exchange and Education on Adoption:** The need for training and education for effective use and understanding of new technologies.

Based on the literature review, survey analysis, and expert interviews, the key drivers of agricultural innovation in Germany today can be categorized into three main themes: obstacles to technology adoption, influences of policy on technology adoption, and the impact of knowledge exchange and education on adoption.

4.7 Obstacles to Technology Adoption

The literature review points out that the use of digital technologies has escalated in Germany with projected adoption rates of about 15-20% in the next five years for barn robotics, section control, and variable-rate applications and maps from satellite data (Gabrieli & Bitsch, 2023). Nevertheless, the adoption of these technologies is not without challenges. The high price of adopting these technologies, their sophistication, and the absence of an unambiguous return on investment (ROI) are the main barriers to technology fostering.

"High costs, the first point, are massive. Such a weed hoe is incredibly expensive. It feels like it costs about 100,000 euros for an eight-row one, considering there's not much to it. We can't afford it, I would like to do it, but it's just too expensive." (Interviewee 1, 2023)

What he aspires to do is illustrated through Interviewee 1, but the most substantial difficulty in technology adaption is profitability or cost-utility ratio. The ratio of benefits is often outweighed by the acquisition of new technology. Farmers are therefore often conservative and prefer legacy technologies in spite of new technology hype.

The aforementioned literature review emphasizes the significance of knowledge sharing and learning for successful uptake of farming technology. Precision Farming has been tried in very small-scale farming making it seem applicable. But such technologies need more knowledge about the soil which will come from farm-specific soil-testing using remote devices like drones, sensors, and satellite. However, this information is often missing, which in turn reduces interesting investments for farmers.

This issue was discussed directly related to the experimental farm in Schleswig-Holstein in the interview with Interviewee 3. In that case, the government invested 200,000 euros in the operation to discover whether it is possible to increase efficiency, productivity and yields using precision farming and smart farming. Five years later, the applied data from drones, soil samples, and sensor techniques together with satellite photography became essential when analysing in what way individual cultivation methods could be improved or which machines or precision farming techniques should be bought to make the operation more cost-effective. Finally, it was determined that the profitability in form of yield did not enhance in similar level to investment costs on required techniques.

"Well, for example, there was this misguided project in Helmstorf with precision farming. They spent about five years recording all sorts of data, including threshold values and other things, and in the end, it turned out that it wasn't even a starting point. So, they don't even know in which direction to continue research. In technology or in optimizing the cultivation program?" (Interviewee 3, 2023)

This provides additional context for the insights in the literature review and survey analysis. The review of the literature emphasizes on acceptance of intelligent machines in agriculture and barriers to adoption including high costs of acquisition and prospects for returns on investment. The trial to establish new technologies is also confronted with other bottlenecks. The ensuing understanding that the new approaches did not necessarily yield rises in efficiency weakened the appeal of new technologies.

"Had these trials shown that yields were higher and production costs were saved, while farmers in the region were more interested in delving deeply into new technologies." (Interviewee 3, 2023)

"Since the yield numbers and costs were more or less the same in the end, the decision of most farmers was that the old analogue methods also still work well." (Interviewee 2, 2023)

The survey analysis defines farms by their stage of digital technology adoption, from Analog Farms without past adoption to Leaders who have fully integrated data-driven operations. The main challenges to digital adoption in agriculture are identified as high costs, uncertain return on investment and technology or data compatibility issues in the survey and the interviews.

The analysis of the survey offers a comprehensive picture of the German agricultural digitalization as well. According to the results of the survey, more than 60% of farms practice digital technologies and on territory of more than a half it were investments for less than four years. Nevertheless, the interview with Langhans confirmed that financial incentive was a crucial factor to overcome obstacle in terms of high investments.

However, von Katte pointed out the problems of adapting new technologies in agriculture. He outlines the high cost of some technologies such as a weed hoes, and the risky nature of investing especially with regard to long-term profitability and functionality, compatibility among others.

Moreover, many machines that embrace new technologies with prospective farmer interests are mostly equipped with technologies only dependent on assumptions, and thus farmers fear usage of these evolving methods may not overcome. This would, therefore, make it impossible for a technology to be resold. For the technologies of startups on the other hand, especially where it involves outright speculative ventures where the very existence of the company is in question, this problem becomes particularly acute. This makes the farmers to be careful, and they often wait for others to take the initial steps.

"High costs, the first point, are massive. A weed hoe is incredibly expensive. It feels like it costs about 100,000 euros for an eight-row one, considering there's not much to it. We can't afford it, I would like to do it, but it's just too expensive. There's also uncertainty in investments because with these hoes, and some technologies, we still don't really know if they will work well in the long term, and one also becomes tied to a system." (Interviewee 1, 2023)

Compared to the survey from PWC which indicated that intelligent agricultural machinery are widely adopted, in particular more than of halves (53%) of the respondents already using or intending to use these machines. Such machines enhance efficiency as well as sustainability, by using resources – energy, water, fertilizers and plant protection products and labour optimally. For 76%, the high acquisition costs represent the greatest obstacle to their usage in Precision/Smart Farming. Besides, every second farmer does not know whether an investment in the required equipment is reproductive." (PricewaterhouseCoopers, 2016)

4.8 Influences of Policy on Technology Adoption

In his interview, Interviewee 2 emphasizes the role of financial encouragements in the smart farming technology. He posits that these incentives must be significant in order to hit the mark. These correspond to the survey analysis findings.

"The financial incentives, such as subsidies, can promote the adoption of smart farming technologies. However, these incentives need to be substantial to be effective." (Interviewee 2, 2023)

Germany's government in 2016 outlined new targets within Climate Action Plan 2050 which are supposed to reduce GHGs by a minimum of 55% by 2030, 70% (GHG) emissions because of the year's use of the electricity mix sector by 2040, and lastly between by approximately (80-95%) come the year 2050 when compared with 1990 levels. The role of policy in adoption of agricultural technologies is a significant one. The review stated that Germany has pointed out their climatic goals to become carbon neutral by 2045. This should encourage the agricultural sector to adopt innovative technologies.

Certainly, there would be considerable support from the political part. However, the informants do not confirm this. In fact, they argue that politics live two years behind, i.e. when the technology is already here the policies are drafted. According to Interviewee 2, politics usually produce rewards for farmers. Langhans argues that the political programs are efficient albeit directed at not well of farmers. The most notable one is the “Bauernmilliarde”, having seen farmers exchange their machinery for others without paying a certain percentage on their new machines. Farmers used this option as it seemed sensible on the surface. However, the producers discovered this subsidy and adjusted their selling prices of machinery to correspond with the subsidy. The upshot was a raised sales price and hence, farmers saved out less money on purchases than most of them had thought. In turn, the resale value of the machine was made almost thrice higher than its original market price. As a result, machines became overpriced than the prevailing market price leading to a rise in the second hand machinery market. This observation was made by Interviewee 2, who sits on the board of German Farmers’ Association and is a lobbyist as well.

Interviewee 4 & Interviewee 5 also substantiate that farmers are ready for self-driving of agricultural machinery. In the world, there already exist grounds on which the autonomous operation of machinery is possible, but political arena does not even have a bill. The political debate rumbles on, the argument stating that autonomous driving is possible, but geography do not allow it and Germany has small and complex roads and field structures. Interviewee 2 supports the above statement asserting that it would be ineffective for tractors to be operated on small field structures until the machines can take an independent decision and switch themselves from one field to another. Any other employee would involve travelling to the field until all the work on one field is done before moving to another. Additionally, Interviewee 3 and Interviewee 2 state that even if autonomous driving on the road is not possible without authority, there will be no efficiency boom and in between, work will not be possible.

"What role do external factors such as trends, technological advancements in related industries, local and national agricultural policies, economic factors play? Yes, trends obviously play a role, but they typically only develop if they can establish themselves sustainably in the

industry. So, there might be a quick fashion trend, but if it becomes outdated due to technological advancements, it's replaced by a new trend. Therefore, for me, a trend wouldn't necessarily play a big role. It's more about the technological progress in related industries, though nothing specific comes to mind right now because there aren't any directly related industries concerning the needs of a farmer for information. But I do believe, well maybe, there is technological progress, like electromobility. If you look at this in terms of the automotive industry, which is increasingly making its way into agriculture, there are these powered autonomous devices that are also solar-operated, for instance, hoeing machines. I think that plays a pretty significant role." (Interviewee 2, 2023)

Interviewee 4 underscores the fact that external drivers, and in particular political ones, determine the individual elements of agricultural practices. As he points out, the direct payments in Saxony have been delayed and this might have serious consequences for many of the farms that can no longer fulfil their payment obligations. This in turn impedes the investments in the sector. He also expresses that a ban in Glyphosate could be disruptive to farming practices and force farmers to change the methods of their farming, this acts as a negative influence on the chances of investing.

Political trade decisions continue to be a major issue for the farmers. Some total herbicides, such as glyphosate, which was in common use in agriculture because it substantially reduces production costs, failed to get renewal of approval hence caused a switch by farmers. But all interviewees insisted that there were no same options. Consequently, investments in new technologies declined as farmers got insecure and felt abandoned especially with Glyphosate use still being observed all over the world (Interviewee 4, 2023).

The European Union in November 2023 drew out the authorization of glyphosate, one of most popularly used herbicide, for another ten years despite lack of agreement among member states. This was backed up by safety assessments from the European Food Agency and the European Chemicals Agency and involved new terms, one of which was a maximum application rate. The result has been the development of technology on the back of farmers and their willingness to invest into something new (*Alternatives for the Use of Glyphosate | UNEP - UN Environment Programme*, n.d.).

Farmers also have to invest more up front since there are more regulations by the authorities which translates into delayed subsidies (e.g., basic premiums) for farmers. It is a tendency that also makes farmers reluctant to make considerable investments in new machinery (*New Farm Bill May Not Be Passed by Year-End Deadline - Marketplace*, n.d.).

"So, financial incentives, as you just mentioned, something like the 'Farmers' Billion', of course, that's going to entice, I believe, any farmer, because farmers who are successful, I would say, always try to evolve. And if someone comes along and says, 'we support you', they are of course quick to join in, because a farmer is fundamentally open to development, as in the end, it's about growing or reaching success." (Interviewee 4, 2023)

Interviewee 5, on the other hand, provides a unique perspective on the use of digital technologies in the horse breeding sector. He mentions the use of AI cameras to monitor horses' behaviour patterns and predict foal births, which has significantly improved efficiency and productivity on his farm. He also discusses the potential for digital technologies to improve management practices in horse breeding, such as monitoring health and scheduling veterinary visits. However, he notes that in the direct agricultural sector, his operations remain relatively traditional, with some use of digital technologies for machine communication and precision farming.

4.9 Impact of Knowledge Exchange and Education on Adoption

In the expert interview with Interviewee 1, he mentions that the lack of information about technologies developed abroad is a challenge. He suggests that more could be done to showcase how modern technologies work and to provide information about technological advancements in other countries.

On the other hand, Interviewee 1, in his interview, emphasizes the importance of knowledge exchange and education in the adoption of agricultural technologies. He mentions that magazines and online sources are valuable sources of information about modern technologies and advancements in other countries. However, he also points out that there is a lack of information about technologies developed abroad, suggesting that more could be done to showcase how these technologies work.

"As information sources, agricultural newspapers inform about trends in agriculture. LOP is quite good in this regard, its name translates to 'Agriculture ohne Pflug'. YouTube can also be

helpful. What I find regrettable is that we hear very little about technologies from abroad here." (Interviewee 1, 2023)

However, the survey also shows that only 63% of farmers are well-informed about precision and smart farming, indicating that farmers feel will informed but potentially do not know what technologies are developed and used an a global scale.

"But someone has to write the table, enter the numbers, ensure that these numbers get into the computer. Maybe they are also read in. Then suddenly there needs to be an IT department in the company because the computer doesn't work. We are certainly becoming more efficient through automation, big data, robotics, and AI, but this creates a new complexity that also requires new personnel, different personnel, new ideas, or challenges you just as much as the old way did. The question is whether the decisions become better as a result. And this is a long-term process. And there's no competition that goes the old way for long enough, or just stays put, because no one dares to. Therefore, there's no comparison." (Interviewee 3, 2023)

Interviewee 3 confirms that although the introduction of smart farming solutions makes operations more efficient, whether this increases productivity remains questionable. He claims that although 'smart' solutions may better visualize data, they complicate the overall process. Employees would need to be trained on new software and technologies. This creates dependencies on individual employees. For instance, if that one employee is not working or is on vacation that day, the system might not function. It would increase complexity, and the interviewees are not in agreement as to whether this necessarily creates an advantage.

This problem would also exist when introducing new machinery. The new capabilities of new machines create complexity that often cannot be understood without training.

5 Conclusion

Our investigation found that for farmers, the development of new agricultural practices, such as Precision and Smart Farming, is diverse and problematic. In his interview, Interviewee 3 draws the authors' attention to this fact mentioning the experimental farm from Schleswig-Holstein as a case study where these complexities can be observed. Results did not justify costs, despite a significant government investment of 200,000 euros to test efficiency benefits as well productivity and yield improvements from these technologies. In the past five years, the company has adopted advanced methods including drones, soil sampling and sensor techniques to collect data that value was not reflected in profits.

In this regard, a major problem is that farmers are not willing to make investments into new technologies. This hesitation is fuelled by several factors: the reliance to a significant extent by many new technologies on assumptions instead of proven results, high equipment costs including precision farming tools and uncertainty about the long-term effectiveness and viability of both; particularly from start-ups. Farmers tend to be cautious because they are afraid of trying out any technology that they may not be able to resell or get further support in the long run.

This is also the case in "Helmstorf". There was no appreciable increase in yields in spite of heavy financial inputs. While the benefits of collecting extensive data are likely to be long term such as saving resources (like plant protection and fertilisers) and preserving soil and biodiversity, these do not directly translate to monetary gains for farmers. It is this disconnect that highlights the need for policy interventions. Without the corresponding increase of yields, farmers cannot afford this technology. As a result, political backing is critical in linking the technological growth and viable approaches in farming.

In other words, the adoption of new agricultural technologies presents potential advantages such as efficiency and sustainability; however, financial limitations, uncertainty and delayed realization on tangible returns hinder their adoption. It is therefore urgently needed that policy initiatives, financial support and demonstration models are put in place to encourage uptake of these technologies. Such measures would reduce the danger of any inferences about the long-term value of new technological investments and encourage farmers to make reasonable decisions related to their future aiming to promote sustainable agriculture.

The Maturity models also shows a similar distribution of maturity levels. This leads to the assumption that there has not been a great development in the integration of digital technologies since 2016. This statement also aligns with the results from the conducted qualitative interviews, where Heidkamp mentioned that there has not been a huge development in the last years and established methods have proven themselves and new methods bring complexity and new problems.

6 Limitations

Although this study has outlined parameters enhancing the use of new methods in corn production, it is hard to provide a full analysis on all aspects, many which would be of interest for further research. Most notably, there is technology adoption which produces long-term effects on the socio-economic lifestyle of rural communities. Insight into the dynamics of how these technologies emerge could be explored by future research, along with their impact on smallholder's livelihoods and the social dimensions in farming communities.

Additionally, the carbon footprint of embracing new technology needs an in-depth enquiry. However, preliminary results show ecological benefits like conserving resources and biodiversity; however, more research is required to identify the total ecological footprint of these technologies.

Furthermore, the subject concerning the relevance of policy and regulation in enhancing or deterring technology adoption in agriculture needs to be discussed even further. Insights into the interplay of government policies, technology innovation and farmer adoption can be very valuable to the policymakers and stakeholders.

Lastly, future research should look into the scale and applicability of these technologies across diverse agricultural setting, crops, weather patterns, and economic environments. This would enhance the universal applicability of information and building technological solutions for different agricultural situations.

The purpose of these suggestions is to identify possible future research directions that would help scholars comprehend the complicated relationships between technology, agriculture, and society.

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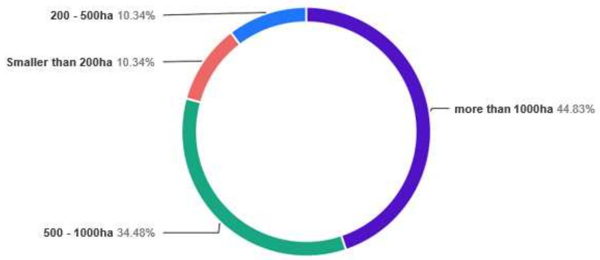
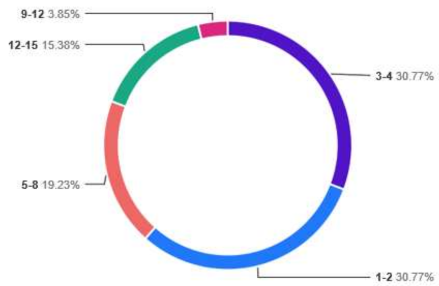
8 Appendix

8.1 Survey

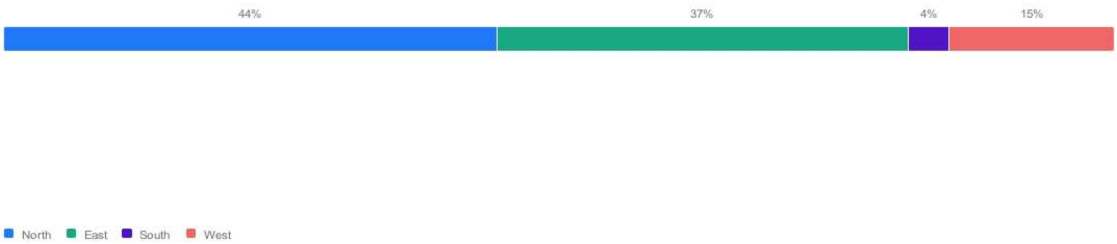
How much agricultural land do you cultivate? 97



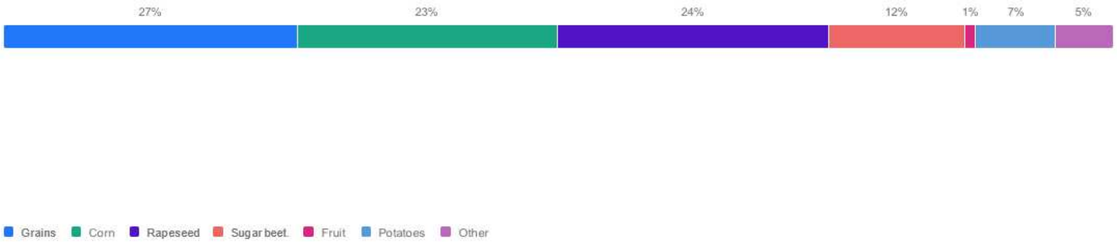
Total employees on your farm?



In which region is your farm located?

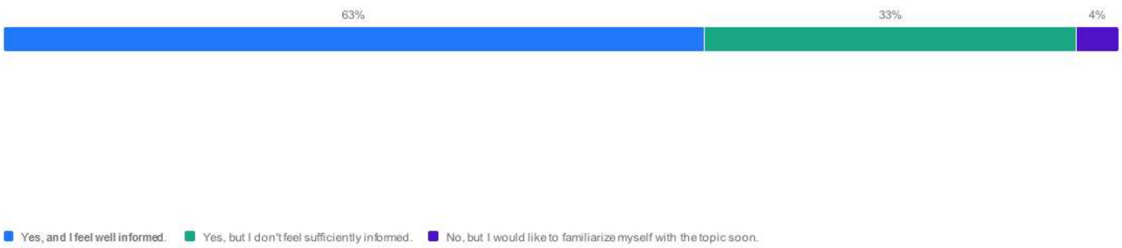


What crops do you grow?

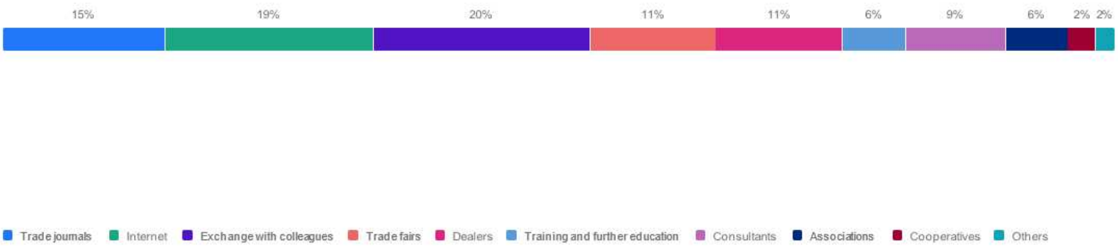


Use of machinery rings ?

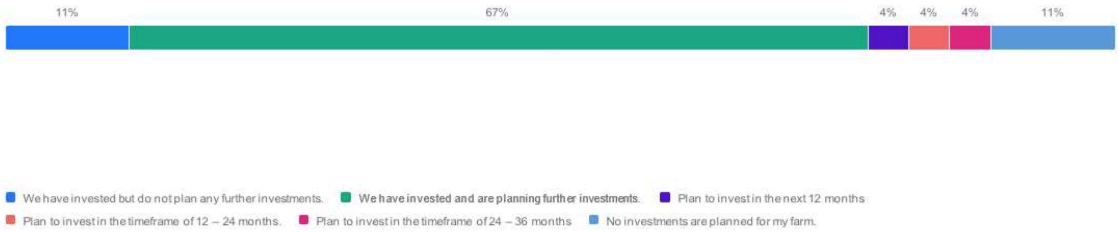
Have you already familiarized yourself with the topic of Precision or Smart Farming? Which of the following statements applies to you?



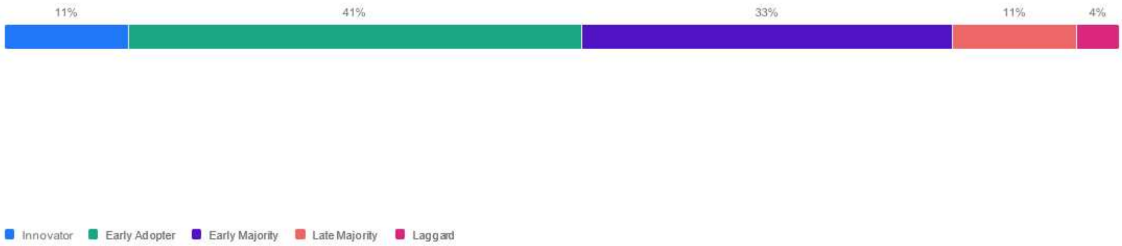
Where do you inform yourself about the topic of Precision or Smart Farming? (Base: all respondents)



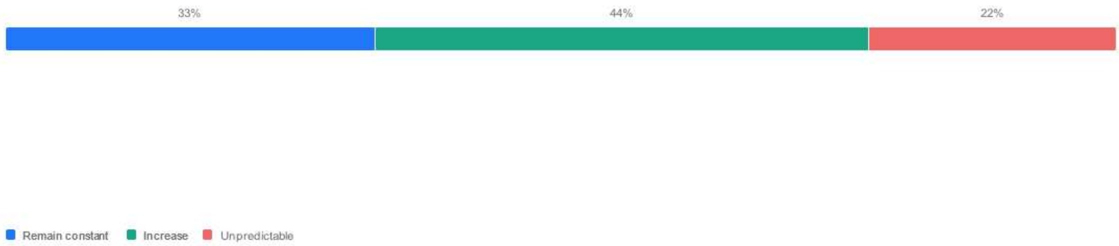
Have you already invested in such new technologies, for example, Internet of Things (Machine to Machine), Cloud Computing, Artificial Intelligence/Big Data, Robotics/Automation? Please also consider investments for the recruitment or training of employees in relation to new technologies. Which of the following statements applies to your farm? ⓘ



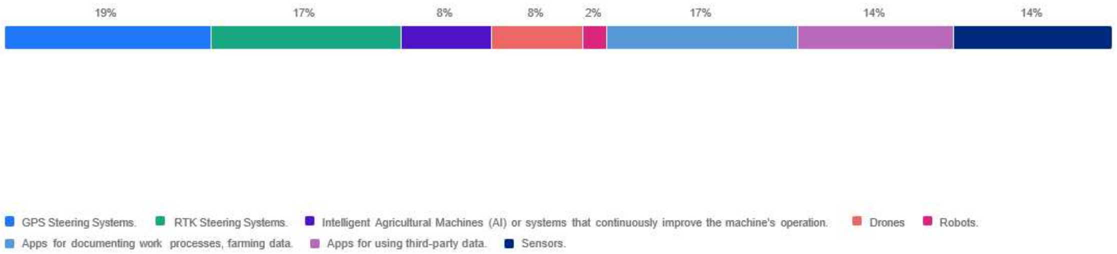
How would you categorize yourself in terms of adopting new agricultural technologies? ⓘ



Compared to your last investment, will your planned investments ... (Base: Respondents who have already invested and are planning further investments.) ⓘ



Which of the following technologies are already being used in your agricultural business? ⓘ



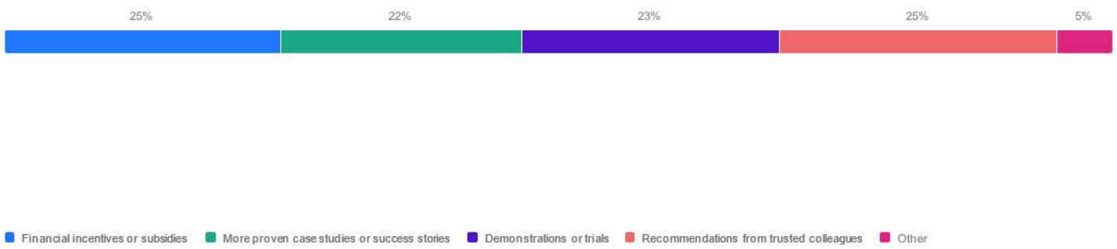
You indicated that you have already invested in Precision or Smart Farming technologies. What changes have occurred in terms of...? Please specify in percentage, an estimate will suffice. (Base: Respondents who have invested in Precision or Smart Farming technologies.)

You indicated that you have already invested in Precision or Smart Farming...	Average	Minimum	Maximum	Count
Increase in process efficiency.	44.54	6.00	100.00	26
Increase in revenue.	31.48	3.00	75.00	25
Cost reduction.	36.60	5.00	100.00	25
Increase in yield.	28.44	0.00	90.00	25
Increase in sales.	32.94	2.00	78.00	17

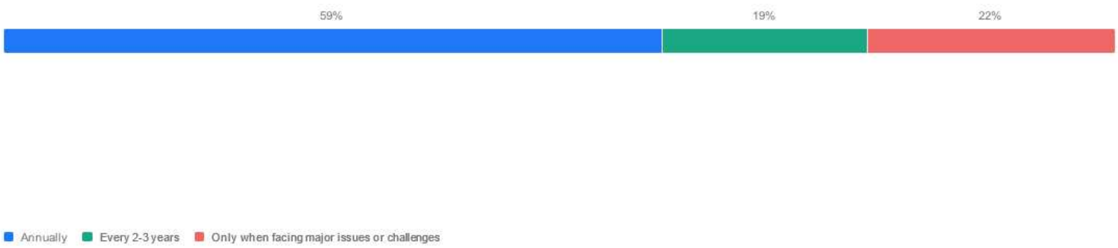
By what percentage were you able to save money ..... last year through the use of Precision or Smart Farming technologies?

By what percentage were you able to save money ..... last year through the...	Average	Minimum	Maximum	Count
On fertilizer	24.80	3.00	80.00	20
On energy	23.71	0.00	100.00	21
On labor	23.67	4.00	100.00	24
On petrol	23.95	3.00	90.00	22
On water	23.07	0.00	71.00	14
On pesticides	22.50	0.00	59.00	18
On fungicides	19.84	0.00	55.00	19
On seeds	25.14	4.00	57.00	21

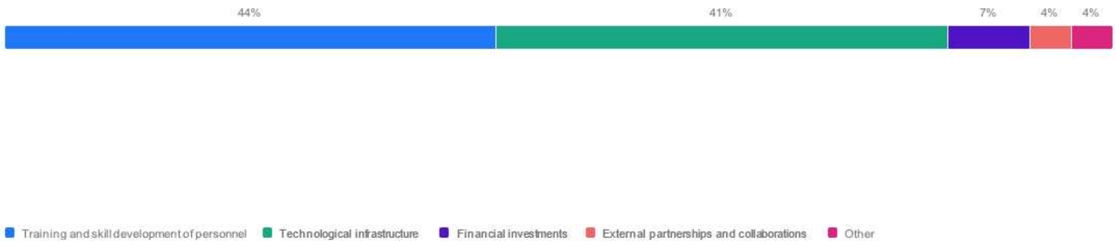
What would encourage you to adopt Precision or Smart Farming technologies faster or sooner?



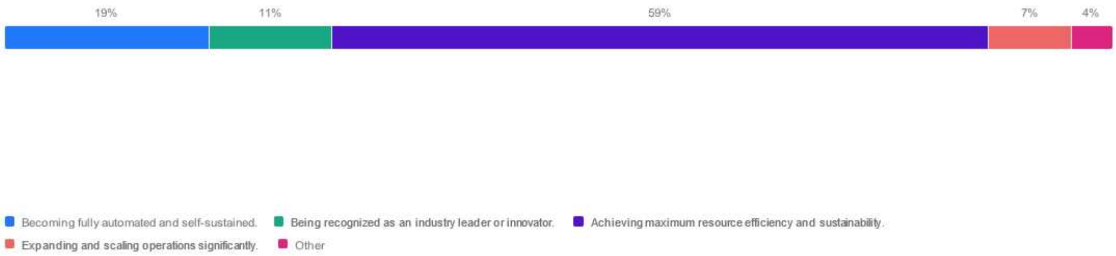
How often do you evaluate and update the resources (human, technological, financial) of your farm?



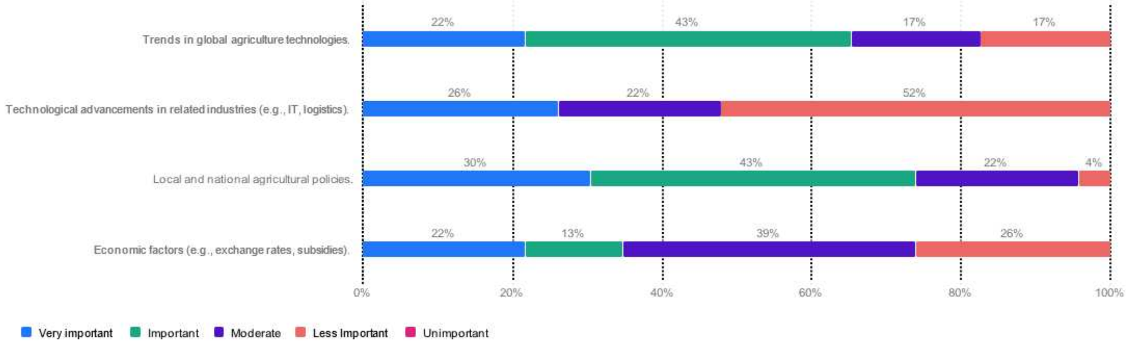
Which resource do you believe would have the highest impact if increased or improved upon for the adoption of innovative technologies?



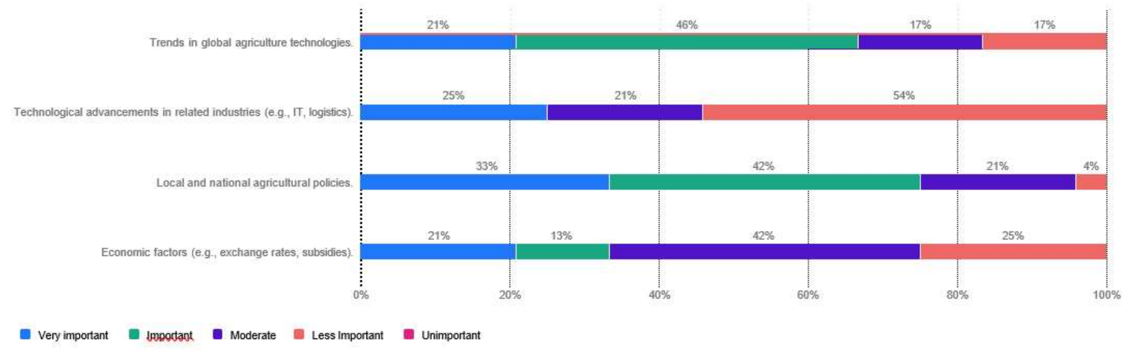
What would you view as the highest achievement or realization for your farm in the context of technological innovation?



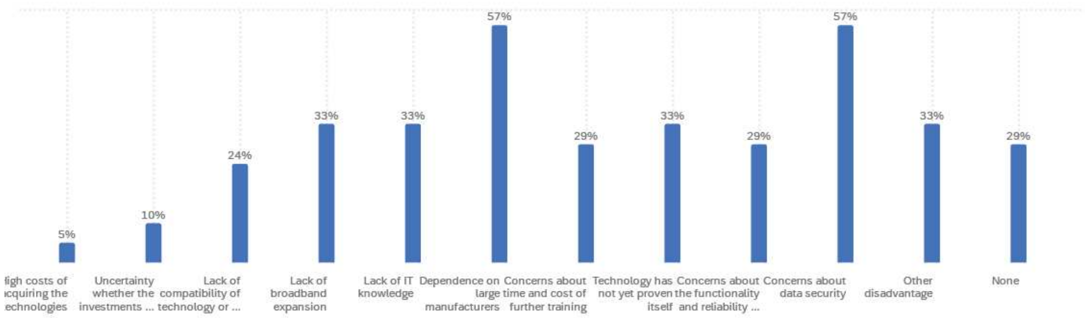
In the context of adopting new technologies, which area do you believe requires the most improvement or strengthening?



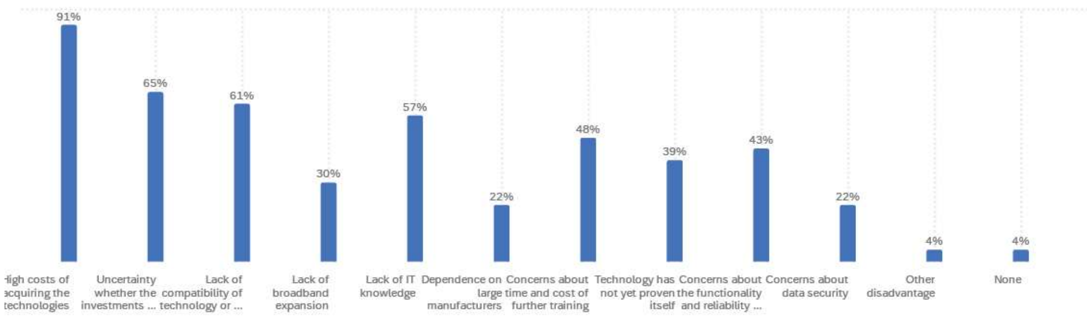
What external factor do you monitor closely that might influence your decisions related to technological investments?



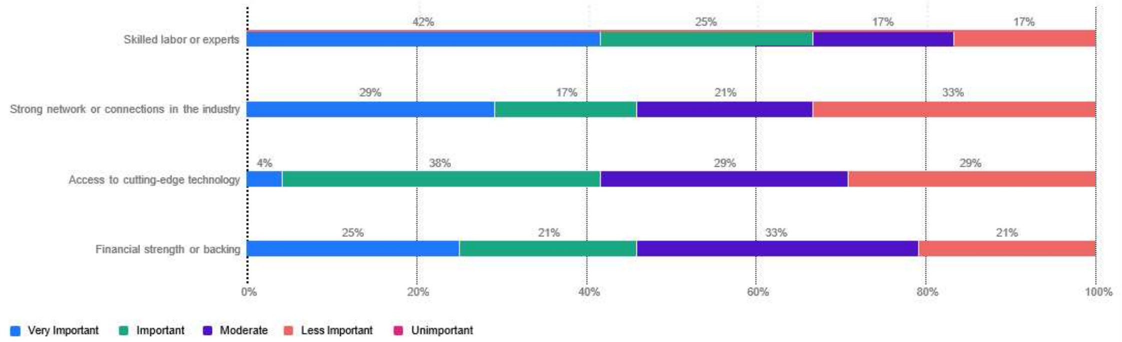
From your perspective, what are the difficulties or obstacles for your business in using Precision or Smart Farming solutions?: No difficulties (No)



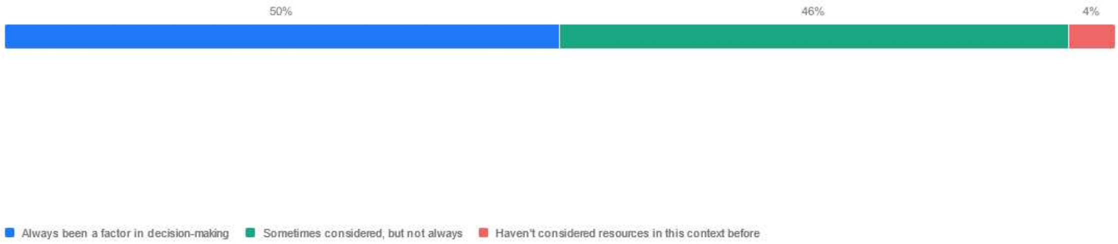
From your perspective, what are the difficulties or obstacles for your business in using Precision or Smart Farming solutions?: Difficulties (YES)



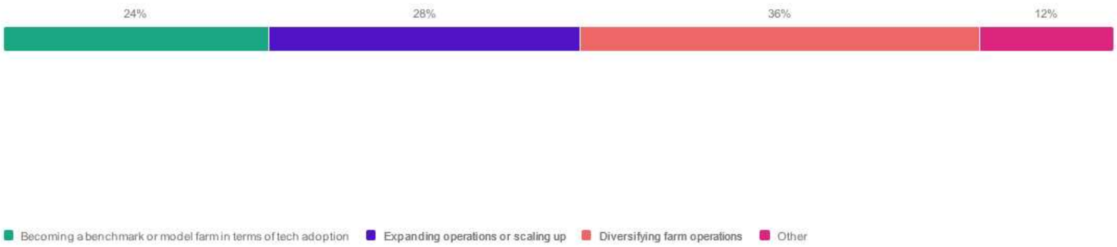
What unique resource does your farm possess that gives it an advantage in adopting innovative technologies?



In what ways have these resources (previous question) influenced your past decisions to invest (or not invest) in new technologies



Once the basic operational needs of the farm are met, what are the growth or aspirational goal for your farm in terms of technological adoption?



8.2 Interview Script

Thank you for allowing us to conduct this interview. The question to be answered is as follows: What are the major determinants of agricultural innovation in Germany today? What prevents a farm from being more innovative?

1. How have investments in new technologies such as IoT, cloud computing, AI/big data, and robotics affected the efficiency, productivity, and sustainability of your farm?
2. Technological adaptability and future readiness: "How do you assess and prepare your farm for future technological advances and emerging trends in agriculture?"
3. What are the main challenges or obstacles you face in adopting precision or smart farming solutions, such as high costs, investment uncertainty, lack of compatibility, or lack of broadband expansion?
4. Environmental and climate change considerations: "How do external environmental factors, especially climate change, influence your decisions to adopt certain agricultural technologies?"
5. What role do external factors such as trends, technological advances in related industries, local and national agricultural policies, and economic factors play in your decision-making process for investing in new technologies?
6. How do you inform yourself about precision or smart farming? What information sources are most valuable? Do you feel there are enough opportunities to get informed, or is there something missing to make an informed decision?
7. How do you assess the role of financial incentives or subsidies, proven case studies, demonstrations in making decisions to adopt precision or smart farming technologies?
8. How do you assess and update the resources (human, technological, financial) of your farm to support the adoption of innovative technologies?

These interview questions aim to gain deeper insights into the factors influencing the adoption of innovative technologies in agriculture, the challenges faced by farmers, and the strategies used to overcome these challenges. By discussing these topics with a specialist, you can gain a better understanding of the key factors for agricultural innovations in Germany today.

8.3 Interview Transcript

8.3.1 Interview Between Caspar von Guionneau and Enno Wilhelm von Katte

Introduction:

Caspar von Guionneau introduces the session, asking Enno Wilhelm von Katte to present himself and his agricultural operations.

Enno Wilhelm von Katte's Introduction:

Enno Wilhelm von Katte describes his agricultural business, focusing on the cultivation of various crops and livestock management. He highlights the size of their operation, the diversity of crops grown, and the methods used, including direct seeding and strip-till.

Technological Advancements in Agriculture:

Discussion about the integration of technologies like IoT, cloud computing, AI, big data, and robotics in their farming practices.

Enno explains the use of satellite data for creating application maps for seeding, plant protection, and fertilization.

Cost-Savings and Efficiency:

Enno mentions a 3-5% savings in production materials due to technological integration.

He emphasizes the importance of GPS in improving farm profitability by at least 25%.

Challenges and Limitations:

The high costs of advanced machinery and uncertainty in investment due to fluctuating support from agricultural policies.

Issues with network coverage and the slow rollout of 5G impacting operational efficiency.

Impact of Climate Change and Environmental Factors:

Enno addresses how climate change and environmental factors influence their decisions regarding agricultural technology adoption.

He notes that while technology is used to better understand and adapt to their environment, direct investments specifically due to climate change are not prevalent.

Political and Economic Influences:

Discussion on the role of politics in farming, touching upon import-export dynamics, subsidies, and the impact of agrarian policies.

Challenges posed by bureaucratic processes and inconsistencies in funding and support at federal and state levels.

Future Preparations and Trends:

Enno speaks about staying informed on technological trends in agriculture, both domestically and internationally.

He expresses a desire for more demonstrations of new technologies by local dealers and manufacturers.

Limitations in Technological Advancements:

Acknowledgement of the limitations in current technologies, particularly in precision agriculture, and the economic viability of adopting new technologies.

Discussion about the practicality of autonomous farming in their specific operational context.

Closing Remarks:

Caspar von Guionneau concludes the interview, summarizing the challenges and opportunities in modern agriculture discussed by Enno Wilhelm von Katte.

The provided text is a detailed conversation between Caspar von Guionneau and Johannes Langhans, focusing on various aspects of agriculture, specifically related to precision farming, smart farming, technological advancements, challenges, and the impact of political policies on agriculture. Given its extensive nature, here is a translated summary suitable for a master's thesis appendix:

8.3.2 Interview Between Caspar von Guionneau and Johannes Langhans

Main Focus:

The interview explores how investments in technology, including the Internet of Things (IoT), cloud computing, and artificial intelligence, have influenced the efficiency, productivity, and sustainability of agricultural operations.

Technological Integration:

Johannes Langhans discusses the integration of technologies like IoT in managing farm operations, highlighting how it streamlines internal logistics and enhances decision-making efficiency.

Cost and Efficiency:

The conversation touches on the cost-benefit analysis of new technologies in agriculture. Langhans notes that while there are significant upfront costs, the long-term benefits in terms of resource saving and efficiency can be substantial.

Challenges and Limitations:

The challenges include high costs, compatibility issues between different manufacturers' technologies, and uncertainties in investment due to fluctuating agricultural policies and market conditions.

Impact of Climate Change and Environmental Factors:

Langhans addresses the role of environmental factors, especially climate change, in shaping decisions related to agricultural technology adoption. He notes that while technology is used to better adapt to environmental challenges, the direct investments specifically due to climate change are not the primary focus.

Political and Economic Influences:

The discussion covers the significant role of politics in agriculture, including the influence of agrarian policies and subsidies on farming practices and technology adoption.

Future Preparations and Trends:

Langhans speaks about the importance of staying informed about technological trends in agriculture. He emphasizes the need for technologies to be user-friendly and broadly applicable across different farm sizes and types.

Limitations in Technological Advancements:

Langhans points out the limitations of current technologies, particularly in precision agriculture, noting the economic viability and practicality of adopting new technologies in diverse farming operations.

Closing Remarks:

The interview concludes with a discussion on the importance of data integrity and ownership in the context of smart farming. Langhans emphasizes the need for farmers to have control over their data and for technologies to be adaptable to individual farm needs and conditions.

8.3.3 Interview Between Caspar von Guionneau and Henning Heidkamp

Question 1: How have investments in new technologies like IoT, cloud computing, AI/big data, and robotics/automation affected the efficiency, productivity, and sustainability of your farm?

Henning: These technologies, from IoT to robotics, represent the digitalization you're talking about. We've always tried to engage in these areas, like early adoption of precision seeding. Our approach is to invest in these technologies as they prove their efficiency and productivity. The first step, like using a computer, is unavoidable. I see digitalization in three clusters: everyday technology like computers and machine controls, debated technologies like parallel track systems, and visionary technologies that are not yet market-ready, like drone technologies for chlorophyll or plant health monitoring.

Caspar Von Guionneau: So, drones are not yet a focus for you because they are not market-ready?

Henning: Yes, there are no market-ready drone solutions presented to us as end-users that justify the investment. We are cautious and only invest in proven solutions.

Caspar Von Guionneau: Do you use application maps on your farm?

Henning: We don't use them because there's no clear functionality or benefit, like in nitrogen application. I am informed, but there are no solutions yet.

Henning: We sometimes doubt if digitalization has brought efficiency. With technologies like big data and AI, we can handle more complex data, but it requires more attention and doesn't necessarily lead to better decisions. It's a long-term process without a clear comparison to traditional methods.

Henning: In our farm, we are replacing manual labor with robotics, especially for simple tasks like egg sorting. But there's always the concern that if technology fails, we need people who can compensate.

Caspar Von Guionneau: Can you quantify the increase in your efficiency or productivity?

Henning: We sometimes question if there's been a real gain in efficiency, especially with AI and big data. The complexities these technologies introduce often require new personnel or the same amount of time as before.

Caspar Von Guionneau:** How do you prepare your farm for future trends?

Question 2: What are the main challenges or obstacles you face in adopting precision or smart farming solutions, like high costs, investment uncertainty, lack of compatibility, or inadequate broadband infrastructure?

Henning: Early investment in market solutions can become obsolete quickly. Innovations must be well-established in the market to be truly beneficial. Costs are not an issue if there's a clear return on investment. The challenge is that the benefits of these solutions are often not immediately apparent or clear.

Henning: The past has shown that staying updated is essential. We use technologies like automated egg sorting in poultry farming, but there's always the concern of over-automating and lacking manual backup. Our approach is to keep up-to-date without necessarily being pioneers.

Caspar Von Guionneau: What other technologies, aside from GPS and RTK support, do you use in your machines?

Henning: We're incorporating automation in our farm operations, replacing manual labor with machines, especially for simple tasks. However, we maintain a balance to ensure we have the necessary human workforce in case of technological failures.

Caspar Von Guionneau: How do you inform yourself about precision or smart farming? What are your most valuable information sources? Do you feel there are enough resources for you to make informed decisions?

Question 4: How do you educate yourself about precision or smart farming? What are your most valuable sources of information? Do you feel there's a gap in available resources to make informed decisions?

Henning: My knowledge is somewhat outdated. We know about the capabilities, like field mapping and creating application maps, but the practical application and decision-making based on these technologies are unclear. I haven't come across new literature or insights on this.

Caspar Von Guionneau: Do you think there's been a decline in interest or progress in agricultural digitalization since 2016?

Henning: There was a trend where many feared missing out on digitalization, but that has subsided. We've learned that some technologies don't just become standard, like smartphone apps for agriculture. However, there hasn't been a significant breakthrough in digitalization where one feels compelled to adopt it urgently.

Henning: We keep up with digitalization, but it hasn't translated into obvious success yet. The real turning point will be when digital solutions become essential for competitive farming.

8.3.4 Interview Between Caspar von Guionneau and Julius Marshall

Julius von Marschall: I run a 1200-hectare farm in Saxony. Initially, we invested in modernizing outdated equipment. We've upgraded to using farm management systems like Next Farming and the John Deere Operation Center, enhancing productivity and sustainability.

Julius von Marschall: Over the years, our wheat yield has significantly increased, thanks to technology and machine efficiency. We've adopted RTK GPS-guided driving and improved inter-machine communication.

Julius von Marschall: Technological adaptability is key. We learn about new technologies through fairs, magazines, and working groups. It's crucial to have the right staff who can effectively use the technology. External factors like politics and regulations also significantly impact our decisions regarding technology adoption.

Julius von Marschall: We're planning to invest in a new grain facility and are always on the lookout for innovative technologies that can enhance our operations, especially as we adapt to changing agricultural practices and environmental conditions.

8.3.5 Interview Between Caspar von Guionneau and Philipp Langels

Caspar von Guionneau: We're discussing the impact of new technologies like IoT, Cloud Computing, AI, Big Data, and robotics on farm efficiency, productivity, and sustainability.

Philipp Langels: Our farm primarily focuses on crops like rapeseed, wheat, barley, and renewable energy sources like maize for biogas. We've built biogas plants in collaboration with an investor. Aside from crop farming, we're also involved in horse breeding.

Philipp Langels: In terms of digitalization, we're quite traditional in crop farming, with minimal technological advancements. Our primary focus has been on maintaining a classic farming approach without significant digital integration.

Philipp Langels: We've made some strides in the horse breeding sector. We've installed AI cameras in stables to monitor behavior patterns and predict foal births with high accuracy. This technology has greatly improved our efficiency and productivity, offering a more restful approach than traditional methods.

Philipp Langels: Our farm utilizes technology to a certain extent, like machinery that communicates with each other and GPS systems. We're exploring precision farming to optimize resource use but haven't fully implemented it yet.

Philipp Langels: External factors like climate change and environmental policies significantly influence our decision-making, especially in adopting new agricultural technologies. We aim for resource efficiency, particularly in plant protection and fertilization.

Philipp Langels: Financial incentives and subsidies play a crucial role in adopting new technologies. Demonstrations and case studies are important for making informed decisions.

Philipp Langels: A major challenge in adopting new technologies is finding the right balance between practicality and innovation. We prefer to observe and learn from pioneering farms before fully committing to new technologies.

Philipp Langels: There's a need for more integrated digital systems that can simplify complex farm operations and decision-making processes.