Lisbon School of Economics & Management
Universidade de Lisboa

MASTER

MANAGEMENT INFORMATION SYSTEMS

MASTER´S FINAL WORK

DISSERTATION

THE BENEFITS OF INDUSTRY 4.0 FOR THE AGRICULTURAL SECTOR

AFONSO LEÇA GONÇALVES

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SUPERVISION:
PROFESSOR DOCTOR WINNIE NG PICOTO

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“Talent without working hard is nothing.”

Cristiano Ronaldo

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ABSTRACT

This dissertation explores the benefits of Industry 4.0 technologies for the agricultural sector. The rapid growth of the global population, combined with escalating challenges such as climate change, resource scarcity, and food insecurity, calls for the adoption of innovative, efficient agricultural practices.

The study highlights how technologies like the Internet of Things (IoT), Artificial Intelligence (AI), Robotics, and Cloud Computing (CC) can be integrated into modern farming practices, leading to improvements in productivity, resource management, and sustainability. Through case studies of two companies—GESBA, a banana production company, and Madeira Wine Company—the research investigates how Industry 4.0 technologies optimize agricultural processes, enhance product quality, and contribute to environmental sustainability.

Key findings indicate that the adoption of smart technologies leads to increased efficiency, cost reductions, and improved decision-making in agriculture. However, barriers such as high initial investment costs and a lack of digital literacy among farmers remain significant challenges. This research provides valuable insights into the economic implications of Industry 4.0 for agriculture, particularly in enhancing competitiveness, market access, and profitability. It also highlights the future potential for expanding technology adoption across diverse agricultural contexts to ensure long-term sustainability.

Keywords: Industry 4.0, Agriculture 4.0, Smart Farming, Precision Agriculture, Sustainable Agriculture.

RESUMO

Esta dissertação explora os benefícios das tecnologias da Indústria 4.0 para o sector agrícola. O rápido crescimento da população mundial, juntamente com o aumento de desafios como as alterações climáticas, a escassez de recursos e a insegurança alimentar, exige a adoção de práticas agrícolas inovadoras e eficientes.

O estudo destaca a forma como tecnologias como a Internet of Things (IoT), a Inteligência Artificial (IA), a Robótica e o Cloud Computing (CC) podem ser integradas nas práticas agrícolas modernas, o que origina melhorias na produtividade, na gestão de recursos e na sustentabilidade. Através de estudos de caso de duas empresas - a GESBA, uma empresa de produção de bananas, e a Madeira Wine Company – o presente trabalho investiga a forma como as tecnologias da Indústria 4.0 otimizam os processos agrícolas, melhoram a qualidade dos produtos e contribuem para a sustentabilidade ambiental.

As principais conclusões indicam que a adoção de tecnologias inteligentes conduz a uma maior eficiência, a reduções de custos e a uma melhor tomada de decisões na agricultura. No entanto, barreiras como os elevados custos de investimento inicial e a falta de literacia digital entre os agricultores continuam a ser desafios significativos. Esta investigação fornece informações valiosas sobre as implicações económicas da Indústria 4.0 para a agricultura, particularmente no que diz respeito ao aumento da competitividade, do acesso ao mercado e da rentabilidade. Para além disso é também destacado o potencial futuro para expandir a adoção de tecnologia em diversos contextos agrícolas para garantir a sustentabilidade a longo prazo.

Palavras-Chave: Indústria 4.0, Agricultura 4.0, Agricultura Inteligente, Agricultura de Precisão, Agricultura Sustentável.

GLOSSARY

AI – Artificial Intelligence

CC – Cloud Computing

DSS – Decision Support Systems

DL – Deep Learning

DRA - Directorate of Agriculture in Madeira

GESBA – Empresa de Gestão do Setor da Banana, Lda

IG1 – GESBA 1

IG2 – GESBA 2

IG3 – GESBA3

IoT – Internet of Things

ML – Machine Learning

IMW1 – Madeira Wine 1

IMW2 – Madeira Wine 2

IMW3 – Madeira Wine 3

MWC – Madeira Wine Company

RQ – Research Questions

ROI – Return on Investment

RAS - Robotics and Autonomous Systems

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1. INTRODUCTION

The human population is growing exponentially, which means that the resources necessary for human life will decrease rapidly at a dangerous pace. One of the main resources for human life is food, more specifically all types of food produced by agriculture. With starvation and malnutrition reaching all-time highs, companies and farmers must develop efficient and waste-free agricultural systems (Muhie, 2022).

In addition, climate changes are altering the environment mainly due to greenhouse gas emissions by the main production sector such as agriculture. With these climate alterations, external factors to agriculture such as variability of precipitation, and rise in droughts and floods, will lead to groundwater depletion, and soil degradation causing a reduction of productivity in agriculture (Biel et al., 2018).

As the population continues to grow and the environment becomes more unstable, consumers will have to take caution in the quality of their food. In order to meet food demand, by 2050 food production will have to be doubled or famine will continue to rise. With the factors contributing to scarce resources such as water and even land, which continue to decrease, farmers need to be able to implement smart and updated solutions to oppose these issues and increase their crop yield with minimal resources wasted (Khan et al., 2021).

On the other hand, in the past decade, there have been significant technological breakthroughs, especially when it comes to advancements in the industry sector, with the creation and development of technologies set to increase productivity and decrease surplus (Araújo et al., 2021). The current evolution of the industry sector is Industry 4.0, as it stands as the present and the future of the industry sector, and it can be redeemed as the future of farming as well (Biel et al., 2018). This trend named Agriculture 4.0 uses technologies such as Internet of Things (IoT), Artificial Intelligence (AI), machine learning (ML), Robotics, and Cloud Computing (CC) towards a more sustainable, productive, and environmentally friendly agriculture by monitoring and controlling the weather, soil, water usage, fertilization, and diseases (Araújo et al., 2021).

Considering the problems regarding overpopulation and world famine, the introduction of Industry 4.0 in agriculture may be considered a useful revolution in the

sector toward more sustainable and productive farming worldwide. Though, the proposed research questions (RQ) are:

RQ1: Why are Industry 4.0 technologies beneficial for the agricultural sector?

RQ2: What are the challenges to the implementation of Industry 4.0 technologies in the agricultural sector?

With the aim of answering these research questions, the following objectives were set:

O1: Verify the benefits and barriers that Industry 4.0 can bring to this sector.

O2: Evaluate the economic outcomes of implementing Industry 4.0 technologies in agriculture (profitability, market access, and competitiveness).

O3: Understand the challenges behind Industry 4.0 technologies and how to surpass them.

In order to meet the objectives, two case studies were conducted with different companies within the agricultural sector. The primary source of information is semi-structured interviews alongside three top-level managers of each company, with different roles in the organization.

This document, structured into six distinct chapters, was written with the assistance of Artificial Intelligence to guide the paper's format and also to correct mistakes. Starting with the first chapter, we find the introduction, which outlines the reasoning behind the selection of the topic, articulates the research objectives, and delineates the study structure. Next, in the second chapter, a deep analysis of the literature is conducted, including the relevant theoretical foundations of the topic in question. The third chapter presents the chosen methodology and outlines the empirical investigations carried out. In the fourth chapter, the organizations studied are displayed alongside the reasoning behind the choices. The fifth chapter contains the analysis and discussion of the obtained results. Finally, in the sixth and last chapter, the study's conclusions, contributions, inherent limitations, and recommendations for future research are presented.

2. LITERATURE REVIEW

Throughout this dissertation, there are several important concepts within Industry 4.0 and their relevance to the agricultural sector that are discussed and defined in this

literature review. Moreover, in this literature review, there is an extensive assessment of the changes in, not only the production part of the agricultural sector but also the impact of Industry 4.0 on the supply chain and socio-economical level.

2.1. Industry 4.0 in Agriculture

There are many issues worldwide that heavily impact the agricultural sector. The increase in demand for food due to demographics, the stress on natural resources, climate changes, and food waste are all problems damaging to the agricultural sector. A practical solution presented to counteract these problems is Agriculture 4.0, as it tends to disrupt regular farming practices by using new technologies (Biel et al., 2018).

The incorporation of Industry 4.0 in agriculture arose alongside the impact of digital transformation as well as the need to enhance economic growth and agricultural production. By implementing the technologies used in Industry 4.0, the agricultural sector went through a revolution by integrating smart technologies, sensors, actuators, and communication technologies into farming practices, thus creating Agriculture 4.0 (Kovács & Husti, 2018).

On the other hand, the digitalization of the agriculture sector alongside Industry 4.0 is not always possible due to the existing barriers in this sector. The main setbacks to digitalization are the cost associated with smart systems, the lack of knowledge from farmers about these new technologies, concerns about the return on investment from the implementation of these technologies, the lack of trust from farmers in the technologies as there are few empirical evidence of the benefits they bring to the sector and, regulations and laws can have a significant impact as they change (Abbasi et al., 2022).

2.2. Key Technologies in Agriculture 4.0

Agriculture 4.0 includes a range of technologies for the improvement of farming practice's efficiency, sustainability, and productivity. These technologies interact to form an integrated system that relies on data for automatic and systematic coordination of farming activities. The most noticeable technologies are smart and precision agriculture tools, their digitization and automation, and the embedding of cyber-physical systems in IoT.

2.2.1. Smart and Precision Farming

Smart Farming, smart agriculture, digital farming, or Agriculture 4.0 provide technological tools to help farmers face several challenges inherent to the agricultural sector. "Likewise, a wide variety of parameters related to environmental factors, weed control, crop production status, water management, soil conditions, irrigation scheduling, herbicides, and pesticides, and controlled environment agriculture can be monitored and analysed in smart agriculture to increase crop yields, minimize costs, enhance product quality, and maintain process inputs through the use of modern systems" (Abbasi et al., 2022, p.2).

The potential impact smart farming has on agriculture is tremendous as it can optimize resources used in production and also increase crop yield. By using technologies such as IoT, remote sensing, and AI, several processes within the agricultural process can be handled in a better fashion (Javaid et al., 2022).

Precision Farming is a process for farming that requires a set of practices that utilize high-tech solutions, such as GPS-assisted tractors and unmanned aerial vehicles, which aim to increase productivity and quality, thus reducing manual labour and enhancing sustainability. It is believed that real-time data collection and sensing technologies are some of the main components to increase productivity as the farmers can gather the information in real-time and make more effective decisions towards sustainable production. (Ferrari & Fresco, 2018).

Nowadays the expansion of precision farming depends on the economic and technological evolution of the world as well as the changes in legislation worldwide. Despite this process's importance and consequential advantages, it has not been very usable in smaller farms and less developed countries, but it is mainly limited to large farms in developed countries (Finger et al., 2019).

By integrating smart farming systems, farmers can make informed decisions that increase productivity, reduce costs, and improve environmental sustainability. Technologies like machine learning and AI play a key role in this by analysing large datasets to forecast crop growth patterns, detect diseases, and enhance harvesting precision (Kashapov et al., 2019). This fusion of technology allows farmers to tailor

agricultural practices based on real-time data and predictive analytics, resulting in a more resilient farming system.

2.2.2. Agricultural Digitization and Automation

The transformation of agriculture to the digital and technological world has been very significant and tremendously important in achieving optimal results. The digitalization of the agricultural process can affect the formation and development of integrated systems for crop production as they can control the amount of fertilizer, detect diseases, and optimize crop yield. This process aims to improve productivity, and the quality of agricultural products, and reduce costs by implementing analytical information systems and cutting-edge technology in the production process. As digitalization inevitably happens, the information systems installed have to be reliable and adapt according to real-time changes, however, they should be easily accessible to the user so that they can make informed decisions and increase the overall crop yield (Kashapov et al., 2019).

Digitalization has transformed the agricultural sector by automating processes, enabling remote management, and optimizing decision-making through advanced data analytics. Cloud computing and data-driven systems have become essential components of modern agriculture, providing farmers with access to computational resources without the need for expensive on-site infrastructure (Radadiya et al., 2016).

Cloud computing allows farmers to store and analyse vast amounts of data, such as weather patterns, soil conditions, and market prices, helping them to make more informed and strategic decisions. This technology also facilitates the use of Decision Support Systems (DSS), which provide actionable insights by processing real-time agricultural data (Zhai et al., 2020). DSS tools have been shown to improve operational efficiency by assisting farmers in optimizing resource allocation and planning crop cycles.

The digitalization of agriculture is an important process to develop the sector, however, several challenges can delay this process. The main barrier to the embrace of a digital agricultural sector is the lack of investment in some countries which leads to farmers maintaining cheaper methods of production with overall low production. Psychological barriers, installation of ineffective information systems, and lack of adequate training all constitute major barriers to the implementation of digitalization in agriculture leading to less sustainable farming on all accounts (Alt et al., 2020).

Furthermore, automation technologies, such as robotics, have also revolutionized agricultural production by reducing labour-intensive tasks and enhancing precision. Robots can perform tasks such as planting, harvesting, and spraying pesticides with greater speed and accuracy than manual labour (Liu et al., 2021). The use of autonomous systems has been particularly beneficial in areas where labour shortages are a significant challenge. In addition, by automating repetitive tasks, farmers can focus on more strategic activities, ultimately leading to increased profitability and productivity.

2.2.3. Cyber-Physical Systems and Internet of Things (IoT) Integration

"Digital transformation is disrupting the agricultural world. IoT technologies allow correlations of structured and unstructured data to provide insights into food production" (Biel et al., 2018, p.16).

The application of IoT came as a central part of Industry 4.0 as it helped create a smarter and more connected world. Naturally, this technology has taken part in revolutionizing the agricultural sector alongside Agriculture 4.0. The technologies related to IoT that are relevant to agriculture and help in varied processes to improve productivity, supply chain efficiency, food safety, and natural resource management can be, for example, precision farming, livestock monitoring, smart greenhouse, fishery management, and weather tracking (Liu et al., 2021).

IoT in the agricultural process can be broken down into four key steps. The first step involves data gathering at the physical layer, where various environmental parameters such as temperature, humidity, pH levels, and water levels are monitored. Next, the collected data is transmitted through the network layer using communication tools like Bluetooth. In the third step, this data is stored in the service layer, typically utilizing CC. Finally, in the application layer, the stored data is used to develop smart applications that enable farmers to optimize and enhance their farming practices through these technologies (Abbasi et al., 2022).

Integrating cyber-physical systems in farming can be a steppingstone to the future as the benefits of this technology are immense and can lead to additional value for the food supply chain and more sustainable agriculture. The cyber-physical systems can assure optimal results as they interconnect intelligent sensor networks for monitoring and control, and with these systems there is a real-time monitoring of the crops planted.

Within these systems, precision agriculture is one of the most applied, as it uses sensor networks, intelligent analytical applications, and smart logistics systems in order to provide solutions to optimize soil quality, productivity, and crop selection according to soil and weather conditions (Caramihai et al., 2017).

The integration of these technologies not only improves resource management but also enhances traceability within the agricultural supply chain. Technologies such as blockchain can be used in conjunction with IoT systems to track the journey of products from farm to table, ensuring food safety and quality standards (Sharma et al., 2021). This increased transparency and traceability help farmers meet regulatory requirements and build consumer trust.

2.2.4. Artificial intelligence (AI) and Robotics in farming

Artificial intelligence is considered to be one of the most important drivers towards Agriculture 4.0, given their ability to discern intricate patterns, trends, and relationships within diverse and multifaceted agricultural data, these systems excel at making precise predictions. As a result, they establish a robust groundwork for enhancing decision-making and managing operations more effectively in agriculture (Araújo et al., 2021).

By using this technology combined with IoT, big data, Machine Learning, Deep Learning, and others, it is possible to improve crop production by enhancing processes in real-time such as monitoring, harvesting, processing, and marketing. Furthermore, the technologies within AI, such as ML or DL, can help by monitoring and predicting certain models related to weed detection, yield prediction, or disease identification (Abbasi et al., 2022).

In addition, Robotics and autonomous systems (RAS) are widely used in the agricultural sector as they can replace human tasks in agricultural labour. The use of these systems has the potential to impact production patterns and processes through several applications such as fruit counting and harvesting, leaf peeling, selective spraying, 3-D mapping, and others (Liu et al., 2021).

Intelligent farms are capable of using robotics to perform everyday tasks without the human workforce. For instance, planting, harvesting, or spraying pesticides and monitoring crops and soils can be done by robotics by using algorithms fed by drones gathered data, or other software technologies (Javaid et al., 2022).

2.2.5. Decision support systems in agriculture

"As advanced information systems and Internet technologies are adopted in Agriculture 4.0, enormous farming data, such as meteorological information, soil conditions, marketing demands, and land uses, can be collected, analysed, and processed for assisting farmers in making appropriate decisions and obtaining higher profits" (Zhai et al., 2020, p.1).

Data analytics aligned with DSS is critical during the production process however it is being widely used in the decision-making process. By using this technology in processing, logistics, marketing, and food supply management, managers can make informed decisions and change production and consumption patterns depending on the data analysis (Liu et al., 2021).

Even though the potential of DSS is recognized in its role to help farmers in crop production by providing important information. However, its success is limited and has failed throughout the years due to some mishaps in its conception and implementation. Some of the main reasons for the failures of DSS can be tracked down to the lack of computerization among farms due to its initial cost, also the systems' complexity can sometimes be a barrier to its success as the farmers are prone to discharge them if they do not understand the interface behind the end-product. Additionally, some systems require specific inputs to formulate valuable hypotheses which the farmers sometimes are not able to provide, and the DSS can also fail to support more than one exceptional circumstance in the environment surrounding the crops, leading to less insightful predictions (Lindblom et al., 2016).

2.3. Economic Implications of Industry 4.0

The implementation of Industry 4.0 in agriculture has large economic implications for the sector. By using robots, IoT, monitoring systems, and data analytics, the agricultural process becomes more efficient whether in resources such as pesticide use or also in cost due to more efficient resource management such as optimized water usage and less dependence on human labour, leading to lower labour costs. Additionally, by adopting new technologies to the process, the agricultural sector can increase its competitiveness in the global market and with accurate management of resources and improved

productivity, a country's position relative to others can elevate in the international trade market (Prigoreanu & Idriceanu, 2023).

Alongside the specialization and increase in knowledge by the farmers, comes better-informed decisions from real-time data and predictive analysis which will lead to increased crop yields and consequentially, higher incomes for the farmers. Moreover, the increase in efficiency in agriculture practices will automatically stimulate growth in the agricultural economy (Prigoreanu & Idriceanu, 2023).

By improving crop quality and yield, economies that depend on farming for livelihood can either export products overseas and create value for the farmers and the economy itself or raise prices domestically ensuring growth in the local economy. As they increase local production, fewer and fewer food imports will take place, positively affecting the producers. In addition, as the local culture evolves and develops regarding technology and the economy, it can attract investment, further boosting the economy (Collado et al., 2018).

Furthermore, the integration of technology helps farmers meet strict international standards for food safety and sustainability, which is crucial for accessing premium export markets. By improving compliance with environmental and food safety regulations, Industry 4.0 technologies enable farmers to secure higher profits through access to new customers and higher-value market segments (Ronaghi, 2020).

On the other hand, several disadvantages have been considered in implementing Industry 4.0 and its technologies into crop production. The main impeachment remains the initial investment to develop, install, and train workers to operate the new technologies. Small producers have a hard time keeping up with the new technologies, mainly due to a lack of private or public funding, even though the long-term benefits and cost savings outweigh the initial cost (Collado et al., 2018).

2.4. Industry 4.0 in Agricultural Supply Chain

"Supply chain refers to the design, engineering, production and distribution processes of goods and services from suppliers to customers." (Ronaghi, 2020, p.399).

In agriculture, the supply chains are very important so the crops harvested can reach their final consumer. With a reliable supply chain, the whole agricultural process can

ensure efficient resource utilization, by optimizing water, fertilizer, and labour usage, it can lead to more sustainable practices without depleting natural resources, it can enhance food quality and security by using technologies such as Blockchain and IoT, ensuring that they meet safety and health standards and also reducing the risk lower quality products (Sharma et al., 2021).

With effective supply chains, the coordination and collaboration between stakeholders increases leads to fewer delays, and reduces inefficiencies. By adding automation technologies to the supply chain, the processes will become much quicker as well as effective due to the decrease in reliance on manual labour, which will eventually lead to economic viability because of the reduced waste and cost. As the logistics and the flow of goods improve, the supply chains provide the farmers with better access to more customers and improve economic prospects which will also allow them to adapt accordingly to what the market demands are for a better outcome and higher income for the producers (Sharma et al., 2021).

Furthermore, having an enhanced supply chain increases the literacy among farmers and their readiness to use new technologies in their production process, which will eventually lead to cost-effectiveness in the long run with the benefits of a rise in productivity, income, and also the integration of achieving sustainability goals (Bawa & Bhaskara, 2021).

3. METHODOLOGY AND DATA COLLECTION

The following study is conducted around the concept of Industry 4.0, especially in its impact on the agricultural sector.

Since the research questions regarding this thesis are: “Why are Industry 4.0 technologies beneficial for the agricultural sector?”, “What are the challenges to the implementation of Industry 4.0 technologies in the agricultural sector?”, the study conducted consists of two case studies, using a qualitative approach with the technical analysis of the content alongside the gathering of important statistical information about the company, allowing for deeper study conducted (Yin, 2018).

According to the guidelines by Saunders et al. (2009), the research questions and the objectives of the investigation are very important to set the initial approach for the study conducted. The main objective of this thesis is to understand the impact of Industry 4.0

technologies in the agricultural sector and, by setting this goal, the clearer path to enlightenment about the subject turned out to be the conduction of a case study.

In this context, where the technological impact is critical to the outcome of the study, Pozzebon & Freitas (1998) tell us that the use of a case study is a well-thought strategy. Moreover, the fact that digital transformation and the update of new practices can rise at any moment can be better looked into with an on-time study, and also the fact that Industry 4.0 is a relatively current can lead to a lack of literature meaningful to this study (Yin, 2018).

Along with the arguments stated by Yin (2018), the study needs to have a unit of measurement or comparison. In this thesis, the aim is to understand the impact of Industry 4.0 by studying different companies in the agricultural sector and the same region, in order to understand the differences and similarities between relatively to the introduction of new technologies in their process and how it evolved their company.

3.1.Data Collection Methodology

According to Yin (2018), one of the best and most primordial ways to collect data for a case study is through interviews. In any case, interviews can consist of all types and formats, however, to match the context of the current study, semi-structured interviews were conducted as a primary source of data. This method is the predominant means of data collection in qualitative research, where the effectiveness of the interview guide significantly influences the results obtained, due to the adaptability and flexibility exhibited to ensure the complexity of the interviewee (Kallio et al., 2016).

The script of the interviews conducted was the product of an extensive literature review on the matter at hand, thus leading to a comprehensive understanding of the topic being investigated. The literature review presented earlier does not have an objective to answer the research questions, but its main goal is to allow the person conducting the study to frame more relevant and more precise questions relative to the subject studied Yin (2018). The questions formulated for the script were also thought of sequentially, in order to guide the interview in the best way possible, even though the order does not need to be meticulously followed, thus ensuring the interviewer some spontaneity and the interviewee the capacity to contribute with relevant information about the company itself (Kallio, 2016). Also, at the beginning of the interview, the interviewees had an

explanation of the investigation being conducted, its objectives, and the role of the interviews themselves.

Furthermore, selecting the interviewees is an important step in creating the case study and, consequently, a theory based on the proposed methodology (Eisenhardt, 1989). Therefore, the people selected to participate in these interviews are professionals in the agricultural sector, particularly with management-level positions to ensure the most possible knowledge of the company´s evolution on the subject. Within the two companies selected, three employees each were chosen to provide a different point of view about the evolution of the company regarding the use of Industry 4.0 in their process.

The two companies chosen for this study were GESBA (Empresa de Gestão do Setor da Banana, Lda), a banana production company, and MadeiraWineCompany, which focuses on wine and grape production. These two companies operate in the same area which reduces the interference of external factors and offers the same outcome regarding environmental and cultural factors. Additionally, selecting different types of companies with distinctive crops can effectively reach a more complex study by observing certain technologies in unique crops.

The choice of each company came with the fact that GESBA oversees most of the banana production in Madeira Island and has already implemented technologies to innovate their process and become more operationally efficient. Whereas MadeiraWineCompany has a smaller dimension and is still looking out for the benefits Industry 4.0 technologies can bring to their production process by developing several studies.

Given the reach and unexpectedness of the theme, the investigator chose to have only six interviewees, from two different companies, from the agricultural sector, and the same region. Thus, the validity of the results increases, reducing the chances of deviation from external factors such as wind, water availability, or natural catastrophes.

3.2. Data Analysis Methodology

Following the directions by Yin (2018), the interviews were recorded, with the previous consent of the interviewees, for a better understanding of the content of the interviews. Afterward, the recorded interviews were transcribed into written documents, using Microsoft Word, more specifically the Voice Dictate function aligned with a

meticulous overview of the data to ensure minimal transcription errors and increase precision. Additionally, the interviews were conducted in Portuguese to ensure the most perception on the interviewees' part and then were translated into English for further analysis.

In order to produce useful and quality data, a secure and objective analysis of the content derived from the interviews must be conducted, therefore being able, in the end, to create theoretical knowledge from such analysis (Bardin, 2016). The main goal is to synthesize relevant information capable of answering the RQ initially asked. Therefore, an exhaustive and detailed, as much as possible, qualitative analysis is conducted.

As recommended by Saunders et al. (2009), this process can be handled through the use of the software named Computer Assisted Qualitative Data Analysis (CAQDAS), instead of the manual method traditionally applied. The software chosen for this data evaluation is the recent version of MAXQDA Analytics Pro 2022, due to its ability to code text and create graphic representations of the analysis alongside, the classification and organization of the acquired data.

According to Saunders et al. (2009), the coding process translates into the identification of categories, defined as codes, which are then used to group data. This process facilitates the connection between data, the hypothesis, and its realization, and, subsequentially, the arrival of conclusions and execution of quantitative analysis.

The coding process relies on coherent and connected categories to allow a well-defined analytical board leading to the advanced part of the analysis (Saunders et al., 2009). Therefore, the categories chosen are based on the subjects identified in the literature review as well as categories brought up from the data collected.

After the installation of the software, the next step was to download the documents of the interviews. Later, categories and subcategories were created from the designated subjects or codes, to create text segments for the coding. For the creation of these codes, the first step consisted of the creation of main categories, aligned with the topics established both in the literature review and in the interview script. Afterward, as the interviews were being read, subcategories were created with the “in vivo” approach, where the name is defined according to interviewees' responses (Corbin & Strauss, 2008). At the same time, the subcategories were reviewed to verify possible repetitions or

similarities between them. In the Visual Tool of MAXQDA, there are several options on how to present the analysed data, however, the option of creating a Code Matrix was the most interesting. With this matrix, we can have an overview of the topics discussed in each one of the interviews (Gizzi & Rädiker, 2021).

As shown in Figures 1, 2, 3, and 4 (see Annex C – MAXQDA Software), the Code Matrix obtained from the three interviews with GESBA's and MWC's employees shows us all the discussed aspects of the interviews, respectively. In addition, the Sum option was selected to verify the total number of times a certain topic was approached and the proportion of codes per interview. As a result of this careful examination, a total of 256 codes were created.

Then the analysis of the codes was conducted for each of the case studies individually, i.e. within-case analysis, and, through cross-case analysis where the goal is to establish common patterns, themes, and differences, enabling the researcher to evaluate the results of the two companies to reach further conclusions.

4. CASE STUDY

In this thesis, two distinct case studies were conducted with two different companies. In these case studies, semi-structured interviews were held with three employees of the same company although, with separate functions within the company. The goal was to understand the unique points of view from different positions in the company regarding the evolution of the agricultural process within the company aligned with Industry 4.0 technologies.

By selecting two companies from the same region, the comparison between them can be made with less interference from external factors because they share the same factors which can tamper with their outcome, crop-wise. On the other hand, the choice to have two companies with different types of crops allows the study to reach for more complexity and observe various types of technologies used depending on the specific crop.

4.1.Organizations Display

4.1.1. Case Study 1 - GESBA

GESBA is a banana-producing company from Madeira Island. The company was selected to participate in this case study since it monitors most of the major banana

producers on the Island intending to reach the best product possible. In the last fifteen years, GESBA has strongly invested in the training of farmers and staff of the company, alongside innovation and modernization of the sector with the development and requalification of new infrastructures which allowed the quality stamp of their brand. In 2023, the banana production company-wide increased 10,88% leading to almost 26 million euros in Turnover.

Nowadays, GESBA harbours the production of more than two thousand banana producers, taking part mostly in the harvest and collection of the bananas followed by the classification, certification, packaging, and preparation for distribution and commerce with the help of 278 employees. These processes are only possible through the innovation of the company and the use of Industry 4.0 Technologies, mentioned in Table 1 (Annex A), by developing a research centre facility with fifteen thousand square meters intending to create new practices and technologies in the agricultural process, considering the certifications the brand relies on, and also in a biological production method (Internal Documentation).

4.1.2. Case Study 2 - Madeira Wine Company, S.A.

The following organization selected for this case study is a wine-producing company from Madeira Island, with roughly thirty employees, created in 1913. The Madeira Wine Company, S.A. (MWC) distinguishes itself by taking advantage of the island's tropical climate and beneficial conditions to grow vineyards distinct from any other in the world. This company was chosen for this case study because of the increasing difficulties in grape production and the necessity to evolve as a brand to ensure maximum quality and efficient global distribution (Internal Documentation).

The MWC oversees grape production from over three hundred and thirty farmers throughout the year to support industry development and provide them with modern practices and devices to enrich production besides controlling 8,4 acres of grape production on their own, mounting up to nearly 47 tons of grapes in the year 2023. Even though there are no technologies present in the agricultural process, in the present year, the company is developing several projects to ensure the progress of the industry. Among them, there is a research and development program to understand how climate change can impact the viticulture on the island and there is a project where the farms owned by the

company are collaborating with the Directorate of Agriculture in Madeira (DRA) to help develop a project to implement Precision Agriculture in the company's vineyards (Internal Documentation).

5. RESULTS AND DATA ANALYSIS

This chapter displays a thorough analysis and interpretation of the gathered data from the two case studies conducted. The attained results consist of semi-structured interviews conducted on three different employees from the two companies selected as well as information related to the company. In addition, the results obtained are discussed considering the existing literature, thus establishing a comparative framework to validate the research objectives.

Following Yin's (2018) approach to multi-case study methodology, the findings presented in this chapter are both from within-case analysis and cross-case analysis. These types of analysis combined allow for a thorough examination of the cases individually as well as both cases together evaluating patterns and distinctions from both companies.

Additionally, as stated in the previous chapter, the data gathered was analysed through the software MAXQDA, which allowed the researcher to categorize the interview subjects according to the topics discussed in the literature review.

5.1. Results Overview

In this chapter, the findings of the interviews conducted address several aspects of the impact of these technologies on agricultural practices, including efficiency, sustainability, profitability, and market access. By developing a multi-case approach, it is possible to evaluate the influence that Industry 4.0 technologies can have on both banana and grape production. Each of the sub-chapters represents the codes that originated in the interviews and were then selected through MAXQDA, providing a thorough examination based on empirical data.

The organization of the results in this chapter has a goal, the comprehensive analysis of the advantages and disadvantages of Industry 4.0 technologies and how they can act in real-world conditions in the agricultural sector. The chapters about the Benefits of Industry 4.0 for Agriculture offer a wider insight on the gains these technologies bring, whereas the chapters about Efficiency, and Yield Improvement show more specific

attributes of the technologies and how they can be used to improve productivity, reduce resource usage, and optimize decision-making processes.

In addition, the chapters regarding Market Access, Profitability, and Resource Allocation provide the answers to how the technologies can aid the companies´ financial and operational status by utilizing different technologies such as automation, real-time data collection, or precision farming techniques. Furthermore, there were two chapters included in the results about the Barriers to Industry 4.0 Adoption and the strategies GESBA and MWC are trying to deploy to counteract these challenges. By understanding the companies´ restraints such as high initial investment costs or lack of digital literacy, it is possible to better evaluate the strategies planned to mitigate these risks.

Finally, this study discussed the Processes Before Industry 4.0 Adoption, which details the previous steps to Industry 4.0 adoption, and how they can prepare themselves for such eventualities with the help of certain approaches for instance resource planning. workforce training, and feasibility studies. Alongside these processes the Future Implementations of each company were discussed because they offer a forward-thinking perspective, underlining how both companies plan to adopt new technologies, including predictive models and automated systems, to enhance productivity and sustainability.

5.2. Benefits of Industry 4.0 for Agriculture

The adoption of Industry 4.0 technologies in agriculture promises to bring several significant advantages as GESBA´s and MWC's employees discuss. The interviewees enlightened the subject by referring to relevant topics such as improvement in quality, efficiency, sustainability, traceability, and decision-making processes.

One of the most important aspects studied that would validate the implementation of Industry 4.0 Technologies is product Quality and Customer Feedback. By implementing automation in the process, a quality rise has been detected, especially in the packaging process "With this assembly line, the quality of the banana leaving from the factory has improved certainly" (GESBA 3). The improved handling of the bananas during packaging has had a noticeable direct impact on the quality of the bananas, as the interviewee GESBA 3 (IG3) states "With the improvement in the processes, the quality of the product itself has improved for sure". Moreover, both interviewees GESBA 1 (IG1) and GESBA 2 (IG2) confirmed that both consumers and producers have expressed positive feedback

regarding the product quality. The interviewee IG1 states "The end consumer feels better about our product because it has better quality due to the improvement of labour conditions, whether in the factory or the fields", also adds the producers' reactions as "(…) the producers feel proud about the way their product is being taken care of in the factory". The interviewee IG2 further acknowledged the positive impact on the customers about the product and the new practices "(…) the end product is better, so I believe the customers' feedback has been positive(...) The ones that visit our development centre seem impressed with the progress". However, the interviewee IG3 claims that some issues have arisen due to the distributors' lack of compliance with specific guidelines "(…) there have been some complaints... Bananas have to be stored at an ideal temperature of between 12 or 14 degrees Celsius, but sometimes the distributors... do not comply with these specifications".

Regarding MWC one of the main benefits acknowledged was the increased Operational Efficiency the technologies can offer. Both interviewees MadeiraWine1 (IMW1) and MadeiraWine3 (IMW3) mention that by implementing certain technologies, MWC can reduce manual labour and optimize productivity. According to interviewee IMW3 and Liu et al. (2021), by implementing monitoring technologies, they will be able to "perform live-time assessments of the plant and act on it in the fastest way possible, increasing efficiency and reducing the farmers' efforts", and the interviewee IMW1 back up the statement by saying that these technologies would allow "(…) or a more accurate harvest of the grapes, without the need for farmers to do check-ups on the field". Furthermore, these technologies can enhance the monitoring capabilities of the company, as suggested by interviewee MadeiraWine2 (IMW2), the company is performing a study to verify these exact characteristics. The study aims to understand and control external factors that influence crop quality and productivity, "(…) conducting a study to understand the viability to implement sensors that can measure and control external factors such as density, humidity, and temperature (…)". Additionally, the interviewees IMW1 and IMW3 supported the previous statement by mentioning that with these monitoring technologies, the company can make more informed decisions about resource allocation, ultimately leading to higher yields and better quality products.

In terms of Sustainability, GESBA has made significant strides toward responsible resource use, a key benefit of Industry 4.0 technologies, which was backed up by the

MWC's employees. The implementation of technologies in GESBA's process allows the company to be more efficient, resource-wise, "resources such as water or fungicides are applied more precisely, thus decreasing its waste" (IG3). Furthermore, the employees recognize the new assembly line has its benefits, but it also requires more energy than the manual process. However, as the interviewee IG3 states, the processing centre is powered by solar panels which reduce the ecological footprint. In addition, the interviewee IG1 corroborated these facts and claimed that: "There has been a reduction in water and fertilizer usage, leading to lesser environmental impact, especially when it comes to water resources". Likewise, the interviewees IG1 and IG2 agreed that the use of technologies that allow the monitoring of crops leads to the increase in "(…) efficiency in the usage of water, fertilizers, or pesticides" (IG1), as well as "(…) lack of hydric resources globally, (…)" (IG2) can be mitigated by concentrated watering systems, "fewer resources have been wasted by using a more concentrated watering system" (IG2), which stands by the information by Finger et al. (2019) and Caramihai et al. (2017), as they also explain how precision agriculture technologies minimize resource waste and optimize crop production. According to the MWC interviewees, there is a necessity to perform sustainable agriculture due to the scarcity of natural resources such as water, and interviewee IMW1 attests to the possibility of countering this lack of resources, "In order to counteract these problems and other resource scarcities, studies have to be conducted to understand how we can be more sustainable in the usage of space, water, fertilizers, or pesticides". In addition, interviewees IMW2 and IMW3 stated that managing some of these inputs with the technologies that can be implemented will lead to increased efficiency and reduced resource waste, further improving MWC's commitment to sustainability.

Another concern brought about by both companies was the Enhanced Traceability through the supply chain. While in MWC the interviewees IMW1 and IMW3 state that implementing systems capable of efficiently monitoring and tracking the grapes from harvesting to bottling and then creating a database with several aspects about the grape behind the wine, will increase the transparency throughout the supply chain, as Sharma et al. (2021) mentions, the implementation of technologies in the same processes at GESBA have made a difference, according to interviewees IG1 and IG3. The reason for this can be explained by "(…) the implementation of the barcodes(...) there has been an

increase in the transparency of the supply chain" (IG3), i.e. the application of barcodes in the bananas as they come to the processing centre along with the database being implemented, allow the company to keep track of every shipment and deal with any issue effectively, "It is easier to track down who produced the banana and where to reach the root of the problem" (IG3). The same was corroborated by the interviewee IG1, as she mentioned that "with the implementation of barcodes... a large database was created, which allows us to keep track of every banana shipment, from what producer it is, what quality it is, and what certification it has". At last, Improved Decision-Making was one of the benefits identified by implementing Industry 4.0 technologies. All three GESBA's employees agree on this matter due to "improving efficiency and automating the processes, leaves less margin for error, facilitating the decision-making process as a whole" (IG3) and also the role of sensor technology in a much more conscientious decision-making process, just as Zhai et al. (2020) mentions. The interviewee IG1 supported the premise by saying: "With the monitoring of the crops with sensors, the decision-making process is much faster because the farmer gets live information and can act on it", the interviewee IG2 added that following the use of sensors, the data gathered can be used on the database to facilitate the decision-making process.

In summary, integrating Industry 4.0 technologies in the agriculture process is poised to bring substantial benefits, including better product quality, enhanced operational efficiency, greater traceability, and a stronger focus on sustainability.

5.3. Efficiency

The implementation of Industry 4.0 technologies in the companies' processes can increase their efficiency, and with the interviews conducted, topics such as time savings, automation of processes, and labour efficiency have been discussed to determine how these technologies have improved the company's agricultural productivity.

One of the most recognizable effects of the technologies implemented in the companies´ process is Time-Saving. Both companies' interviewees emphasized this aspect as interviewee IG1 stated "With the monitoring of the crops with sensors, the decision-making process is much faster because the farmer gets live information and can act on it". The interviewee also asserted the future importance of the app being developed "(…) to facilitate the process of knowing if the banana bunch is right for harvest with

more accuracy". On the other hand, interviewee IG2 highlights the achievements of the technological irrigation systems regarding time savings, stating: "Instead of watering for 30 minutes each day, farmers now water for fifteen minutes every two days". The interviewee also stresses the importance of the sensors for faster and more accurate actions according to the plants' necessities and, adds the reduction for on-site visits, taking less time from the farmers' schedule, thus improving efficiency. In MWC's case, this aspect was brought up by all three interviewees and further upheld the same benefits efficiency-wise as IMW3 stated, "With these technologies implemented, we hope to perform live-time assessments of the plant and act on it in the fastest way possible, increasing efficiency and reducing the farmers' efforts", or in other words, the real-time monitoring ability of MWC would enable the company to quickly respond to changing environmental conditions, optimizing resource use and minimizing delays in decision-making.

The increase in efficiency in GESBA's processes, especially in the production and packaging lines, comes from the Automation of Processes. Interviewee IG3 explains that the process suffered a massive shift and now the bananas go through the processing centre aided by robotics which reduces the margin for error, "Automating the processes leaves less margin for error (…)". The comments about the robotization of the process were supported and explained by interviewee IG1: "The robots read the barcodes and take the bananas to the right path to be processed". Alternatively, the interviewee IG2 brought up transportation automation "Some automated transportation systems such as cable wires or monorails are being implemented to facilitate the transportation in steep fields", further demonstrating how automation contributes to GESBA's efficiency in all stages of banana production.

Lastly, Labour Efficiency, mentioned by both companies, is a crucial factor for a company's increase in efficiency, and the technologies implemented can help turn the workforce into more productive while reducing costs at the same time. While at GESBA it was highlighted by IG1 and IG3 that robotization has streamlined the packaging process, with less need for manual labour, thus reducing costs: "These technologies increase the efficiency of the packaging process while reducing cost and improving the productivity among the workers" (IG1) and interviewee IG2 emphasizes the ongoing decrease in labour on the island and states that the sensor technology enables precision

farming with less effort, "These technologies mainly increase efficiency(...) farmers can act accordingly and more precisely, (…)". In MWC, on the other hand, it was brought up by interviewees IMW1 and IMW3, as they stated that the introduction of these technologies in MWC´s processes, such as robotization of the harvesting and transportation method, would increase efficiency and decrease human reliability and effort. For example, interviewee IMW1 stated the following: "(…) there should be a robotization of the harvesting with the existing qualified machinery for it, taking off the human effort in this part. For example, instead of one person doing a task for 8 hours with great effort, a machine can do it in a matter of minutes with little to no effort from the person (…)".

To conclude, the integration of Industry 4.0 can increase the operational performance of the company. Time savings can be achieved through sensors and apps that facilitate real-time decision-making and reduce manual labour. The introduction of automation has simplified operations in the production and packaging process at GESBA, improving accuracy and cutting down on labour costs, just as Liu et al. (2021) and Javaid et al. (2022) confirmed. Finally, in terms of the efficient use of labour, there has been advancement as technology enables employees to work efficiently and MWC expects to dramatically improve efficiency in vineyard operations by reducing labour-intensive tasks through automation and enabling faster decision-making through real-time monitoring.

5.4. Yield Improvement

Industry 4.0 technologies can contribute to crop yield improvement. The interviews conducted explain how practices such as predictive analysis or environmental monitoring can positively affect the overall crop yield for the two companies.

The ability to use Predictive Analysis to make more informed decisions regarding resource allocation or crop management can be challenging but effective, according to Abbasi et al. (2022) and Javaid et al. (2022). As interviewee IG2 states, "(…) using the sensors and the app, a database can be constructed to allow for predictions, and consequentially, more informed decisions can be made, especially regarding resources allocated to the harvest". The interviewee augments to this argument that having predictive capabilities can allow one to anticipate crop needs and adjust farming practices accordingly. Additionally, the three interviewed subjects from MWC mentioned the

future relevance sensor technology would have in MWC's processes as the data collected would allow for the creation of predictive models that would allow for more accurate decision-making. The interviewee IMW1 stated the following: "(…) with the sensors and drones, we will be able to evaluate what the plant needs regarding water and nutrients. Additionally, we will be able to perform a live evaluation of the state of maturation of the grapes and then create predictive models, which will allow for a more accurate harvest of the grapes", strengthening the point that the technologies implemented would allow for improved forecasting models that would refine their agricultural practices.

In addition to the predictive analysis, the interviewees also mentioned the importance of sensor technology as it transmits real-time data and enables farmers to quickly act on said information, increasing productivity, which performs Environmental Monitoring and affects the overall Crop Yield Improvement. The three MWC employees mentioned the possibility of introducing sensors to monitor and control environmental conditions, which would lead "(…) to perform live-time assessments of the plant (…)" (IMW3) and therefore help make adjustments to the vineyard's environmental conditions, ensuring that crops are grown under optimal conditions. Moreover, the interviewee IMW1 emphasized the importance of these technologies for assessing the influence of external factors that would contribute to higher yield and improved grape quality. Likewise, the GESBA employees also supported the previous claim that the implementation of precision water systems with the sensors allowed for optimization in the use of water and fertilizers, as interviewee IG2 states: "Alongside these sensors, there have been implemented precision watering systems that carry not only water but concentrated solutions of fertilizers that stimulate the plant's growth", backed up by interviewee's IG3 statement: "With the sensors in the ground, we can understand what nutrients the banana plant needs, and respond with the precise amount of fertilizers, which in turn improves the overall yield". In addition, the GESBA interviewee highlighted the importance of robotization of certain tasks which leads to "(…) labour has been reduced, eventually reducing overall costs and improving crop output" (IG2).

In summary, the combination of environmental monitoring and predictive analysis plays a vital role in improving crop yield. The use of sensors, drones, and digital tracking systems allows for real-time monitoring of critical environmental variables, enabling more accurate predictions about crop needs and harvest timing. By harnessing live

information, forecast models, and advanced systems, these technologies can enhance work planning and resource utilization, leading to more productive agricultural practices and positively impacting overall yield.

5.5. Market Access

The banana market is very competitive as GESBA tries to distribute its process globally. GESBA´s strategies need to take into account the market pressures from all over and therefore have to find ways how to differentiate its product, improve traceability, and increase competitiveness towards other brands through the use of Industry 4.0 technologies. On the other hand, this topic was not brought up during the interviews with MWC's employees, thus elevating its importance for GESBA's Industry 4.0 strategy.

In the company's eyes, the main challenge for market access is the International Market Pressures GESBA faces. It is a fact that the banana industry is dominated by large-scale producers in the South American region, which hinders GESBA´s possibilities to increase its market share. The same was confirmed by interviewee IG2 as he stated the following: "The main problem of this industry is that it is controlled by the United States through plantations in South America. Whilst they produce thousands of tons per day, in Madeira we produce twenty-six thousand tons each year". Additionally, GESBA is a government-owned company, it has to obey the restrictions imposed by governing bodies such as the European Union (EU), which force GESBA to adhere to certain sustainability and quality standards, but decreases its possibility to take production to larger scales, "Some restrictions from the European Union regarding sustainability and overall product set back the banana production" (IG2).

In order to respond to the current market pressures, GESBA continues to focus heavily on high-quality production and sustainable practices to set apart their product from the competition, based on procedures mentioned by Sharma et al. (2021) and Ronaghi (2020). This effort is confirmed by interviewee IG2, "To distinguish ourselves from the competition we need a better product, made from sustainable practices according to our environment", and aims to appeal to the market segment where quality and ecological responsibility are valued. In addition, interviewee IG2 corroborates the market strategy implemented by the company and adds that the current labour conditions, whether in the processing centre or the fields, enhance the perceived value of the product and the

company as a whole, which can be crucial for Market Differentiation in competitive markets.

GESBA's strategy for improving its market access, Certification and Traceability Technologies was one of the improvements the company set out. Regarding the supply chain, GESBA implemented the barcodes on the crates that got to the processing centre and used them to track every shipment and to create a database, thus increasing transparency, "With the implementation of the barcodes leading to the database to identify which farmer produces which banana crate and its certification, there has been an increase in the transparency of the supply chain", said interviewee IG3. With enhanced traceability systems, GESBA now can face complaints and issues more effectively, as interviewee IG3 stated. Furthermore, interviewee IG1 emphasized the importance of these systems in their process as they act with minimal error to ensure compliance with quality standards and improve GESBA's market credibility.

It is clear that the implementation of Industry 4.0 technologies has Enhanced Market Competitiveness as GESBA improved operation efficiency and product quality. Interviewee IG1 defends that lowering production through automation, enabled the company to set competitive prices while maintaining high standards of product quality. Interviewee IG2 also stated: "We possess the banana with more nutrients relative to the ones in South America", which goes according to GESBA's strategy as it distinguishes itself from the competition by offering a high-quality product that consumers are willing to pay more and positioning GESBA as a premium brand. Lastly, interviewee IG3 stated the fact that the efficiency gained by the use of these technologies, not only reduces costs but also aligns with consumer preferences for sustainable practices.

While GESBA faces intense pressures and challenges from international competition and regulatory restrictions, the company´s commitment to high-quality, sustainable production and the use of advanced technologies, as advised by Prigoreanu & Idriceanu (2023), position the "Banana da Madeira" brand enabling them to compete in both local and international markets.

5.6 Profitability

While in GESBA the adoption of Industry 4.0 technologies at GESBA has increased efficiency, crop yields, and has reduced costs, MWC is still considering these

technologies by performing thorough cost-benefit analyses to ensure that the long-term financial benefits outweigh the initial implementation costs.

Both interviewees IG1 and IG3 agree that the robotization in the packaging process and the automation of some processes lead to an increase in productivity, while ultimately reducing overall costs, as the processing centre can handle larger amounts of produce, reducing manual labour and minimizing mistakes. In the fields, with the automation of some processes, interviewee IG1 stated: "With the robotization of some tasks, labour has been reduced, eventually reducing overall costs and improving crop output". Additionally, interviewee IG2 stated the importance of sensor and monitoring technology in optimizing production processes, thus resulting in higher yields, and consequently, a higher Return on Investment (ROI). GESBA's profitability also comes from the Cost Reduction of their processes by implementing technologies such as automation or robotization. The three GESBA employees interviewed agree that the automation of some processes while reducing labour and resources, increases overall efficiency and decreases costs due to lower operational costs. Additionally, with sensor technology, resources can be allocated precisely, which reduces both input costs and, all while maintaining cost-efficiency.

On the other hand, MWC is going through the process of conducting a feasibility study to understand the viability of certain technologies in their process, and one of the most important steps is to evaluate the Cost-Benefit Analysis. The interviewee IMW2, who is responsible for the project says that the study is being conducted and "(…) If the results are beneficial and the cost-benefit analysis comes back positive, we will try to implement it on a larger scale", which shows the importance of the cost analysis for the implementation of the project. Additionally, the interviewee IMW1 stated that the comprehensive studies address both the technology's technical and financial impact on operations.

In conclusion, the initial investments have provided a return on the investment for GESBA by improving productivity and reducing costs through automation, precise resource management, and enhanced crop yields. These findings indicate that the strategic adoption of advanced technologies has been a crucial factor in enhancing the company's profitability whilst, at MWC, studies are still being put in place to ensure that any

investments in technology are aligned with their profitability goals, and that show that the decision to adopt Industry 4.0 technologies at MWC is contingent upon detailed cost-benefit analyses.

5.7. Resource Allocation

The effective allocation of resources, particularly nutrients, water, and fertilizers, is essential for optimizing agricultural productivity. Industry 4.0 technologies, such as sensors and actuators, offer precise control over these inputs, ensuring that they are used efficiently, according to Ferrari & Fresco (2018).

Precision Agriculture, as explained in the literature review, helps optimize resource allocation at GESBA. According to interviewees IG1, IG2, and IG3, the sensor technology allows for the measuring and monitoring of several parameters which allows for a more targeted approach to the resource application, "(…) sensors were implemented to monitor the amount of nutrients or water the banana plant needs". Interviewee IG2 also adds that the ability to quickly respond to changing conditions is a key benefit of precision agriculture, as it allows farmers to optimize resources and minimize waste, "These technologies mainly increase efficiency because the sensors transmit a live feed of the plant necessities to the farmer who can act accordingly and more precisely, whether it is water, Ph level, or even fertilizers.". Additionally, the interviewee states the importance of predictive models to help farmers anticipate the needs of their crops and plan, decreasing the chances of misusing or overusing resources. Additionally, the MWC employees also agree that with the implementation of sensor technology, one of the key areas can be Nutrient Control. With this technology, according to interviewees IMW1, IMW2, and IMW3, the levels of nutrients in the plants would be monitored and regulated in real-time, which would allow the company to respond quickly to changes in plant health, ensuring that nutrient levels are maintained for optimal growth and also maintaining sustainable farming practices.

Additionally, both companies agree on the effect of these technologies in the Efficient use of Water and Fertilizers in crops. This statement was confirmed by interviewee IG1 who said: "There has been a reduction in water and fertilizer usage, leading to lesser environmental impact (…)", which aligns with the company's commitment to sustainable agriculture. The main reason for using less water and fertilizers comes from the

implementation of new precision watering systems, according to interviewee IG2, by not only optimizing water usage but also carrying "(…) concentrated solutions of fertilizers that stimulate the plant's growth." for more efficient use. With the use of these systems, the changes were noticeable, "Farmers now water for fifteen minutes every two days instead of watering for 30 minutes each day", said interviewee IG2. As for MWC employees, the three interviewees confirmed the role of sensor and actuator technology not only in nutrient control but also in water control as the technology will be capable of regulating both of them to ensure optimal resource allocation and real-time adjustment of both water and fertilizers. Interviewee IMW3 stated: "There is a project being developed that uses technologies such as sensors and actuators to measure weather, humidity, water level(...) allowing for live-time assessments of the plant", leading the company and the farmers only to apply water and fertilizers when necessary, reducing waste and ensuring that resources are used efficiently.

In conclusion, the use of sensors and actuators to control nutrient levels and manage water and fertilizer use offers significant potential for improving resource allocation at GESBA, and in the future for MWC. Through real-time monitoring and precise control, both companies can ensure that resources are allocated to maximize productivity while minimizing waste.

5.8. Barriers to Industry 4.0 Adoption

While Industry 4.0 technologies significantly benefit agricultural operations, their adoption is often hindered by several barriers, which Alt et al. (2020) confirm. Even though GESBA has already implemented Industry 4.0, several challenges remain for them and MWC, especially in regions with unique cultural and geographical characteristics like Madeira Island. In the interviews conducted, some similar topics were brought up such as terrain challenges, infrastructure barriers, cultural barriers, technical barriers, and cost-related barriers, which can be observed in Tables 7 and 8 (Annex C), for GESBA and MWC, respectively.

5.9. Strategy for Overcoming Barriers

In response to the challenges present in Industry 4.0 Adoption at both companies, some strategies have been put in place or are still being implemented in the companies' processes. GESBA has considered several factors that have helped supersede the

obstacles to Industry 4.0 adoption through collaborations and partnerships, education and training, and financing in its strategy as demonstrated in Table 9 (Annex C). Similarly, the interviews conducted with MWC employees, in Table 10 (Annex C), showed the intention of using the same strategies by adopting a multi-faceted approach to overcoming the barriers to Industry 4.0 adoption.

5.10. Processes Before Industry 4.0 Adoption

The adoption of Industry 4.0 technologies involves several preliminary processes that organizations must go through to ensure successful implementation. The interviews lead to the conclusion that these processes such as resource planning, collaboration with external partners, comprehensive project development, feasibility studies, extensive workforce training, and problem-solving are mostly mentioned by the employees of both companies.

Resource planning was a crucial initial step for the preparation of Industry 4.0 technologies adoption at GESBA. In this step, GESBA evaluated the necessary resources, such as water, fertilizers, and qualified labour for efficient implementation of the technologies. According to interviewee IG1, the proactive approach allows the company to optimize resource use, decrease waste, and consequently increase crop health and yield. Additionally, the interviewee defends the use of the stock management tool as "(…) it allows us to know where the major producers are, where they are located, what they bring in, etc.", and provides the managers with sufficient information to allocate resources more accurately and effectively.

External collaboration, as mentioned before shares a paramount importance for the strategy of both companies and possible technology adoptions. More specifically, interviewee IG3 states that by collaborating with external sources, GESBA can ensure that the company and its farmers have access to the latest information and skills to effectively use new technologies in their processes. Whereas in the interview IMW3 explained the importance of these collaborations because it would allow MWC to access the necessary expertise and financial resources to implement certain technologies. Project Development is another crucial step in preparing for Industry 4.0 adoption, as it was stated by all six interviewees from both companies. In the MWC's point of view, the projects were important in the pre-adoption phase, as currently they are developing a project to

insert certain technologies in their process and it is crucial to plan to look for potential opportunities or threats and evaluate possible external partnerships to put the project in place. On the other hand, GESBA's employees emphasize that projects come from long hours of studies and preparations, which aim to identify areas for improvement either in operational efficiency or product quality. The following step, as mentioned by interviewee IG2 is to search for external funding, once the project is approved, "A project gets sent out to the European Union to attract funding for further development.".

Nonetheless, these projects, for either company, go through a process called Feasibility Studies, which are essential to evaluate the potential impact of a certain technology or a certain practice on the companies' operations. In GESBA's case, as interviewee IG2 mentions, most of the studies are conducted in the research centre to assess their viability, "Before the implementation of these technologies or any technology in the agricultural process, such as watering systems, or even what fertilizers to use, studies are conducted with multiple outcomes in the Banana Development Centre.". Moreover, the interviewee disclaims that most of the studies that go through the research centre do not have positive results, and those that do, go through even more intensive testing on the field. However, the interviewee states that rigorous testing is imperative when dealing with new practices, minimizing the risk of failure and maximizing the likelihood of success. In the MWC's case, the interviewee IMW2 stated the following: "Right now, we are conducting a study to understand the viability of implementing sensors that can measure and control external factors such as density, humidity, and temperature (…) If the results are beneficial and the cost-benefit analysis comes back positive, we will try to implement it on a larger scale", backed-up by interviewees IMW1 and IMW3, showing the company's effort to evaluate the practicality and cost-effectiveness of the new technologies.

The final process for implementation preparation goes through Workforce Training, which according to Prigoreanu & Idriceanu (2023), aims to ensure that all employees and farmers are equipped to deal with the new technologies and practices. Both companies' employees underlined the importance of this stage in the implementation of new technologies in the companies processes in order to take full advantage of the potential of Industry 4.0 Technologies by the time it is implemented, thus increasing overall productivity and efficiency. Interviewee IG3 even emphasized the company´s

commitment to follow through on the implementations in the field, thereby providing farmers with the tools necessary to perform their daily operations, “We as a company offer training to the farmers to be aware of new practices, technologies, and how they work, along with technical support after the implementation of the technologies.”, which was supported by IMW2 claim by stating, “If the project is approved, the next step will be to give training to those who will handle the technologies for a better understanding of it and a more efficient use of the tools”. Finally, Problem-Solving, brought up by the MWC interviewees, is an ongoing process in the company’s approach to adopting Industry 4.0 technologies. The interviewee IMW1 emphasized this as being an inherent issue in the company because they only go looking for solutions if there is a problem to be solved, “We only look for solutions when we have a problem or a lack of some resource. Nowadays, we come across a lot of challenges, so we need to find creative solutions to our problems”.

In summary, the adoption of Industry 4.0 technologies involves several key processes, including external collaboration, project development, workforce training, feasibility studies, and problem-solving. These processes are essential for ensuring that the company is well-prepared to integrate advanced technologies into its agricultural operations. While MWC is still in the project phase of these strategies, GESBA has laid a strong foundation for the successful integration of advanced technologies into its agricultural practices.

5.11. Future Implementations

As both companies looked forward to integrating Industry 4.0 technologies in its process for the future, the interviewed subjects were asked during the interview what the next steps toward innovation looked like. For GESBA the interviews revealed numerous possible implementations to enhance operational efficiency, product quality, and resource management. As shown in Table 5 (Annex C) the interviews displayed a rising interest by GESBA to implement technologies focusing on sensors and monitoring systems, improved traceability, drones and aerial monitoring, automated transportation, automation and robotics, predictive models, and big data analytics. As for MWC, the implementation of Industry 4.0 technologies in agriculture presents several opportunities for improving vineyard management, as displayed in Table 6 (Annex C). The company is exploring multiple future technologies, including automated transportation systems,

digitalization, drones, sensors and actuators, big data, and predictive models. These future implementations are expected to significantly improve operational efficiency, resource management, and decision-making in their agricultural practices, leading to more sustainable and productive outcomes.

6. CONCLUSION

The present study's objective was to analyse the benefits of Industry 4.0 Technology on the agricultural sector. To answer the RQ about both case studies, a qualitative analysis was conducted based on semi-structured interviews and with the help of the software MAXQDA.

Regarding the first RQ: "Why are Industry 4.0 technologies beneficial for the agricultural sector?", it was possible to verify that while these technologies have shifted many of GESBA's farming processes, the same cannot be said about MWC as the company is facing more challenges and is still in the early stages of adoption of technology in its process, however highlighting their potential. In fact, both companies are seeing Industry 4.0 technologies as current and future solutions for the issues inherent to the sector.

The findings confirm that Industry 4.0 technologies offer several benefits, including improved resource management, reduced labour costs, enhanced traceability, and increased productivity. The benefits of these technologies in GESBA were emphasized, as the use of sensors and precision irrigation led to better management of water and fertilizers, while automation reduced labour demands. Additionally, the improvements in the company's process led to an increase in crop yields and more efficient resource allocation. In the case of MWC, although not yet fully implemented, the planned adoption of these technologies is expected to bring similar benefits by reducing manual labour and increasing operational efficiency.

Furthermore, the two case studies illustrate how Industry 4.0 technologies can be adapted to different types of crops. In the case of bananas, GESBA successfully employed automation, sensors, and precision irrigation to address challenges specific to its crops, such as the need for large-scale, efficient production on steep terrains, and the declining workforce. For MWC, which focuses on grapes, the proposed technologies for future implementations such as drones and environmental sensors are designed to optimize

grape harvesting and quality. The study demonstrates that while the types of technologies may vary slightly, the principles of Industry 4.0 can be applied across different crop types to enhance productivity and efficiency.

The second RQ: "What are the challenges to the implementation of Industry 4.0 technologies in the agricultural sector?", was similarly identified across both case studies. GESBA and MWC both encountered several barriers to adoption, such as the high initial cost of technologies, the harsh geographical landscape of the island, cultural resistance, particularly among older workers, and the need for specialized training to operate and maintain the new systems, which means that companies in this sector need to be prepared for multiple eventualities and challenges.

While GESBA overcame some of these challenges through external collaborations, training initiatives, and securing financial support, MWC is still developing projects through feasibility studies to determine the viability of certain technologies. Nevertheless, both companies agree on the same approach to ensure the innovation of their agricultural processes to become more operationally efficient and reduce overall costs.

Economically, the case studies showed us different results regarding each company. For GESBA, the economic outcomes of adopting Industry 4.0 technologies have been largely positive. The reduction in labour costs, combined with more efficient resource management, has improved profitability. The increased traceability and quality control facilitated by automation has also enhanced GESBA's market access and competitiveness, particularly in exporting high-quality bananas. For MWC, which is facing a rough patch due to the decrease in grape production the future results of technology adoption remain speculative, but the anticipated benefits include reduced labour costs and improved product quality, which are expected to enhance the company's competitiveness in the long term.

6.1. Contributions

This thesis makes several important contributions to both the theoretical understanding of Industry 4.0 in agriculture and the practical application of these technologies within the sector. From the theoretical point of view, this study provides knowledge on the application of 4.0 technologies in agriculture by providing empirical evidence from two distinct case studies. On the other hand, from a practical standpoint,

other organizations, or even the ones presented can take advantage of the investigation, by getting to know current practices and the benefits of technology adoption in the agricultural process. All these aspects are covered in the literature review and complemented in the presentation and discussion of the results of the case studies.

There are some research studies about the agricultural sector, however most of them consider different realities than the one in Portugal, more specifically, in Madeira Island. In addition, the importance of improving agricultural processes towards sustainability is increasingly rising due to changes in climate and food necessity.

6.2. Limitations and Future Research

While this study makes significant contributions, it also has limitations that future research can address. First, the study is limited to two case studies, which, while providing deep insights, may not fully capture the diversity of agricultural practices globally. Future research could expand this work by including more case studies across different agricultural contexts and regions.

Secondly, the research of the case studies was made by qualitative analysis, which relies on the interviewees' point of view. In the future, more statistical analysis studies could be conducted to quantify the impact of Industry 4.0 Technologies in the agricultural sector.

Furthermore, as MWC has not fully implemented Industry 4.0 technologies, some of the conclusions about the potential impact in this case are speculative. Future longitudinal studies that follow the implementation process in such companies could offer more concrete insights into long-term outcomes and challenges.

Finally, this research primarily focuses on larger-scale agricultural enterprises. Future studies could explore how small- and medium-sized farms can adopt Industry 4.0 technologies, including the barriers they face and the specific types of support they require.

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APPENDICES

Annex A – Interview Script

Introduction

Afonso Leça Gonçalves, student in the Masters in Management Information Systems in ISEG Lisbon.

Purpose: Understand the antecedents and the impact of implementing Industry 4.0 in the agricultural sector.

Disclaimer: All the information and archives shared during the interview are strictly confidential and are exclusively destined for the individual or the university to whom they are destined.

Context

Nowadays, there are many problems worldwide impacting the agricultural sector, such as the increase in demand for food, less natural resources, and climate change, among others. The implementation of Industry 4.0 in regular farming can pose as a disruption to regular farming practices and contradict the many current issues the agricultural sector faces.

By adding Industry 4.0 technologies such as Internet of Things (IoT), Blockchain, Big Data Analytics, and Artificial Intelligence (AI) into farming practices, a new revolution came forth named Agriculture 4.0. These concepts consist of using smart technologies, sensors, actuators, robots, computational and decisional analytics, and digital communication tools which can improve the whole sector whether in productivity and supply chain efficiency or food safety and natural resource management.

Interview Script

1. Where is your company located?
2. How many employees does your company have?
3. What type of farming does your company engage in?
4. What is the size of your farm in acres or hectares?
5. Has your company adopted any Industry 4.0 technologies? (Yes/No)
   5.1 If yes, which technologies have you adopted? (e.g., IoT, AI, robotics, big data, drones, automation, blockchain)

5.1.1. Why did your company adopt that particular technology?

5.1.2. What year did you start adopting these technologies?

5.1.3. How have Industry 4.0 technologies impacted your farming operations? (e.g., increased efficiency, reduced costs, improved yield)

5.1.4. How did these technologies change the way decisions are made in your company?

5.1.5. How have these technologies impacted your resource usage? (e.g., water, fertilizers, energy)

5.1.6. What is the customer and shareholders' feedback before and after the implementation of the technologies regarding the end product?

5.1.7. How have they affected traceability and transparency in your supply chain?

5.1.8. What challenges have you encountered while implementing Industry 4.0 technologies? (e.g., high costs, technical difficulties, lack of skilled labour)

5.1.9. How have you addressed these challenges?

5.2 If not, what barriers have you encountered to implement these technologies?

6. What processes have you gone through before implementing these technologies?
7. What resources or support does your company need to implement Industry 4.0 technologies?
8. What type of Industry 4.0 technologies are you planning to implement in the future, if any?

Annex B – Interview Configuration Summary

***Table 1**: Interviewee Characterization*

Interviewee	Gender[1]	Company	Position
IG1	F	GESBA	Manager
IG2	M	GESBA	Banana Development Centre Director
IG3	F	GESBA	Product Quality Supervisor
IMW1	M	MWC	Director of Viticulture
IMW2	F	MWC	Quality and R&D Director
IMW3	M	MWC	Vendor

***Source**: Elaborated by author*

[1] M = Male | F = Female

***Table 2**: Interview Configuration*

Interviewee	Type of interview	Duration[2]	Date	Pages
IG1	On-site	29 min	29/08/2024	11
IG2	On-site	46 min	29/08/2024	15
IG3	On-site	20 min	29/08/2024	10
IMW1	On-site	24 min	29/08/2024	10
IMW2	Online (Microsoft Teams)	22 min	06/09/2024	13
IMW3	On-site	20 min	30/08/2024	9

***Source**: Elaborated by author*

***Table 3**: Theoretical Basis for the Interview Guide*

Question	Dimension	Source(s)
5.1.1. Why did your company adopt that particular technology?	The impact of Industry 4.0 technology in agriculture.	Biel et al. (2018)
5.1.3. How have Industry 4.0 technologies impacted your farming operations?	Changes in the agricultural process due to the implementation of technologies.	Abbasi et al. (2022) Javaid et al. (2022) Kashapov et al. (2019) Alt et al. (2020) Fernández & Sadjadi (2023)
5.1.4. How did these technologies change the way decisions are made in your company?	Data-driven decisions.	Zhai et al. (2020) Lindblom et al. (2016)
5.1.5. How have these technologies impacted your resource usage?	Sustainability in agriculture.	Biel et al. (2018) Abbasi et al. (2022) Javaid et al. (2022) Kashapov et al. (2019) Alt et al. (2020) Fernández & Sadjadi (2023)

[2] min = minutes

5.1.6. What is the customer and shareholders' feedback before and after the implementation of the technologies regarding the end product?	Reaction of shareholders to the implementations.	Prigoreanu & Idriceanu (2023) Collado et al. (2018)
5.1.7. How have they affected traceability and transparency in your supply chain?	Quality and transparency of the supply chain.	Ronaghi (2020) Sharma, et al. (2021) Bawa & Bhaskara (2021).
5.1.8. What challenges have you encountered while implementing Industry 4.0 technologies? 5.1.9. How have you addressed these challenges? 5.2. What barriers have you encountered to implement these technologies?	Challenges in implementing Industry 4.0.	Abbasi et al. (2022)
6. What processes have you gone through before implementing these technologies?	Antecedents for implementing Industry 4.0 technologies.	Alt et al. (2020) Fernández & Sadjadi (2023)
7. What resources or support does your company need to implement Industry 4.0 technologies? 8. What percentage of your annual budget is allocated to the adoption and maintenance of Industry 4.0 technologies?	Necessary funds and resources to implement technologies in the agricultural process.	Collado et al. (2018)
9. What type of Industry 4.0 technologies are you planning to implement in the future, if any?	Possible evolutions towards more technological agriculture.	Kovács & Husti (2018)

***Source**: Elaborated by author*

Annex C – Interviews Data

***Table 4**: GESBA's Existing Technology*

Dimension	Technology	Year of implementation	Mentions
Decision Support Systems	Stock Management Tool Barcode Scanner	2023	IG1 IG3
Cyber-Physical Systems	Sensors and Actuators	2022	IG1 IG2 IG3
Precision Farming	Precision Irrigation Systems	2017	IG1 IG2
Automation	Robotization of the production line	2023	IG1 IG3
Automation	Automated Transportation Systems	2020	IG1 IG2

***Source**: Elaborated by author*

***Table 5**: GESBA's Future Implementations*

Dimension	Technology	Mentions
Cyber-Physical Systems	Sensors and Actuators	IG1 IG2 IG3
Automation	Automated Transportation Systems	IG1 IG2
Artificial Intelligence	Predictive Models	IG2

Cloud Computing	Data Warehouse	IG2 IG3
Smart Farming	Drones and Aerial Monitoring	IG1 IG2

***Source**: Elaborated by author*

***Table 6:** MWC's Future Implementations*

Dimension	Technology	Mentions
Automation	Automated Transportation Systems	IMW3
Cyber-Physical Systems	Sensors and Actuators	IMW1 IMW2
Artificial Intelligence	Predictive Models	IMW1
Cloud Computing	Big Data	IMW3

***Source**: Elaborated by author*

***Table 7**: GESBA's Barriers to Industry 4.0 Adoption*

Barrier	Mentions	Quote
Terrain Challenges and Infrastructure Barriers	IG1 IG2	"The island topography is very steep which hinders the harvesting process." (IG2)
Cultural Barriers	IG1 IG2	"Most of the farmers are of advanced age and tend to resist new practices or tools to develop their process." (IG2)
Technical Barriers	IG2	"While implementing the sensors back in 2022, we found that they were ill-calibrated and were not that reliable." (IG2)

Cost-Related Barriers	IG2 IG3	"The main challenge is the resistance from the farmers to adopt new technologies and practices, as well as the financial effort some farmers have to do in the beginning of the implementation"(IG3)
Cost-Related Barriers	IG2	"Also, some restrictions from the European Union regarding sustainability and overall product sets back the banana production" (IG2)

***Source**: Elaborated by author*

***Table 8**: MWC's Barriers to Industry 4.0 Adoption*

Barrier	**Mentions**	**Quote**
Terrain Challenges and Infrastructure Barriers	IMW1 IMW2 IMW3	"(…) our island's terrain is very steep, complicated to grow large plantations, even more so with the decrease of available area for crops (…)" (IMW1)
Cultural barriers	IMW1 IMW2 IMW3	"(…) the aging of the farmers prevents a faster evolution of the processes, due to resistance to new practices and tools that can help them make their job more efficient (…)" (IMW3).
Technical Barriers	IMW1 IMW3	"(…) another difficulty with implementing technologies in our process is because we work with small plots of field, alongside the use of the pergola system which toughens the automation process (…)" (IMW1)
Cost-related Barriers	IMW1 IMW2 IMW3	"(…) technology implementation costs are high and the wine industry in Madeira Island is in a recession (…)" (IMW3)

***Source**: Elaborated by author*

***Table 9**: GESBA's Strategies for Overcoming Barriers*

Strategy	Mentions	Quote
Collaborations and Partnerships	IG1 IG2 IG3	"If a certain technology gets approved within the company, a project gets sent out to the European Union to attract funding for further development." (IG2)
Training and Education	IG1 IG2 IG3	"We offer training to the farmers to be aware of new practices, technologies, and how they work, along with technical support after the implementation of the technologies in their processes." (IG3)
Financial Strategies	IG1 IG3	"Mainly funding from the European Union (…)" (IG1)

***Source**: Elaborated by author*

***Table 10**: MWC's Strategies for Overcoming Barriers*

Strategy	Mentions	Quote
Collaborations and Partnerships	IMW1 IMW3	"These studies normally come through the university due to some protocols, however, they need to give more input in the implementation of new technologies as well as other outsourcing companies with the same goal (…)" (IMW1).
Training and Education	IMW1 IMW2 IMW3	"(…) the next step will be to give training to those who will handle the technologies for a better understanding of it and a more efficient use of the tools (…)" (IMW2)

Financial Strategies	IMW1 IMW2 IMW3	"(…) a project has to be sent out to ask for funding from the shareholders and external investors as well, such as the government (…)" (IMW3)

***Source**: Elaborated by author*

Annex D – MAXQDA Software

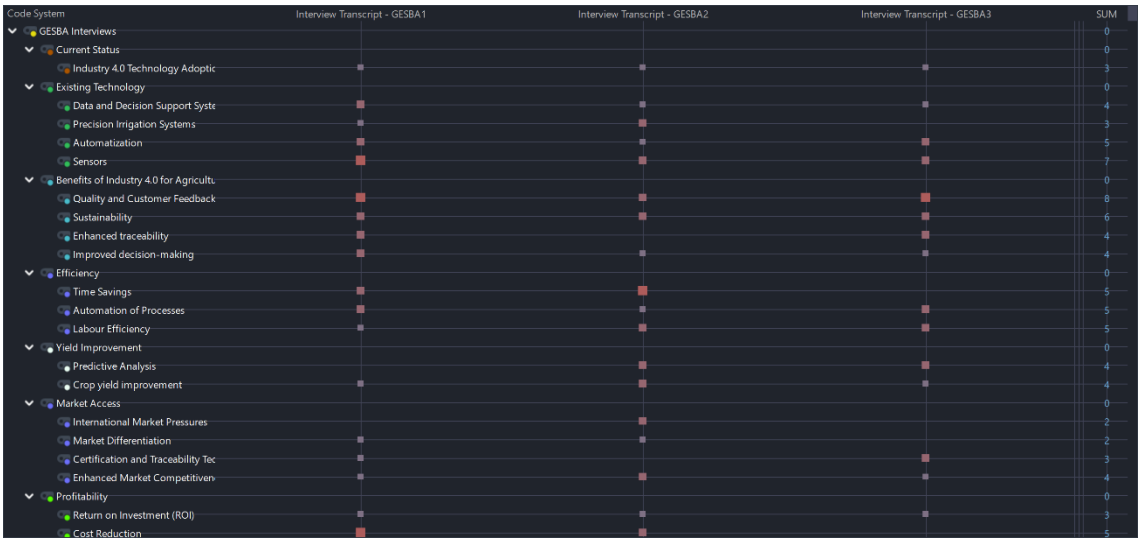

***Figure 1:** Code Matrix Visualization by each interview (GESBA)*

***Source**: Elaborated by author*

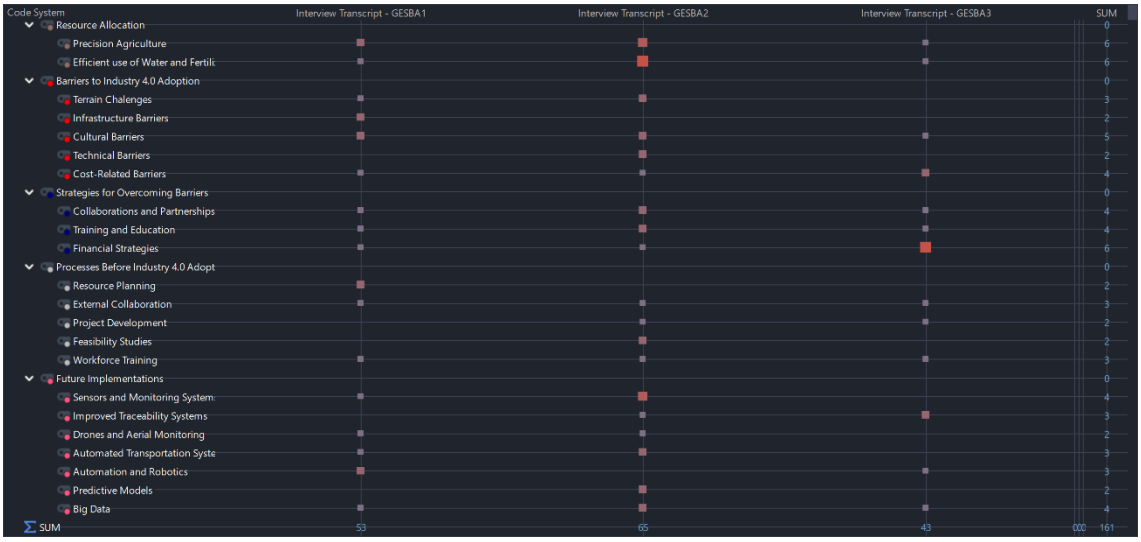

Figure 2: Code Matrix Visualization by each interview continued (GESBA)

***Source**: Elaborated by author*

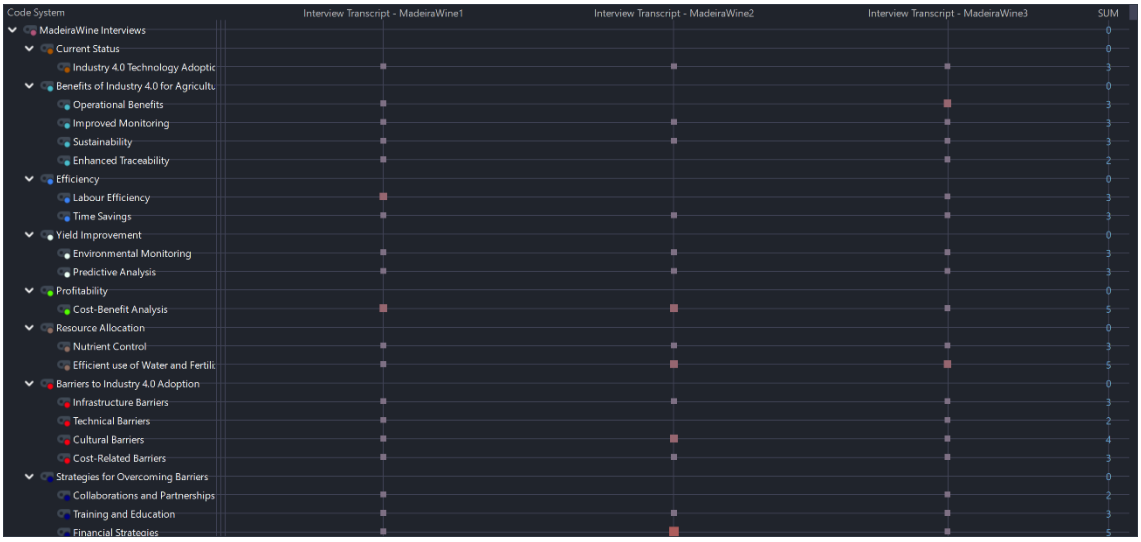

***Figure 3**: Code Matrix Visualization by each interview (MWC)*

***Source**: Elaborated by author*

***Figure 4**: Code Matrix Visualization by each interview continued (MWC)*

***Source**: Elaborated by author*

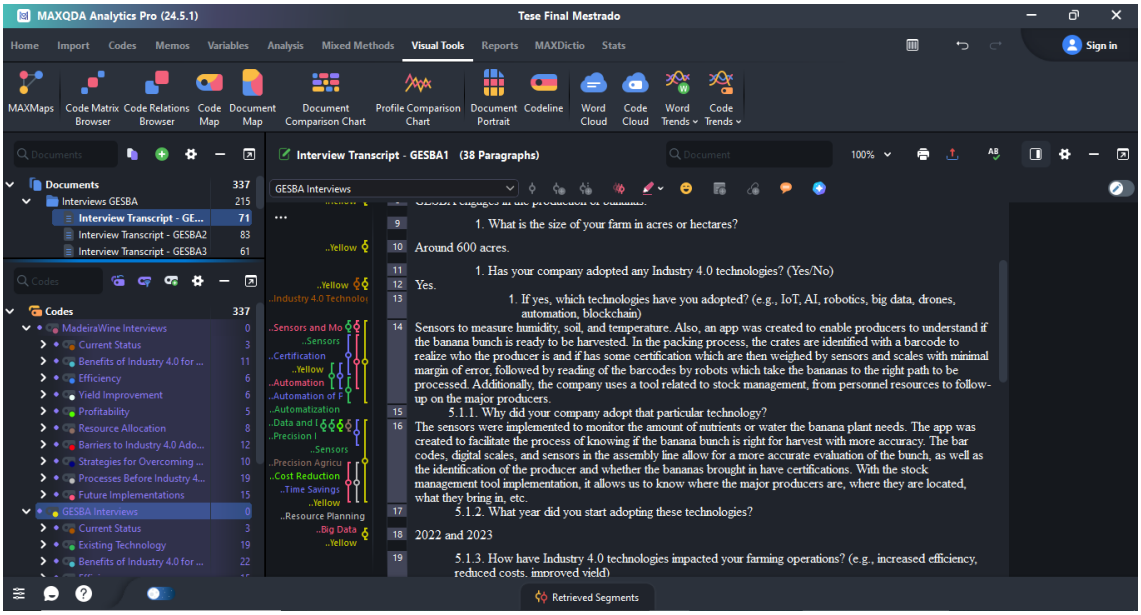

***Figure 5**: MAXQDA Software Sample*

***Source**: Elaborated by author*