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The impact of digitalization on the agricultural sector

How can digitalization help the agricultural sector to achieve Sustainable Development Goals (SDGs) in the case of Belgium?

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Abstract

By 2050, the world population is projected to reach 9.8 billion individuals, which poses significant challenges such as food insecurity and unhealth, natural resources scarcity and pollution and food waste. Therefore, the current food industry must have a radical transformation to actively ensure people's well-being and create a sustainable environment. Over the years, technology has become a major player in global industries, it is of the essence for each stakeholder within the food supply chain to follow this global trend starting with farmers. Belgium presents a unique case as half of its territory is used for agricultural purposes which made us raise concerns on the effectiveness of the system because Belgian farmers generate low profitability. All these thoughts bring us to the aim of this study, to determine the importance of digitalization in the agricultural sector and its influence on the achievement of the Sustainable Development Goals in Belgium. Therefore, we conducted a qualitative and quantitative approach through interviews with Belgian farmers and retailers and a survey of the Belgian population. Based on the results, two solutions that can benefit the agricultural sector emerged: to aid farmers improving in regenerative farming supported by agricultural technologies and precision farming and to introduce urban greenhouse supermarkets. The solutions highlight that digitalization has a positive correlation with the agricultural sector and can play a role to achieve Sustainable Development Goals in Belgium. In fact, by better embracing technology, Belgian farmers will increase their cropping intensity, reduce tremendously the use of natural resources, have better control of environmental unpredictable factors, ensure transparency and raise their margins. This master's thesis develops the project management required according to the maturity level of both solutions. Finally, our thesis invites further research on this topic analyzing more in-depth the feasibility of the urban greenhouse supermarket project in partnership with professionals in this domain.

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GLOSSARY

3D	Three Dimensional
Agtech	Agricultural Technologies
AI	Artificial Intelligence
AR	Augmented Reality
B2C	Business to Consumer
BCG	Boston Consulting Group
CAGR	Compound Annual Growth Rate
CETA	Centre d'Etudes Techniques Agricoles
CO2	Carbon Dioxide
COP	Conference Of the Parties
CPI	Consumer Price Index
EGNOS	European Geostationary Navigation Overlay Service
EMF	Electromagnetic Fields
ESG	Environmental, Social and Governance
EU	European Union
GDP	Growth Domestic Product
GIS	Geographic Information System
GPS	Global Positioning System
GS1	Global System of Standards
IMF	International Monetary Fund
IoT	Internet of Things
IPCC	Intergovernmental Panel on Climate Change

IT	Information Technology
LED	Light-Emitting Diode
NGO	Non-Governmental Organization
PAAW	Photo-Activated Adhesive Work-holding
PFAL	Plant Factory with Artificial Lights
pH	Potential of Hydrogen
PWC	PricewaterhouseCoopers International Limited
QR Code	Quick Response Code
R&D	Research & Development
RFID	Radio Frequency Identification
SDG	Sustainable Development Goal
UK	United Kingdom
UN	United Nations
UNSTAT	United Nations Statistics Division
VR	Virtual Reality
VRT	Variable-Rate Technologies

CHAPTER ONE: INTRODUCTION

Food companies becoming active contributors to healthy people on a sustainable planet. This goal seems far away, yet radical transformation is urgently needed in our current food industry.

While the food industry is a vital sector that includes a network of actors, starting with farmers and ending with consumers, that collectively supply food. It also contributes to a critical part of global greenhouse gas (GHG) emissions as it counted for one-third of it in 2021 (Charles, 2021) against one-fourth in 2019 (Ritchie, 2019a). While we expect there to be 9.8 billion people by 2050, fewer and fewer people are active in agriculture (Ojo et al., 2018). The share of employment that agriculture represents worldwide plunged from 43% in 1991 to 26% in 2021 (World Bank, 2021b). Regarding the ratio of GDP that agriculture represents and the surface that it is currently using, it is quite low. In fact, 46% of the global habitable land is for agricultural purposes (Ritchie, 2019b), but it is equal to only 4.3% of the world's GDP (World Bank, 2021d). Concerning food waste: 33% of the food that is produced, that is 930 million tones globally, is either lost or wasted. That amount could be used to pull 800 million people out of hunger (Dora et al., 2021). All these figures illustrate the inefficiency and unsustainable practices that the current agriculture sector is experiencing.

Besides the technological advances, a reason behind this diminishing workforce is the fact that the sector does not manage to attract the younger generation. It is seen as a traditional labor-intensive domain that implies many sacrifices not remunerated accordingly (Alderman, 2021). 88.1% of European farmers were older than 40 in 2020, with the vast majority even above 65% (Eurostat, 2020). The aging farmer population reveals the more profound need for the sector to reinvent itself for the youth to believe in its success. To prevent workforce shortage and at long-term worldwide hunger, systemic changes need to be undertaken toward a more digital, innovative, efficient, profitable, and sustainable way to handle the planet's scarce resources. Additionally, with people becoming more conscious and careful about the environmental impact they may have, the sector is facing increasing pressure of shift. People want to become informed buyers. Even though such changes require heavy and costly effort from the companies, all companies will sooner or later be forced to undergo these adjustments to face future trends.

Feeding the world in an equitable, healthy, and sustainable way is not something that can be done overnight. The right balance must be found between urgency and long-term stable vision. A shift from traditional food production towards one based on a continuous innovation dynamic is needed to embrace technology and connectivity. At every step of the supply chain, actors must be open to systemic changes in their core practices.

Among the solutions to enhance sustainable practices in the food sector, we will deep dive into the impact of digital innovations on agriculture. Digitalization has the potential to play a significant role in promoting sustainable food systems by improving traceability, resource management efficiency and reducing food waste throughout the supply chain.

More precisely, this master thesis aims to investigate **How can digitalization help the agricultural sector to achieve Sustainable Development Goals (SDGs) in the case of Belgium?**

Initiated by the United Nations in 2015, every one of the 17 SDGs (see Appendix 1) represents a global goal to free the world from poverty, enhance sustainability in business practices and ensure that all people enjoy peace and prosperity by 2030. All these SDGs are one and indivisible, focusing on the universal aspect of implementing these goals: these should be applied to every single life in all the countries of the planet. A more detailed graph with the concerned goals is to be found in Appendix 1 (SDGs, 2017).

In the first part of the thesis, we will explore the current state of digitalization worldwide and specifically in Belgium. This will involve examining the general environment, the challenges, the three paradoxes, and the existing implementations in the market. After providing a global overview, we will outline the methodology employed, including the various steps taken and the rationale behind them. Additionally, we will discuss our understanding of each key player and explain how we gathered the necessary data.

Moving forward, we will analyze and discuss the data we have collected, seeking to establish connections between our literature review and the new insights obtained from Belgian stakeholders. By identifying the key challenges specific to Belgium, we will then propose a "go-to-market strategy" that outlines a practical approach to addressing these challenges and implementing sustainable digitization initiatives.

Concluding the thesis, we will summarize our findings, answer the research question, and reflect on the lessons learned, the obstacles encountered, and potential avenues for future research.

CHAPTER TWO: LITERATURE REVIEW

2.1 Context

Nowadays, digital technologies are essential tools to enhance more efficient and sustainable growth in industries (OECD, 2021). With the advent of Food technologies[1], the food industry is no exception to this rule. For example, a whole system of entrepreneurs and start-ups thinks about how the industry could be viable in the long run knowing the escalating rarity of natural resources.

Some examples of networks and actions of Food technologies can be enumerated:

- AgTech - available at the farmers' level including drones, sensors, and farm management software, food science - mainly focusing on the ingredients and alternative products that are more sustainable.
- Foodservice - implementing technology in the hospitality industry.
- Consumer tech - improve and ease how the consumer cooks, meet the best nutritive target and manage their diet.
- Delivery and supply (DigitalFoodLab, 2023).

Even though the digital aspect of Food technologies has risen, the mindset of improving the practices has been implemented ages ago. How else would we have managed to feed a population that is now four times bigger than hundred years ago (Shepherd et al., 2020)? However, there is a switch of focus noticed these last few years. Whilst the main driver of these developments used to be for producing more and profit-driven, nowadays other factors entered the equation such as the switching consumers' behavior toward more local and healthy products and the importance of sustainable resource management (Hetler, 2022).

Concerning the scarcity of resources, recent studies have shown that to satisfy the needs of 9.8 billion people by 2050, the food production volume will need to double (Ojo et al., 2018). However, resources, as we know them now, will not be indefinite or enough to meet this growing demand. Whereas by the midcentury, 9.8 billion will be the number of people on earth, and this is expected to turn 11,2 billion by 2100 (Ojo et al., 2018). Innovation and digitalization

[1] Food technologies is any technology that improves food production, distribution and supply (Hetler, 2022).

play therefore a crucial role: producing more, with fewer resources and still ensuring safe and nutritious food. In other words, producing in a sustainable way where one must base its action and business model on long-term and shared value creation (Abbate et al., 2023).

Following these first findings, the scope of this master's thesis will be: **How can digitalization help the agricultural sector to achieve Sustainable Development Goals (SDGs) in the case of Belgium?**

We decided in this master's thesis to measure the possible improvements with the Sustainable Development Goals.

Since 2015, the Sustainable Development Goals (SDGs) have been seen by the UN General Assembly as pillars to achieve global goals by 2030. Three dimensions are targeted: economic, social, and ecological dimensions. Although they are being subdivided into 17 different SDGs, one goal cannot be achieved without the other making them one and indivisible from each other with a special focus on "universality". The purpose is not only to erase poverty and live more sustainably in the South but rather at the world level.

To monitor the progress toward achieving the SDGs, 246 indicators have been introduced by UNSTAT in 2016. It is important to know that not all indicators can be applied to every goal and every country. The country must take ownership of this project and collect measurable, accessible, and timely data. Specialized organizations, including the United Nations, the World Bank, and national governments will hence compile and report the data at global, regional, and national levels helping the implementation of efficient policies and programs.

We can distinguish very clearly the three different values: **Universality** (it applies to everyone and everywhere) - **Integration** (we cannot achieve some without taking into consideration the others, we have to achieve them as a whole) - **Transformation** (to achieve these goals we will have to make substantial changes) each one is important individually, but they are all interconnected.

2.2 How are digital innovations helping the food industry?

Now the global context is known, this section is going to illustrate how technologies can help the food industry at all levels of the supply chain whether it is at the beginning with the farmers, followed by the retailers, or at the end with the consumers.

2.2.1 The use of digitalization supports farmers

As the starting point of the supply chain, farmers hold the key to any product's origin. With the demand continuing to rise, it becomes crucial to enhance sustainable efficiency through the utilization of technological advancements.

A. Precision Farming - on-site and real-time information

The 90s marks the advent of precision farming. It aims to improve **crop yields and resource management** by **collecting precise on-site and real-time information** supported by a mix of advanced technologies. Thanks to interconnected tools, efficient strategies can be put in place combining the right intervention at the right place and time in a specific area. Assessing the precise needed amount of fertilizer, irrigation, and pesticide diminishes labor time and enhances productivity and cost-effectiveness (Fuglie, 2016). This results in a reduction of waste of natural and human resources. Consequently, the costs will drop meaning an increase in profit in a sustainable way.

The **technology** used is three-fold: the data collection tools, the field intervention tools, and the prediction tools.

- Concerning the technologies used for collecting the data, they oversee how to assess the health status and needs of the crops. Some areas of the field require more interventions than others during the growing process. The tools will identify the causes and the exact spots where the interventions are necessary. Among the tools collecting these pieces of information, one can enumerate the Satellites for high-resolution images and the Internet of Things including the sensors and the drones (Akhter & Sofi, 2021).
- Precision farming also includes several field intervention tools: the GPS and GIS (geographical information system) provide the real-time location of the machinery, the autosteer enables the machinery to follow the most efficient patterns in an automatic

way and the Variable Rate Technology (VRT) monitors the number of inputs released at a precise area (Fuglie, 2016).

- Finally, artificial intelligence and machine learning will be useful for yield prediction, water regulation, and the detection of diseases and weeds (Fuglie, 2016).

An **example** of a company that offers such a tool is called Aerobotics. With the use of drones and artificial intelligence, the company is tracking and giving detailed insights about the yields, for example, specific zones where there are some infestations for example. After analyzing those insights, the farmers can make better-informed decisions regarding the number of resources to give to the crops (Aerobotics, n.d.).

B. Vertical farming - controlled indoor farming in reduced spaces

Vertical farming, also known as plant factory. This is a type of indoor urban farming. As the name mentions, the **concept** is to migrate agricultural activity from rural zones to urban areas. That would significantly reduce the transport distance between the production and consumption place since it is expected that by 2050, two third of the global population will be settled in urban areas (European Parliamentary Research Service [EPRS], 2022). No more wide fields exposed to uncertainty, but instead indoor controlled infrastructures with a minimized space required. Due to a lack of suitable land to grow crops or plants in the future to meet the growing demand, we must find a way to increase the cropping intensity per given area. Vertical farming refers more precisely to intensive crop production systems on stacked vertical shelves (Butturini, M., & Marcelis, L. F., 2020).

Worldwide, the vertical farming market is expected to grow tremendously. According to Statista, while the market represents currently 5.6 billion US$ it is forecasted to reach 35.3 billion US$ by 2032 (Statista, 2022b). Between North America, Asia-Pacific, Europe, and the rest of the world, Europe represented the second largest vertical farming market in 2020 with a value of 1.35 billion US $ right after North America with 1.38 billion US $ (Statista, 2020). A combination of several factors has contributed to its rapid growth during these recent years: significant investments have been mobilized, the creation of many start-ups in this domain, a decline in prices for LED lighting technologies, and rising demand for healthy, fresh, and local products but also the fact that many buildings are remaining uninhabited since the financial crisis of 2007-2008 (Spruijt et al., 2015).

To reach vertical farming, specific **technologies,** and methods are used namely Hydroponics[2], Aeroponics[3] (type of hydroponic) and Drip irrigation[4] (Despommier, 2009) that eliminate the need for soil and embrace advanced technologies. These innovative systems encompass a wide range of components, including lighting, watering, and waste management systems. Furthermore, an array of sensors and smart devices are deployed to autonomously monitor and precisely adjust environmental conditions. This integration of cutting-edge technology allows for efficient control and optimization of growth conditions. Machine learning algorithms and automation play a vital role in fine-tuning and managing these installations, ensuring optimal crop development and overall operational efficiency (European Parliamentary Research Service [EPRS], 2022).

Overall, vertical farming brings three key **benefits**: saving natural resources such as water, fertilizer and pesticides, producing crops in a more consistent and reliant way given the fact that the yields are not limited by seasons and can be produced throughout the whole year in a regulated environment (Baraniuk, 2022) and finally it diminishes the required surface area or even does not require any additional at all since it can be built on roofs of already existing buildings (Butturini, M., & Marcelis, L. F., 2020).

In Europe, we can distinguish four types of vertical farms:

- PFAL - plant factory with artificial light. This type is located in industrial buildings. The English Jones Food Company launched its PFAL in 2018 that will reach full capacity +/- 400 tons of leafy greens annually for its 5120 m2 requiring 12.3km of LED light bars (Butturini, M., & Marcelis, L. F., 2020).
- Container farms one of which can be seen in Paris founded by Agricool specializing in strawberries and making use of aeroponics (Butturini, M., & Marcelis, L. F., 2020).

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[2] Hydroponics is the technique of growing plants using a water-based chemical nutrient solution rather than soil (National Agricultural Library, n.d.)

[3] By including fish in the plant water, aquaponics is the practice of using fish excrement as nutrition for the plants (Wongkiew et al., 2020)

[4] Drip Irrigation can help you use water efficiently. A well-designed drip irrigation system loses practically no water to runoff, deep percolation, or evaporation. Drip irrigation reduces water contact with crop leaves, and stems, and fruit. (Shock, 2020)

- In-store farms are located where the products will be consumed or sold directly, for example in a restaurant or supermarket. The German company Infarm, launched in 2013, was in 2019 already settled in approximately 350 in-store retail and distribution centers in several European countries (Butturini, M., & Marcelis, L. F., 2020).
- Appliance farms are meant for at-home or office use and are therefore adequate for private use scale. Estonia has a start-up called Click & Grow launched in 2009 (Butturini, M., & Marcelis, L. F., 2020)

			
PFAL	Container farm	In-store farm	Appliance farms

Figure 1: Four types of vertical farms (Butturini, M., & Marcelis, L.F., 2020)

Regarding Belgium, we have several examples of vertical farms: PLNT in Antwerp, Urban Crops Solutions in Waregem, Vertiberry (from Urban Harvest) in Brussels, Microflavour Brussels, and even the Colruyt group for Bio Planet.

C. Regenerative farming

Regenerative farming goes beyond minimizing its impact, it seeks to restore all degradation that traditional agriculture practices cause to achieve sustainable food production (O'Donoghue et al., 2022).

To encourage farmers to adopt regenerative farming practices, the integration of **precision farming** and **agricultural technologies** is essential for farmers. The soil is the core of regenerative farming. With Machine Learning, Artificial Intelligence and the Internet of Things including sensors and satellites farmers can examine the soil condition and keep it healthy. Sensors and Artificial intelligence are also making it possible to track the farm animals' health as well as a monitor when the animals are grazing. This type of farming is highly advantageous

for small farms because it is less expensive than other agricultural production systems (McLennon et al., 2021).

Regenerative farming encompasses a range of techniques aimed at restoring and enhancing the health of agricultural ecosystems. We will delve into each of these techniques, providing a comprehensive understanding of their importance to farmers and their food systems. The techniques listed below are among the most employed methods in regenerative farming (Futurebridge, 2022):

Conservation tillage

The crop residues from the previous year are being effectively recycled by leaving them on the fields, both prior to and following the planting process. Typically, these residues provide coverage to approximately 30 percent of the soil surface area (Futurebridge, 2022).

Cover cropping

The idea is to plant roots or plants into the soil whose main purpose is to cover the soil instead of harvesting it. This is still a very manual and time-consuming solution for farmers (USDA, 2023). Technology will therefore be of great help.

Holistically managed grazing

The concept revolves around mimicking the natural movement patterns of wild animals when managing livestock. So, they divide the fields into several squares and make sure the livestock moves from square to square over a short period of time. By adopting this approach, animals graze in a manner that ensures thorough coverage, the farmers then effectively remove the untouched portions of the grass and plants on the field. This practice has the potential to significantly boost grass productivity and allows the soil to recover faster and healthier without demanding excessive resources or relying heavily on technology (Futurebridge, 2022).

Perennial cropping

The concept behind perennial crops revolves around their ability to persist year after year without the need for replanting, the roots go deep in the ground and serve as a protection. This

approach offers multiple benefits to farmers. Firstly, as mentioned earlier, it significantly enhances soil health, thanks to the roots that do not allow the soil to break and reduce the chance for erosion, contributing to its long-term vitality. Secondly, farmers can reduce resource-intensive practices like frequent tillage and replanting, thereby conserving valuable resources and minimizing their ecological footprint (Futurebridge, 2022).

Agroforestry

As implied by its name, the practice involves planting trees alongside crops. This approach proves beneficial on multiple fronts: it provides essential shelter for crops that require protection until they are ready for sale, and it acts as a natural barrier effectively mitigating soil erosion and preserving the integrity of agricultural land (Futurebridge, 2022).

An **example** of a current technology that can help farmers transition to regenerative farming practices is Terramera. Their goal is to cut global synthetic pesticides by 80%. Their technology is called Actigate Targeted Performance, it makes the organic inputs more effective by immediately putting them in the targeted cells and therefore it will exceed the synthetic pesticides and fertilizers (Terramera, n.d.). Another player is called earth optics, they have a sensor technology to analyze the soil. They generate real-time data maps of the fields (EarthOptics, 2022).

D. Web of connections among actors in the agricultural sector

Communication between farmers is highly important as sharing knowledge between each other or even providing an easy way for farmers to order some livestock or products they need. **Technology** can fix that easily with a digital platform and Artificial Intelligence (Wood et al., 2014). For example, a company called Farmers Business Network, is a commerce that allows farmers to order farm products or services and deliver them to the farm. This is valuable because there is a farmer community where they can communicate and give insights about Farmers Business Network's products and services (FBN, n.d.).

E. Digital Twin farming - Virtual replica of physical agricultural operations

Digital Twin farming is creating an exact copy of the farmers' operations, but virtually. It offers extreme control over the physical operations of an organization. Moreover, it provides support when dealing with complicated operations with the use of digital innovations.

With the **use** of the Internet of Things sensors, Satellite imaging, Big data, and Artificial Intelligence, the farmer can track and monitor the operations in real-time. Having a perfect replica, one can easily experiment and optimize based on real-time data. That saves an enormous amount of time, and investment and allows the benchmark of numerous scenarios (Pylianidis et al., 2021).

Farmer Edge is a software company that gives digital infrastructure to organizations. They provide the farmers with immediate datasets from the farm and turn that data into valuable information (Farmers Edge, 2023).

An overview of the various applications of digitalization to support farmers can be found in Appendix 2.

2.2.2 The use of digitalization makes the whole supply chain more transparent

Transparency poses a significant obstacle within the food industry. The origins of products, the processes involved in their creation, and the reliability of the information provided are all essential questions that need to be addressed.

A. Standardization to evaluate the effectiveness of sustainability efforts

A common set of metrics for Environmental, Social, and Governance reporting is being used by more and more businesses worldwide which gives some standardization to measure the sustainability efforts of companies. In 2021, at the COP26, a new International Sustainability Standards Board was announced by the International Financial Reporting Standards. The goal is to offer sustainability standards for every business. According to O'Hearn et al, ESG metrics did not focus enough on social metrics, especially workforce, and did not focus at all on health and nutrition. Therefore, new ESG metrics need to be created to give food businesses standards.

The metrics will focus on sustainable practices that are also connected to health and nutrition (O'Hearn et al., 2022).

Sustainion is a platform from TurnKey Group that helps businesses meet all ESG demands. It helps an organization track and understand data to maximize business efficiency and contribute to people and the planet (Turnkey, 2023).

B. Capability to conveniently trace the entire supply chain

- Digital mapping

A map is being created about the whole supply chain and given to those who are running it. The digital map gives an overview of every step in the supply chain and therefore offers transparency. This tool allows supply chain managers to make more informed decisions. The digital map gathers details of every facility and organization in a food supply chain, this gets listed in a database and offers a detailed view of the chain through a website which makes it easier for companies to understand information about the whole supply chain (Donaldson, 2021).

- Blockchain

Blockchains allow for more traceability and transparency in the supply chain. All transactions are kept on a network, the network gets continuously controlled by an algorithm (Donaldson, 2021).

Currently, Happerley, a UK company, is building the biggest secure transparent food and drink network. All the customers will immediately be aware of the supply chain processes when buying a product (FeedMeTruth, n.d.).

- RFID technology

According to the definition in the dictionary *Le Robert*, RFID, Radio Frequency Identification technology is a remote identification method using radio frequency markers and readers. It encompasses RFID identification, RFID applications for identifying objects (stock management, etc.) and people (access control, payment cards, etc.) (Le Robert, 2023).

Thanks to an attached RFID tag to a good, one can track each stage of a product from raw materials to a finished product. Next, a device collects all the data from the RFID tag and finally, there is a database to store the data collected by the device (Costa et al, 2012). The adoption of this technology has led to increased transparency and security within the food supply chain, resulting in several significant benefits. Firstly, it enables businesses to maintain a smaller inventory and require fewer personnel for managing operations. This, in turn, facilitates a higher turnover of inventory and reduces the likelihood of food waste. Secondly, it makes it easy for food chains to detect an issue and enables food companies to solve it faster. Important to note, that the widely used barcode or Universal Product Code identification can be replaced by RFID technology if it continues to evolve (Costa et al, 2012).

An example is FoodlogiQ, a software company that offers solutions for the food industry. Their first solution is FoodlogiQ connect, it provides companies with software to control the supply chain, seize all the necessary data to be compliant with the Food Safety Modernization Act and reach a high amount of traceability. This software can recognize some food issues and solve them. Another solution is FoodLogiQ's Track + Trace, which gives an overview of all the important events that are happening with the products during the supply chain process (FoodLogiQ, 2022).

2.2.3 The use of digitalization helps fight food waste

Alongside the production of food, another obstacle lies in utilizing the produced food efficiently by ensuring timely and accurate delivery to the appropriate destinations. Digitalization can play a pivotal role in overcoming this challenge.

A. Smart warehousing

Traditional warehouses often face challenges when it comes to managing food inventory, resulting in significant amounts of food waste. These issues primarily arise because of poor food management during the transportation and storage phases of the supply chain. Therefore, smart warehousing is a solution to fight poor food management in food systems (IEEE Xplore, 2020). Since the advent of Industry 4.0, smart warehousing has emerged as a concept that employs greater levels of automation compared to traditional warehouses.

To shift from a traditional warehouse to a smart warehouse, cyber-physical systems are needed. Cyber-physical systems are computer systems used to create virtual copies of all industrial operations. Smart warehousing includes many technologies that were already mentioned previously. For example, Internet of Things technology is being used to create intelligent solutions to monitor and control warehouses. All these digital innovations lead to more efficient services and lower costs, a better inventory, and fewer errors (Van Geest et al., 2021).

B. Reduce, reuse and recycle

The circular economy, with its focus on sustainability, has received significant attention in recent years, particularly in addressing the pressing issue of food waste (Blackburn et al., 2022). Various companies and startups are actively working towards combating this problem, one notable example being Kitro. Kitro utilizes digital platform technology and artificial intelligence to assist kitchens in managing their food waste effectively.

The process begins with the installation of a device in the kitchen, upon which the bins are placed. Using advanced artificial intelligence software, the device accurately measures and identifies the quantity of waste generated by the kitchen. Remarkably, the software is even capable of categorizing the different types of food waste. This comprehensive data collection enables thorough analysis and evaluation of the waste generated.

By leveraging the insights derived from the data analysis, restaurants and kitchens can make informed decisions and implement strategies to reduce the amount of food waste, ultimately leading to substantial cost savings (Martin-Rios et al., 2020). By targeting the specific food items that contribute the most significant portion of waste, Kitro's solution empowers restaurants to optimize their operations and minimize unnecessary food loss.

C. Dynamic pricing adjusted on-the-fly

A crucial factor of food is time. Since all products have expiry dates, it is a race against time to sell them before the products perish. Customers tend to purchase based on their visual appeal and price. Consequently, the quality of the food becomes a crucial factor in meeting customer demand. It is absurd for some consumers to pay an equal price for a product that in their opinion is less qualitative approaching its expiry date and for a fresh item. Older products tend to stay in supermarkets even though they are still edible (Yang et al., 2021).

This leads to the emergence of dynamic pricing as a significant consideration for customers when purchasing perishable goods. According to Yang et al, retailers must establish a quality-based pricing strategy to generate an equilibrium between supply and demand. Thanks to sensors put on the items and artificial intelligence, one can adjust in real-time its price according to the state of the product, incentivizing consumers by cutting prices to buy even "older" yet edible products (Yang et al., 2021).

2.2.4 The use of digitalization contributes positively to consumer behavior

A. At-home consumption and reduction

Analogically to the 'reuse, reduce and recycle' principle, digital platforms technology has a positive effect on consumer consumption.

An **example** of that kind of business is called "Too Good To Go" which was invented in America in 2020 and is mainly used in Europe. The aim is to fight against food waste. The food stores can easily join the platform and sell bags of food for a small price, the food that the stores usually put in those surprise bags would go to waste at the end of the day so instead people can benefit from good food for a good price (Too Good To Go, n.d.). Another company is Algarmo, this one is focusing on consumer consumption habits. People can easily refill their cleaning product bottles using the PaaW technology that they offer in supermarkets (Algramo, 2022). Those digital companies create awareness amongst their audience and contribute to saving the planet.

B. Knowledge about consumers and companies

Customers are faced with an extensive range of product choices in a store. Their behavior can be influenced by many factors such as quality, price, or quantity. Food companies can invest more effort into a specific strategy focusing on quality for example but whether this will pay off is going to depend on the consumers. To choose the right strategy, companies can analyze consumer purchase habits with the help of technology and figure out consumer preferences. This presents companies with a greater opportunity to appeal to customers (Guiné et al., 2020).

Additionally, it is crucial for consumers to be informed about the practices and products of companies. The digital platforms technology can create awareness among consumers, an

example of such a company is Yuka. By scanning a product, a customer can receive an overview of the health status of the product. Using this platform allows people to make better choices regarding their health (Yuka, 2022). Generating this awareness is a prominent subject that will be further addressed in subsequent discussions.

2.3 What are the key technologies already existing?

Ever since the industrial revolution, humankind never stopped exploring new domains and ways of being more efficient. In time, several revolutions marked history: steam was the primary force behind the first Industrial Revolution, whereas the widespread use of electricity characterized the second. Finally, the third revolution saw the introduction of the early stages of automation and machines.

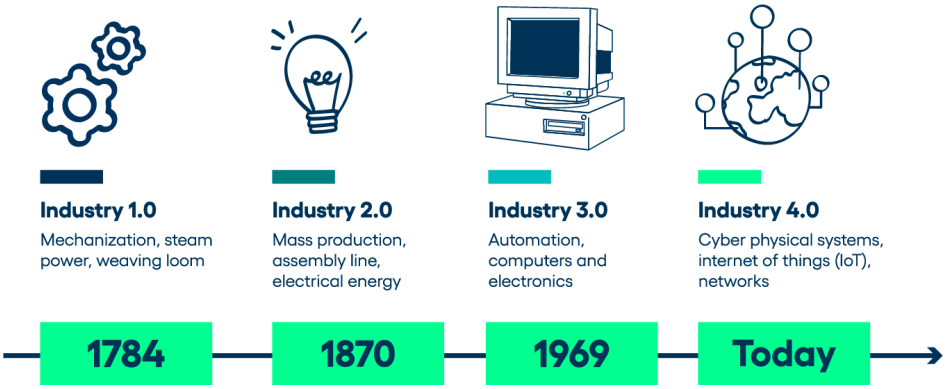

Figure 2: Industry 4.0 (Brightly Software, 2022)

The latest revolution is taking innovation to a whole new level. Beginning around 2015, Industry 4.0 symbolizes a significant switch in the digitization of the manufacturing sector focusing on:

- **Data and connectivity**: Radio Frequency Identification Technology, Internet of Things, Cloud technology, Drones, Satellite imagery and Wireless sensors
- **Advanced analytics**: Artificial intelligence, Big data analytics and Machine Learning
- **Human-machine interaction**: Robotics and Augmented and virtual reality
- **Improvements in robotics**: 3D printing

In summary, cyber-physical systems or intelligent computers are leading this era (McKinsey & Company, 2022).

Around the world, in 2019, more than 200 billion dollars' worth of technology has been invested in the food industry and the amount of money is expected to continue to increase every year (Emergen Research, n.d.). Industries are experiencing enhanced efficiency and transparency as they increasingly embrace and utilize technology. Acknowledging its crucial role in sustainable growth, the food industry is slowly adopting Industry 4.0 principles in its practices too (Atanasova, 2023).

In this part, we will cover today's cutting-edge innovations that are part of Industry 4.0, mentioned above, and relevant to the food industry (Ojo, 2018).

2.3.1 Data and connectivity

A. Radio Frequency Identification technology - Wireless communication by using radio waves

According to research from 2007, **traceability** has become a requirement in many countries for businesses to be promising in the food sector. **Radio Frequency Identification technology**, also called RFID, makes it easier for food companies to **track and trace their products as well as receive information faster**. One attaches an RFID tag to the tracked item; a device collects all the data from the RFID tag to store it. That's how the technology collects new data at low labor costs, allowing companies to slightly adapt their business processes based on the new data and information found. The aim is to automate the operations in the supply chain which will make them more secure (Costa et al, 2012).

Regarding food traceability, there are two different types depending on the way the products are flowing through the supply chain: **backward and forward traceability**. Both need to be thoroughly integrated within the information system to generate the most accurate traceability (Kelepouris et al., 2007). This technology could replace the widely used barcode or Universal Product Code identification in a near future. This contributes towards SDGs such as SDG 3 (Good health and well-being), SDG 8 (Decent work and economic growth), and SDG 9 (Industry and infrastructure) (Nurgazina et al, n.d.).

B. Internet of Things

Internet of Things also called IoT, which **optimizes every process within the supply chain**. This optimization generates a better information stream for all stakeholders as well as more

communication and transparency in the whole chain (Natalia Serbulova et al, 2019). IoT offers, in fact, an **automated process for all the different operations with the use of robots**. Human interaction would therefore decrease tremendously. The supply chain response time is quicker which means that the costs to deliver the same product is lower and less time-consuming. This allows food enterprises to reach more customers and sell more products which generate higher profits (Liu, 2015).

C. Cloud technology

Cloud technology is being used in many sectors and is taking up more and more space in the food industry for several reasons. By storing all the data in the cloud, food companies can **easily access and provide all information needed**. This increases the control over the quality of the products as well as the safety level of the different products. Moreover, the decision-making process becomes more efficient since the search costs and time to reach data decreases (MRO Magazine, 2022).

D. Drones

A technological innovation that uses AI are **drones**. Drones are being used with other technologies such as the Internet of Things, monitoring, and so on. The use of this device is mainly because it offers a **high degree of reliability and flexibility** which means they can be used for various purposes. Drones are being used in the food production processes to guarantee thorough control of food quality. Next to that, drones and more importantly artificial intelligence is an additional tool that **helps people make better-informed decisions** regarding the use of their resources in agriculture, water, or even energy. They are also able to save energy, reduce emissions and improve people's living conditions in general which goes along with SDG 6 Clean Water and Sanitation, SDG 7 Affordable and clean energy, and SDG 12 responsible consumption and Production (D'amore et al, 2022).

E. Satellite imagery

In agriculture, farmers used satellite imaging to get **images of their fields**. The goal of that is to keep track of all the fields, analyze data and take real-time decisions. Satellite imaging offers weather **predictions** and makes it possible for farmers to prepare in case of a disaster (Borkar, 2021).

F. Wireless sensors

The sensors are also present in agriculture. According to Wang et al, sensors are present in **four categories**. The first one is the **environment**; with the sensors the farmers get access to specific external parameters that they should consider. Just like with the satellites, it allows people to have weather reports about each field. Second, with the use of sensors, **precision farming** is a hot topic now. The third category is **machine and process control**. The sensors allow a smooth transmission between machines which also increases the automation between processes. This brings up the two last categories in which sensors are being used, as to know: **automation** and **RFID**. It enables more transparency and traceability along the whole supply chain (Wang et al., 2006).

2.3.2 Advanced analytics

A. Artificial intelligence - Intelligent machines that offer many insights

Another section is artificial intelligence which is present in many areas and steps of the supply chain to help reach the SDGs. Artificial intelligence has many purposes. First, it can **substitute human intelligence** to help machines deal with complicated situations. Next to that, the AI industry can deal with huge **volumes of data** and find ways to solve organizational problems at a faster pace than humans. Third, it can monitor the quality of the food and easily **identify issues** throughout the whole supply chain. Artificial intelligence helps humans be more efficient and productive daily. (Kakani et al., 2020).

B. Big data analytics

Another part of advanced analytics is Big data analytics. **All the data coming from communication technologies** such as the Internet of Things generates huge volumes of data, this is called Big data. This is closely linked to Cloud technology as it is a tool to help manage Big data. Therefore, by extracting the right information from all this data along with using adequate tools and techniques, companies can make **better decisions** regarding food safety, supply chain efficiency, and much more (IEEE Xplore, 2022b).

C. Machine Learning

Lastly, machine learning **leverages data and algorithms to mimic human memory**, enabling increasingly **accurate predictions**. By utilizing historical data, this approach transforms information to produce precise outcomes (Burns, 2021).

2.3.3 Human-machine interaction

A. Robotics - automating tasks 24/7 instead of humans

In the future, more and more robots are going to take over humans' tasks **by working with** them, those are called cobots / collaborative robots, or by **completely taking over** the human workload. Their aim is to achieve tasks with a **high level of steadiness** that humans have difficulties executing. Robots can be present in every phase of the food system. Whether it is in the supply chain or in restaurants. (Duong et al., 2020).

B. AR/VR - Creating a better customer experience

Augmented Reality/ Virtual Reality is mainly used as a strategy to reach customers in the food industry. The objective is to make the **user experience the most appealing** (*Food Industry 4.0*, n.d.).

2.3.4 Improvements in robotics

A. 3D food printing - Creating edible products with 3D technology

Another concept that is gaining a lot of attention lately is additive manufacturing. A part of that is 3D Food printing. 3D Food printing **enables the customization of goods** because it can **create almost any design with environmentally friendly products**. Therefore, it optimizes the economic and social pillars while reducing negative externalities such as releasing harmful emissions. In addition, it lowers food waste since it is on demand and can shorten the supply chain. Finally, the printing process makes the perishable products less subject to expiry dates since they can be monitored (IEEE Xplore, 2019).

2.4 The three paradoxes

The food system has 3 paradoxes. According to Bain & Company, those are the three reasons why, even though NGOs corporations, and the government, are putting a lot of effort into trying to change the industry, things tend not to change as expected: “Farmers would change, but often can’t”, “Consumers say they want to buy, but often do not”, “The market should support, but often does not” (Blasberg et al., 2022). A global summary of these paradoxes can be found in Appendix 3: Fixing our food system depends on solving three paradoxes (Blasberg et al., 2022).

2.4.1 Farmers would change, but often cannot

Most of the time, farmers work individually. Especially after the covid crisis, the agriculture sector only makes a **small margin** on each product and is dependent on several external factors such as the climate, quality of soils, pollution… In this domain, the exposure of a bad year is very high. Therefore, even though they want what is best for the perpetuation of the activity to hand it across generations, **making shifting decisions is complex**. A miss thought choice can jeopardize all the previous efforts (Blasberg et al., 2022).

For example, switching towards more sustainable practices such as regenerative farming and grazing practices rebuilds soils and lowers the carbon in the atmosphere. That would have a great impact on the farmer's sustainable practices, but it represents a major investment in terms of money and time. It, therefore, requires a long-term vision. In fact, it is only after the 5th or 6th year that one can notice greater profits. However, the farmer needs the necessary resources to survive in the meantime knowing that during this adjustment period, lower yields and higher expenses are expected. Not everyone can afford to take this bet (Blasberg et al., 2022).

2.4.2 The market should support, but often does not

Profitability and scale are often key when analyzing our current food system. No matter how the commodities coming from the farmers are produced and where they come from, if they fit the food companies’ standards and budget expectations, the business shall continue. Supply chains are designed such that it is barely impossible or very costly to change their dynamic towards more sustainable practices (Blasberg et al., 2022).

We talked previously about the product price which can be an obstacle if too expensive. In the case of some firms, changing their core business model would mean maybe not meeting their client's price requirements anymore and therefore making huge losses. The fact that there are **numerous steps in the supply chain** does not help either in the transformation process. In fact, there are on average 6 to 8 steps between the moment when growing and consuming food. Finally, many production processes are the **most efficient when producing large** volumes, the economy of scale. Therefore, experimenting on small volumes can be even more expensive. That discourages the firms even more from changing habits (Blasberg et al., 2022).

2.4.3 Consumers say they want to buy, but often do not

87%. That is the percentage of people in Bain & Company's survey that claimed to be willing to pay more for products whose origin is responsible for the environment and social level. However, it happens not to be entirely true when looking at their carts (Blasberg et al., 2022).

The explanation behind it lies in the factors that influence the customers' choices. Quality, taste, healthiness, and mostly the price are crucial components, leaving the sustainable aspect sometimes behind (Blasberg et al., 2022).

Regarding the latter, due to the current context in which we are living, as we know the recession of the global pandemic, the Russia-Ukraine war that skyrocketed energy and food prices, and global supply chain bottlenecks, historically high **inflation** is triggered. Those events impact inflation but are also impacted by inflation (Barklie, 2023).

The latest records coming from the International Monetary Fund (IMF) reflect global inflation of 8.8% in 2022 compared with the prices of 2021. To give an idea regarding Europe and its neighbors, the UK experienced the highest inflation in 40 years of 10.1% in January 2023, Germany's and Italy's CPI were at 8.7% and 10.1% respectively in the same period (Barklie, 2023). Belgium on the other hand was 8.05% (Statista, 2023). As the cost of living remains high, sustainability does not figure at the top of everyone's list.

Besides the price, it appears that it is complex for a lambda consumer to distinguish sustainable products. There is a **lack of simple consumer-friendly information and guidance** on the

products. It should be the producers' responsibility to provide such information to the retailers, but it seems to be more complex than that (Blasberg et al., 2022).

2.5 Current challenges regarding the SDGs

The challenges the food industry is facing in the 20th century are numerous and much intercorrelated. This requires therefore to tackle them not individually, but rather in a holistic integrated way that reverses trends throughout the whole chain, from the extraction of the raw materials to the consumption. According to Bain and Company these challenges of our current food system are in the number of three: straining of natural resources along with pollution, hunger that is related to food waste and food insecurity, and unhealthy (Bain, 2023). All three are happening mainly at different stages of the supply chain. While natural resources management is more of a farmer challenge, most of the food waste occurs between the farmer and retailer step, ending with the health matter concerning the consumers.

2.5.1 Natural resources and pollution (Farmer)

To begin with, the first challenge is the depletion of natural resources along with pollution. Several SDGs are tackling and measuring this challenge: **12 - responsible consumption and production, 7 - clean and affordable energy, and 13 - climate action**. Nowadays, our whole supply chain is designed to be the most profitable and to make the most economies of scale possible. Consequently, choices are driven by what is the least costly for the business rather than what is the best for the planet. Overall, the food industry has the most important impact on the natural resources of all industries. Land, soil, water, biodiversity, minerals, biomass, and fossil fuels are key natural resources on which the food sector relies, and most of them are not managed sustainably or efficiently. One can enumerate many examples that confirm this claim: terrestrial loss linked to food production, soils that are damaged due to erosion, global aquifers that are overexploited, the input of minerals (e.g., phosphate) that do not attain consumers' plates, overfishing, a large amount of water use … (Hajer et al., 2016).

In addition to the world's resources that are becoming scarcer, there is the challenge of pollution. As mentioned in the introduction, food production is responsible for more than one-third of the worldwide CO2 emission, (Charles, 2021). At the top of the list of the major food products that have the largest greenhouse gas emission per kilogram produced (in kilograms of

carbon dioxide equivalent figures: Beef - 99,48 kg, dark chocolate - 46,65 kg and lamb & mutton - 39,79 kg (Statista, 2023). That is not to mention other aspects like the massive use of chemicals.

SDG 12, tackles sustainability in consumption as well as in production to ensure the livelihoods for now and the future. Especially goal **12.2** aims to reach sustainable management and efficient use of natural resources growing towards a more circular economy. Figures from this SDG illustrate that instead of aiming for the independence of natural resources, the contrary is true currently. According to the UN Report of 2022, we see worldwide a growing reliance with the steepest rise in East and South-Eastern Asia in the past 20 years. Another alarming fact is that fossil fuel subsidies remain high, encouraging the production and use of coal, oil, gas, and other fossil fuels that are the reason for a range of adverse environmental and health impacts. Despite the important drop in those subsidies in 2020, in 2019 $526 billion were spent by governments on this matter. This is a huge financial barrier toward renewable energy sources (United Nations, 2022).

This last point leads us to **SDG 7** - clean and affordable energy. During COVID-19 in 2020, worldwide CO2 emissions declined by 5.2%, as the world's activity was lowered. Unfortunately, this was no lasting period since as soon as the safety measure got slowly removed, a record high fossil fuel emission was experienced offsetting all the pandemic-related decline (United Nations, 2022). Another phenomenon is the latest Russia - Ukraine war, energy prices have skyrocketed. Whereas it triggered price inflation, it also leveraged the urge for renewable, local energy (IEA, 2023). Between 2010 and 2019, the portion of renewables in total final energy consumption only increased by 1.6 percentage points reaching 17.7% worldwide (United Nations, 2022). Especially in Europe, this war is drastically changing the government's mindset. The UN report does not provide any data further than 2019, but The REPowerEU plan from the European Commission, which was unveiled in May 2022, calls for the EU to stop relying on Russian fossil fuels by the year 2027. The ambition is to reach a 45% share of renewables in final energy consumption by 2030 and to double Europe's renewable electricity expansion between 2022 and 2027.

Finally, **SDG 13** - climate action. The current situation is a 1.1° rise in temperature since the pre-industrial level (1850-1900). Everyone is already noticing the consequences that are more extreme weather periods: floods, droughts, heatwaves… some regions of the world,

unfortunately, more than others, exacerbating the already settled inequalities and worldwide polarization. Concerning the food industry, 2015-2021 were the years during which the highest temperatures were recorded. If this pattern continues the wrong way, one-third of the worldwide land areas will experience at least moderate drought by 2100, which will have a major impact on the agricultural sector causing food insecurity and malnutrition. To remain under the 1.5°C above pre-industrial levels, agreed upon during the Paris Agreement, the world's emissions of greenhouse gasses must stabilize by 2025, lower by 43% by 2030, and net zero by 2050. Those bold goals need drastic changes through the determined climate actions of all countries. Currently, developed countries have gathered $79.6 billion in 2019, but it is far from being sufficient. The Intergovernmental Panel on Climate Change (IPCC) estimates a needed annual budget between $1.6 trillion to $3.8 trillion until 2050 to reverse nowadays' patterns (United Nations, 2022).

2.5.2 Food waste (Retailer)

The second challenge is how we can **prevent food waste**, which is SDG 12.3. This has been a major concern over the past few years, making new businesses emerge like "Too good, to go" for example.

There is no SDG called this way, but this falls under **SDG 12**, responsible consumption, and production. As mentioned before, if we go on with the prevailing development pathway, a shortage will be encountered of livelihoods soon. As the Earth's capacity is finite, humankind should use the still available resources wisely and efficiently, therefore reducing waste, pollution and promoting a circular economy. In 2020, 13.3% of the worldwide produced food was lost between the harvest and retail markets (on-farm activities, transport, storage, processing, and wholesaling). An additional 17% of the food accessible to the consumer is wasted (household, food service, and retail levels) under which 60% happens in households. In concrete numbers that is 931 million metric tons, or 120 Kilograms wasted per person every year (United Nations, 2022). SDG 12.3 has a bold goal to reduce by half the food waste per person as well as food losses during the food supply chain. One must acknowledge that it is not because food is not edible anymore by humans, that it has lost all its utility. In Appendix 4, the food process is much longer than only edible – loss.

2.5.3 Food insecurity and unhealth (Consumer)

Last challenge concerns **zero hunger and malnutrition** under **SDG 2**. This latter concept appears when there is a lack of nutritious food on a regular basis to the extent that it affects the person's health. As discussed in the section 2.4.3 “Consumers say they want to buy but often do not”, the price of healthy food is a crucial reason why some people cannot afford daily sustainable food. Apart from the financial aspect, malnutrition is also caused by a lack of qualitative, accessible, and understandable information. Malnutrition can occur in different forms: undernutrition, disequilibrium of vitamins or minerals, overweight, obesity… Globally, everyone who has an imbalance of energy intake or nutrients (World Health Organization, 2021).

Regarding hunger, the main causes are conflicts since 70% of the people suffering from it live in regions where war is present. Besides that, as covered in SDG 13, the climate crisis and the extreme weather conditions do not ease wealthy harvest and living conditions (World Food Programme, 2023). The poorest a household is, the bigger the part of the food expenditures is in their monthly expenses (TACOLI, 2019).

SDG 2 not only aims to eradicate food hunger worldwide by 2030 but also to improve nutrition under **SDG 2.2.** While in Western countries the phenomena of “stunting” and “wasted” are not well-known, in 2020 there were still 149.2 million children under 5 years of age, that is 22% suffering from low heights for their age (stunting), and 45 million too thin for height (wasted) because their nutritional needs were not satisfied. As for adults, 1.9 billion are overweight or obese, while 462 million are underweight. (World Food Programme, 2023). This aspect of ensuring good health and well-being is also linked to **SDG 3** - good health and well-being. Regarding hunger itself, the latest figures of 2020 indicated that the number increased by 161M reaching between 720 million and 811 million persons worldwide suffering from hunger (United Nations, 2022) and 900,00 persons globally are struggling with famine in 2023 (World Food Programme, 2023).

2.5.4 Fair distribution of product value (Farmers)

In addition to the challenges enumerated before, there is a last one that is important to tackle to foster a sustainable food industry: ensuring that farmers receive a fair income that reflects

the hard work and effort they invest in cultivating crops. The exact percentage of the revenue that producers earn from the final value of the product remains undisclosed, creating a lack of transparency. Consumers are unaware that, on average, only 15% of the price reaches the farmers, while the remaining portion is claimed by middlemen such as supermarkets. On an hourly basis, the average remuneration is only 3 or 4€ (Enabel, 2020). That is clearly underpaid knowing the fact that the minimum salary that a job student pays is 11.19€/hour (Bruxelles-J, 2023). Therefore, seen as a laborious domain that does not generate profit accordingly, it discourages the youth to make a career in agriculture resulting in aging workers. Figures show that in 2020 in Belgium, 60% of the farmers were older than 50 years. If the industry does not manage to attract more young farmers to ensure succession, this will result in a loss of our food sovereignty[5].

SDG 8 - Decent work and Economic growth, includes this challenge. The target is to ensure everyone that has full and productive employment, and decent work, but also protect labor rights and promote safe and secure working environments. It aims as well to develop an efficient plan to avoid youth unemployment and to protect precarious employment (United Nations, 2022)

[5] Food sovereignty is the right of every country to maintain and develop its own capacity to produce its own essential food, while respecting the diversity of cultures and products. We have the right to produce our own food on our own territory (Alahyane, S. ,2017).

2.6 What is the current situation in Belgium?

Thanks to the multicultural, collaborative, and business-friendly environment that Belgium offers, the country appeals to many powerful international players and new incoming start-ups (Vorontsova, 2022). Attracting promising and **innovative** companies ranks Belgium as a country either in line or above the global European average on sustainability, technology, and talent (EY, 2022).

Regarding national **agriculture**, nearly half of the Belgian territory is used for agricultural purposes, 45% to be precise (Statbel, 2022a). The produced crops can be divided in three different categories: grains, industrial crops, and forage crops. Among the ones that are the most produced, we can find winter wheat, sugar beet, potatoes, and fodder maize with respectively 1.7, 4.7, 3.3, and 6.9 million tons in 2022 (Statbel, 2022b). An interesting fact is that recent values have shown that the GDP share of agriculture in Belgium was only 0.66% in 2021 equaling an added value of 3.94 billion US$, while the world's average represents 10.35%. Besides, coming from the same source, employment in agriculture was only 0.92% (≃ 68 000 workers) of the active Belgian workforce decreasing from 2004 onwards. That is 22% below the global average (TheGlobalEconomy.com, 2021). Behind the impressive number of 46%, one must keep in mind that Belgium is a small country, and that this percentage is only equal to 13 646 km2 (World Bank, 2020).

A noticeable fact is the clearly **inefficient use of fertilizers.** As we can see on the graph on the right, Belgium uses two times more fertilizer than the leading EU countries in agriculture. While Belgium turns around 300 kg/ha of arable land, the others have approximately 160 kg/ha (TheGlobalEconomy.com, 2021b).

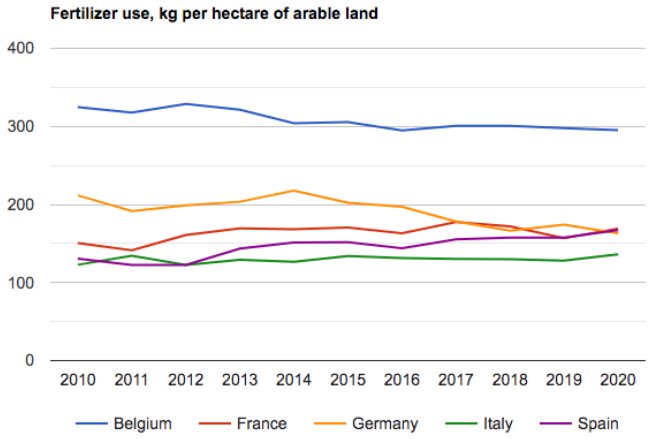

Figure 3: Fertilizer use (TheGlobalEconomy.com, 2021b)

At the European scale in 2021, the **top three** leading countries regarding net added value[6] that the sector represented, where France appeared as first, then Italy, followed by Spain. Even though Germany is not part of the top three, it stood close to Spain, barely equally (TheGlobalEconomy.com, 2021b).

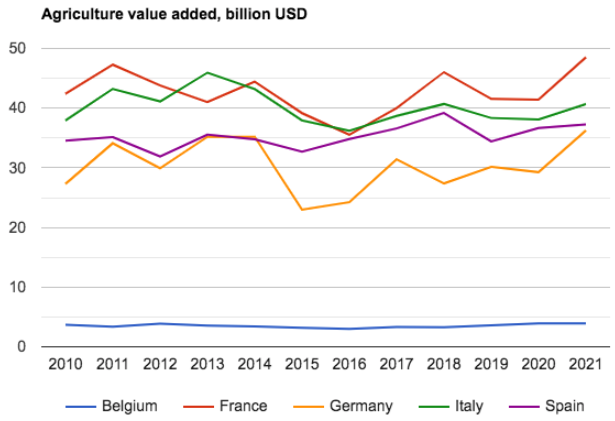

Figure 4: Agriculture value added (TheGlobalEconomy.com, 2021b)

Concerning **sustainability**, the national cleantech ecosystem's focus is growing towards a circular economy, reducing carbon emissions and renewable energy (Vorontsova, 2022) especially solar energy which is very popular among Belgians (87% of the respondents of the PwC's Green Deal survey used it - EU average is 78%). Hydrogen, on the other hand, has a lot of potential to grow as only 7% of them use it - the EU average is 20% (PwC, 2022). The government has already acted for that, approving in 2021 the new strategy and vision enhancing renewable energy coming from hydrogen (Vorontsova, 2022).

At the **technology** and digital level, not all sectors evolve at even speeds. Firms specializing in consumer goods and manufacturing for example appear to fall behind (Consultancy.eu, 2022). Apart from the sectors, the investors have their preferences when it comes to digital skills. Among those that are the most demanded and scarce in Belgium: Artificial intelligence and robotics, cybersecurity, and big data & analytics (EY, 2022). Again, the government aware of the lack has tackled these issues in its National Recovery and Resilience Plan in 2022. Their main objectives are the green transition to which 49.6% of the whole budget is allocated and the digital transformation which has 26.6%. They represent 2 940M€ and 1 575M€ respectively (European Parliament, 2022). Concerning **connectivity**, while Belgium had a digital maturity level higher than the European average level in 2021, it dropped severely in 2022 due to a

[6] "Agriculture value added is the net output of the agriculture sector, including forestry, hunting and fishing, and cultivation of crops and livestock production, after adding up all outputs and subtracting intermediate inputs. Deductions for depreciation of fabricated assets and depletion and degradation of natural resources are not included in the calculation." (TheGlobalEconomy.com, 2021b)

tremendous lack of 5g implementation ranking 16th out of 27 at the DESI level (European Commission, 2022c).

We will go more in-depth about the state of digitalization in Belgium in the following section.

2.6.1 Degree of Implementation of digital innovations in Belgium

It is assumed that if there is a lot of evidence to be found of digital innovation in Belgium, the degree of implementation is high. If there is a medium level of evidence to be found, the degree of implementation is average and could be implemented more, and finally, if they found evidence is low or close to inexistent, the degree of implementation will be low too.

A. Data and Connectivity

Radio Frequency Identification Technology

RFID technology is highly used in Belgium for the protection of data. The use of that technology is present in many sectors in Belgium such as in healthcare, retail sectors or in airports (Linklaters LLP, n.d.).

Moreover, in 2016 a Belgian retailer called JBC implemented RFID technology in their clothing collection. This brings many advantages for the brand because it helps with stock management as well as for the customers because it enhances the customer process at the cash register (De Cat, 2016).

Internet of Things (IoT)

The Internet of Things is an **important part** of Brussels' high-tech ecosystem. Brussels created a Smart city office; they handle projects in 19 regions and offer Smart city solutions including the Internet of Things on a regular basis. With the use of the Internet of Things sensors, a platform has been created to give companies a better understanding of their energy consumption and offer help to use their energy more efficiently (Anciaux, 2023). In Europe, IoT is forecasted to increase from over one billion in 2021 to 2.06 billion U.S. dollars by 2025 (Statista, 2023a).

Next to that, there are many companies that are composed of developers who are specializing in offering Internet of Things solutions in Belgium (GoodFirms, n.d.).

Cloud technology

Belgian companies use cloud technology, but the degree of implementation **depends on the size** of the company. Larger companies are more likely to use cloud technology in their operations, at around 70%. Compared to smaller companies who use it at around 50%. Moreover, Belgian entrepreneurs gathered and created something called Belgian Cloud. A team of Information and Communication Technologies experts is present to share their knowledge and talk about cloud technology. According to research, the amount of implementation of cloud technology varies in regions in Belgium. Brussels seems to be the region that is the most aware and uses the most cloud software (Fiten et al., 2019).

Drones

The use of drones **is increasing** over the years in Belgian companies, it is expected to be more and more used by the government too. However, privacy is very important in Belgium. Therefore, there are some very specific laws that make it complicated to use it. The government needs to make sure the data gathered by drones is protected and secured. Moreover, companies need to prove that drones are not being used for harmful reasons. Thus, new rules and regulations need to be imposed. Now, those problems have not been totally taken care of which means that they will need to be addressed in the near future since the use is increasing (Frąckiewicz, n.d.).

Satellite imagery

Satellite imagery has enhanced over the years and is **widely used** in Belgium. Belmap was created to offer valuable findings to Belgian buildings with the use of artificial intelligence and more precisely satellite imagery. It offers a 3D database of every building in the Benelux, which includes a lot of information such as the age of the building, gardens, roofs, and so on (GIM, n.d.).

Wireless sensors

In Belgium, there is a leader in manufacturing and providing sensing solutions in various sectors such as health care or retail called BEA Sensors. The sensors provide support to industries that are trying to become more and more productive with the use of artificial intelligence (BEA Europe, 2021). Next to that, during the covid 19 the railway sector used smart cameras with sensors to make sure that their employees respected the covid 19 rules such as wearing a mask and keeping their distance (Lenoir, 2020). There are other providers in Belgium, but no more information can be found regarding the use of sensors in Belgium.

B. Advanced analytics

Artificial Intelligence

It has been observed that numerous companies, particularly large ones, in Belgium are increasingly adopting artificial intelligence. Research indicates that Belgium ranks second in terms of artificial intelligence utilization, following closely behind Denmark. Moreover, there appears to be a positive correlation between business productivity and the integration of artificial intelligence, with Belgium showing promising results in this regard. Over 40% of large companies in Belgium are utilizing AI, and on average, 25% of them are actively developing AI solutions (The Brussels Times, n.d.).

Big data & analytics

In 2017, Big data software was already used by **more than 50% of the companies** in Belgium. The amount of technology used worldwide is continuously increasing, therefore we can safely assume that the use of big data has increased simultaneously over the years (Statista, 2023c). However, not much information can be found regarding Big data and analytics.

Machine Learning

When it comes to machine learning, there is limited information available specifically for Belgium. However, considering the close connection between machine learning and artificial intelligence, it can be assumed that the level of implementation in Belgium is similar for both technologies.

C. *Human-machine interaction*

Robotics

More and more companies are trying to automate the operations of their businesses because it includes many benefits like an increase in productivity and efficiency. According to the International Federation of Robotics, more than 10 000 robots have been deployed and placed. This is placing Belgium in the **15th position in terms of robot density worldwide.** Most of those robots can be found in the automotive industry. The use of robots can still be highly used in the food industry. On average 40% of small and medium businesses are not using robots in Belgium, the reason for that is that most of the employees within those businesses usually do not know the advantages that it brings. Also, according to a survey established by PwC, there might be a lack of trust towards robots (PwC, 2023).

Overall, the government knows it is costly for enterprises to invest in robots and automation applications. Therefore, they created initiatives to support those companies and make the price more reasonable (PwC, 2023).

AR/VR

Belgium has a significant presence in AR/VR initiatives, supported by the existence of an AR/VR association. This association is crucial in promoting AR/VR technologies to companies by facilitating connections between AR/VR solution providers and businesses seeking such solutions (VR/AR Association Belgium and Luxembourg, n.d.).

D. *Improvements in Robotics*

3D food printing

MeaTeach 3D Ltd. is the first cell-cultured meat company to go public. They recently acquired the Belgian company Peace of Meat PV. They are focusing on chicken fat to generate cultured meat. By just collecting a few cells from an egg, they can create cultured meat in huge quantities. Now that Piece of Meat MeaTeach has acquired PV, it can lead to an enhancement of the meat by combining both companies' expertise. The new facility in Belgium is going to continue being used for chicken fat in the first place, eventually, this will change, and the

objective is to go big and use 3D printing to create meat pieces such as steak and chicken thighs (Saunders, 2021).

In conclusion, Belgium has achieved a moderate to high degree of implementation in digital innovations, indicating rapid progress in the digital realm. However, there is still room for improvement at the core of the chain. In Appendix 5, a summary of the innovations and their degree of implementation can be found.

2.7 Digitalization for the Agriculture volatile market

Based on our literature review above, we are going to narrow down the scope of challenges that are possible to tackle. Among the three paradoxes, we will proceed with the one of the farmers for several reasons. With the growing demographic mentioned earlier, agriculture is the main sector that will need to improve in efficiency while lowering its impact to answer this demand (World Economic Forum, 2023). Worldwide, 46% of the habitable land is used for agricultural purposes, that is 48 million km2 (Ritchie, 2019b). While 77% of this land is used for livestock including meat and dairy, it is the remaining 23% land of crops that represent 82% of the global calorie supply and 63% of the global protein supply (Ritchie, 2019b). Based on the important impact that has on the **crops**, that will be our focus during the following sections of this master's thesis.

According to a McKinsey report, the agriculture industry faces some challenges on a daily basis, including **rising prices and unfair wages, weather uncertainty, food waste, and shifting consumer behavior requiring more transparency and natural products**. These challenges can be faced through the help of digital innovations and a higher level of technological implementation.

Digitalizing farmers' operations brings out many advantages that lead the whole food sector and all the actors towards a better sustainable future (Banks, 2022). However, the digital adoption of technology in the agricultural sector depends largely on the farmers. The authors claim that whilst the willingness of farmers to use technology is very high, the implementation of digital innovations is low. There are several reasons for this, first, the costs to produce products are currently increasing because of the current situation of post-pandemic and energy crisis. Secondly, the market is very uncertain which increases the farmers' concerns for revenue and thus for expenses as well. Third, given the fact that the farmers' input prices are high, farmers need to optimize their crops as much as possible. Which means they need to have a higher level of output. To reach that, technology is the primary driver (Fiocco et al., 2023).

Based on these premises, we will focus on assessing the most suitable existing technologies for the Belgian market to face these challenges:

- How can digitalization contribute to the **challenges of decent wages**?

- How can digitalization contribute to the **challenges of weather uncertainty and resource management**?
- How can digitalization contribute to **food waste?**
- How can digitalization contribute to the **challenges of transparency toward the consumer**?
- How to **implement** digitalization and **manage** the change?

All of these sub-questions lead to one main research question: *How can digitalization help the agricultural sector to achieve Sustainable Development Goals (SDGs) in the case of Belgium?*

Since every key player in the supply chain is linked one to another, we will categorize the challenges above according to the involved players with the farmers at the center of the relationships. These will be explained more in-depth in the following section. The first two challenges, which are the cropping intensity, and the environmental uncertainty are challenges affecting only the agricultural sector. Next, we will cover the food waste and unfair wages happening between the farmers and the retailers. Ending with the focus on the consumer's relationship with the farmers, how can transparency regarding the growing process of the products be improved to respond to the consumer's increasing healthy food concerns?

	Farmer	Retailer	Consumer
Concrete challenge	Profitability: Cropping intensity and resource management Environment uncertainty	Unfair wages Food waste	Lack of transparency and guidance
SDGs challenge	Natural resources and pollution	Decent work and economic growth Food waste	Food insecurity and unhealthy

SDGs number	SDG 7 SDG 12 SDG 13	SDG 8 SDG 12.3	SDG 2 SDG 3

Figure 5: Overview of the stakeholder's challenges (authors,2023).

2.7.1 Agriculture - resource management and weather uncertainty

Farmers face several challenges when it comes to their crops and yields. The first one is monetary. Farmers are struggling with profitability being squeezed on both sides. On one hand, the input costs for the farmers to produce the food are continuously increasing. According to a BCG report of 2022, prices for fertilizers for example have drastically gone up since the Ukrainian - Russian war given the fact that Russia is the main producer (BCG Global, 2022). On the other hand, they encounter pressure to keep the resale price from increasing. This problem is very much linked to the fact that consumers have to face the fact that the cost of living is going up. Belgium has a relatively high cost of living index of 65.6, indicating that it is quite high compared to other EU countries. According to research, groceries seem to be one of the most expensive costs in Belgium (Travelsafe-Abroad, 2023). Consumers are torn between their sustainable aspirations and economic resources (Naomi, 2021). That phenomenon of increasing input prices and dropping output prices are to be seen in the graph on the right.

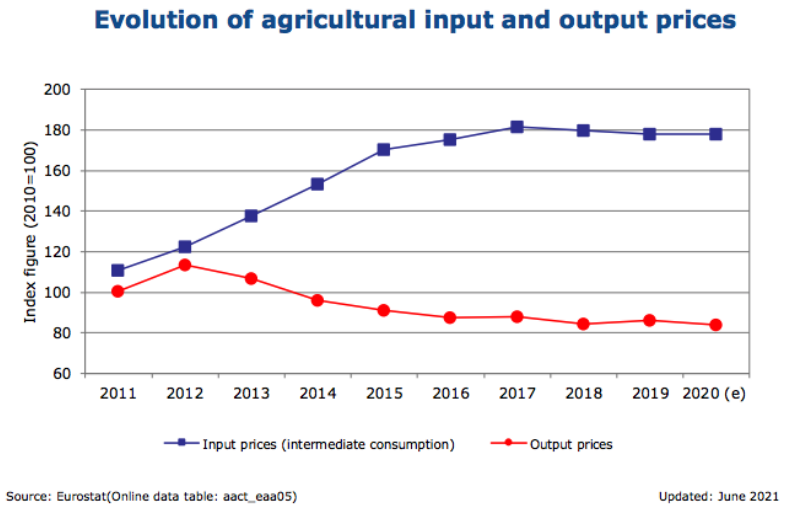

Figure 6: Evolution of agricultural input and output prices (Eurostat,2021)

Consequently, the variable on which the farmers have the most power is how efficiently they manage their **resources** and the volume of the **crops** produced. Therefore, farmers must aim to increase the cropping intensity, that is the number of crops growing in a year in the same area (Iizumi & Ramankutty, 2015), and minimize the use of costly resources and energy such as water, fertilizers, pesticides, …

Another factor that highly impacts the result is the **conditions of the environment** in which the crops grow. All farmers are aware of how much biodiversity, soil and air, the amount of precipitation, light, and temperatures… impact the future harvest (Soft.Farm, 2020). Up until now, these factors are not yet 100% controllable and remain a source of unpredictability. Climate change increases and becomes more and more extreme over the years, which has adverse impacts on food production, especially if fatal weather events occur when the crops are growing (Iizumi & Ramankutty, 2015).

Even though many technologies have been developed over the past few years to tackle these kinds of challenges, not all of them are well-known or used widely due to either a lack of awareness or funding (World Economic Forum, 2023).

Thus, the following challenges will be analyzed and tackled in the Chapter four "Analysis & Discussion":

- Increase profitability: Enhance resource management and cropping intensity needs to be maximized
- Environment uncertainty - external factors are difficult to control

2.7.2 Farmers & retailers - Unfair wages and food waste

The biggest challenge between farmers and retailers is the bargaining power asymmetry between those two resulting in a trade at **low sales prices**. One can sum up the different reasons behind this problem. The first reason has its roots in the concentration of the respective markets. While the agriculture industry is highly fragmented counting many individual operating farmers, the other is concentrated in the hands of only a bunch of key players. Facing giants who have the choice between identical other suppliers reduces tremendously the collective bargaining power on the farmer's side (Clarke, 2022). Due to their reliance on retailers to reach the end consumer, farmers are price takers while they should be price makers. Even though we see the prices of the goods rising, the farmer will have only a small fraction of it. The shares of the end revenue are unevenly divided with a large part going to the middlemen (National Family Farm Coalition, 2019).

Another reason for this is the perishable nature of agricultural goods. These have a limited shelf life and are susceptible to spoilage. This time sensitivity puts farmers at a disadvantage when negotiating with retailers who can exploit this urgency to drive prices down. They may be forced to accept lower prices or unfavorable conditions to avoid incurring losses by not being able to sell their perishable goods which would lead to overproduction and **food loss**. Such losses represent critical costs that not all farmers can absorb.

More awareness concerning this problem is required among consumers because many are ignorant about the extent of food waste. Additionally, a rebalance should take place rewarding each one's effort rationally.

Nowadays, some farmers have decided to cut out the middlemen and immediately sell to the end consumers, one of the reasons is the fact that supermarkets ask for big volumes during the whole year, which offers many challenges for the farmers because they need to have constant production efficiency every day which is complicated (Held, 2023). Whilst cutting the middlemen appears to be an efficient solution, it implies other challenges for the farmers whose core business and expertise do not remain in marketing or B2C sales. Therefore, our aim is to provide farmers with digital solutions that streamline the entire customer journey and facilitate smoother interactions between the two parties. The implementation of digital solutions will not only help prevent food waste but also create a balance between supply and demand. This equilibrium will enable farmers to achieve higher profit margins, as more food will be sold and less will be lost. Additionally, we seek to offer digital solutions that enhance the transparency of product purchases and resale prices for consumers because they are not aware of how much farmers are getting paid for their efforts.

2.7.3 Farmers & consumers - Lack of transparency and guidance

When it comes to consumers, we noticed polarized consumer behavior with different sensitivities. On one hand, a large part of consumers is showing increasing interest in healthy products. According to a Deloitte survey quiring 17 000 consumers in 15 EU countries, it appears that 56% of them claimed healthiness as the most important purchasing factor when opposed to affordability which reached 44%. (Deloitte Belgium, 2021).

The expectations of the consumers change constantly forcing farmers to follow them and adapt accordingly (Syngenta, n.d.). Consumers are asking for more farm-to-fork traceability and transparency. Consumers will show more interest and make informed decisions when purchasing high-quality products if they have certainty regarding the actual quality of those products. Farmers need to inform consumers about the real value of their products (Narayan, 2022). Thus, we will offer digital innovations that can help farmers with farm-to-fork traceability.

CHAPTER THREE: METHODOLOGY

3.1 Introduction

We started by screening the challenges along the whole supply chain with the key actors being the farmer, the retailers, and the consumers. These were summarized into three paradoxes seen previously in the section 2.4 “The three paradoxes”. We narrowed the scope further down by choosing to put the focus on the source of the supply chain, the agriculture industry. After having determined the key focus of our master’s thesis, which can be found in subsection 2.7 “Digitalization for the Agriculture volatile market”. We will proceed with the analysis of the most efficient, yet feasible way to tackle those challenges and what additional factors one must consider implementing those shifts. To achieve that, we mixed primary data with secondary data to support our findings and quantitative sources with qualitative sources to enlarge our reaching area but still have insightful experts’ opinions. To provide a framework for our research methodology, we decided to use the Saunders Research Onion Model. This model is a tool to find the right approach and methods when conducting research.

3.2 Research aims and objectives

This research aims to offer an understanding of how digitalization contributes to the agricultural sector and achieves Sustainable Development Goals. Thus, the main research question is the following: *How can digitalization help the agricultural sector to achieve Sustainable Development Goals (SDGs) in the case of Belgium?*

Several sub-questions have emerged, as mentioned in subsection 2.7 “Digitalization for the Agriculture volatile market”, to answer the thesis question:

- How can digitalization contribute to the **challenges of decent wages**?
- How can digitalization contribute to the **challenges of weather uncertainty and resource management**?
- How can digitalization contribute to **food waste?**
- How can digitalization contribute to the **challenges of transparency toward the consumer**?
- How to **implement** the digitalization and **manage** the change?

To collect data and be able to answer the sub-questions and eventually the main research question, it is crucial to make the right choice of data collection techniques. The Onion model includes philosophical, theoretical, and practical approaches to reach the core layer which is Data collection and data analysis:

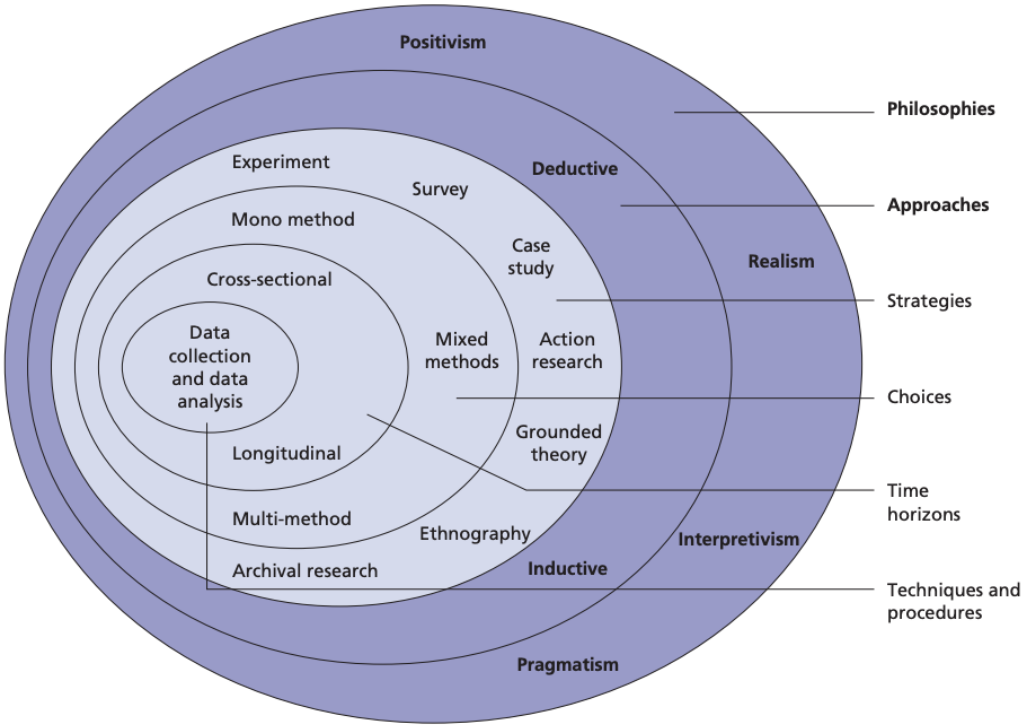

Figure 7: Research Onion (Saunders et al., 2009, p.108).

3.3 Research philosophy

The first layer of the Onion model is related to three assumptions. First, there are ontological assumptions which are about how the researcher sees the world and reality. Second, there are epistemological assumptions that focus on the different ways to obtain knowledge. Third, there are axiological assumptions. Those are assumptions about the way the researcher is dealing with its own values and norms but also consider the values and norms of the respondents/participants of the research (Saunders et al., 2009).

Ontological assumptions: On a daily basis, we are confronted with pressing issues regarding global warming, food waste, hunger and the scarce number of resources for the planet. People

are more and more aware of what is going on in the world and how important the role of sustainability is. We believe the fact people are becoming more knowledgeable about the same topic creates a connection between them. The same can be said about technology, the emerging trend evolves very quickly and makes people evolve too.

Epistemological assumptions: We aim to discover how current digital innovations are helping the food industry, the key technologies that already exist, the degree of implementation of digital innovations in Belgium and the digitalization for the Agriculture volatile market. All of this can be found through one mean, namely through the literature collected that can be found under the chapter two “Literature Review”. The second mean is through data collection. This will be useful to tackle the main challenges for farmers, analyze the importance of digitalization in the agricultural sector and get to know more about consumer behavior of the Belgian population. These two means will help us gather acceptable knowledge to answer the research question.

Axiological assumptions: On one hand, the researchers, in this case, are both students that have emerged in the digital world since they are born and have their opinion about whether digitalization can help or not. Moreover, both researchers have a good understanding of the different challenging issues the world is facing and are fully aware of the different Sustainable Development Goals. On the other hand, the data that needs to be collected must come from people who have a deep understanding of how the agricultural sector works as well as people working for food retailers and Belgian consumers. Every single group for the data collection will have their own personal view on things, keeping an open mind and staying objective is important to understand their view on digitalization and whether it can help achieve Sustainable Development Goals.

Based on these three assumptions discussed, the philosophy in place for this thesis is pragmatism. Saunders et al. state that the most important factor for all three assumptions is the research question. This is the case for this study as well. As part of the pragmatism philosophy, the data collection method that is the most used is the mixed-method design. This is also the best for the researchers where both quantitative and qualitative data are needed to collect data (Saunders et al., 2009).

3.4 Research approach

The next layer of the Research Onion Model is the approach to theory development is inductive. This means that first the data is collected through empirical observations and afterwards a general conclusion will be made. The research made in this thesis cannot be linked through previous theory or research and we aim to develop solutions on how digitalization can help the agricultural sector in Belgium and achieve Sustainable Development Goals (Saunders et al., 2009).

The third layer is the research strategy. There are two different strategies that we followed. The first one is the survey strategy where a large amount of data can be pulled from a certain part of the population to be able to generalize and draw conclusions about certain subjects. A survey allows the researchers to gather quantitative data and therefore enables us to analyze the variables and create relationships. The second strategy is the case study strategy where the environment is completely controlled. This is important because it promotes triangulation, meaning that different sources of data are needed, which is the case here. Interviews will be conducted to gather data (Saunders et al., 2009, p.177).

Next, we will discuss the methodological choice also called data collection method. Based on the pragmatism philosophy and the inductive approach, we decided to use mixed-method design. This means two data collection techniques will be used: interviews and a survey. With both methods, we can draw a deeper understanding of what was established with the literature review (Saunders et al., 2009, p.177).

The next layer is the time horizon. Given that the master thesis has a time constraint, we will use the cross-sectional time horizon. This means that a short period of time is allocated to gather data. In the case of the thesis, the data collection will happen between January 2023 and March 2023, this allows us to have enough time to analyze the data.

The core of the Research Onion Model is going to be discussed in the sub-sections 3.6 and 3.7.

3.5 Sample strategy

To collect data from a relevant sample, we decided to narrow down the sample to farmers and retailers for the interviews and to consumers whom we reached through a survey.

We interviewed two Belgian farmers, the first one is Cédric Dumont de Chassart, who is the owner of a farm in Ramilies-Offus, where he manages livestock, as well as organic and conventional crops. He sells his organic products to supermarkets such as Delhaize. A unique aspect of Cédric's farm is that next to producing goods, he takes care of the packaging and distribution for export (Appendix 6). The second one is Jana Du Bois, owner of a farm in Asse. Her farm is a family business, they have on average hundred cattle. The asset of her farm is the location, it is right next to the periphery of Brussels. (Appendix 7). On the retailer side, we interviewed Veerle Poppe who is a Sustainability strategist at Colruyt Group (Belgium) for nine years (Appendix 8). Colruyt was chosen because it is the largest supermarket in Belgium in terms of sales with a turnover of €7.96 billion in 2020 (Wynne-Jones, 2023). And we also interviewed Geoffrey de Hennin and his wife, owners of one of the many stores in Belgium and France, called Intermarché (Appendix 9). We interviewed the owner of the farm or the retailers because of their experience and most of all, because of their role in the food supply chain.

Regarding the survey, the aim was to be able to make a generalization of the Belgian population. All these characteristics helped the sample population be as accurate and credible as possible to collect the most relevant data to draw conclusions (Appendix 10).

It would be irrelevant to interview stakeholders outside the food sector because they would not be able to answer the questions properly.

3.6 Methods of Data Collection

The main channels through which communication went were E-mail through which we settled the time and date of the calls, WhatsApp or Teams through which we created a group with the interviewee to remind them of the call and send the questions in advance to have the most relevant answers during the interview itself. This type of data was insightful for helping us make a choice between all the challenges. We collected primary data at the three levels of the supply chain within our subject's scope: farmers, retailers, and consumers. For the professional actors, we proceeded with interviews since we did not know what challenges they were going to expose. Interviews are in that way more flexible because the environment is controlled. Interviews are to be found in Appendix 6 to 9. In the consumers' case, on the other hand, it was more interesting to have numerous answers to find a pattern. The survey has been shared

through social media, more precisely LinkedIn, Instagram, and Facebook, to reach a wide sample of the targeted population. As a result, hundred-and-one people answered the survey.

According to Saunders et al (2009, p.153-154), using two different data collection methods is very useful to gather as much data as possible and have more points of view. Moreover, doing interviews and sending out a questionnaire will have various results that might or might not generate a relationship. The advantage of having two methods is that it removes the so-called 'method effect'. The use of only one method could lead to one possible outcome, whereas the use of another method could lead to an opposite outcome. Using the qualitative and the quantitative methods together will lead to a more balanced outcome which will be closer to reality.

3.7 Data analysis techniques

As mentioned above, three levels of the supply chain within our subject's scope were analyzed, farmers and retailers through interviews (qualitative research) and consumers with a questionnaire (quantitative research)

3.7.1 Interviews

A. Farmers

From the literature review we came to these three main takeaways:

1. Farmers face challenges when it comes to their crops and yields regarding profitability (Cropping intensity and resource management) and environment uncertainty (Subsection 2.7.1)
2. The use of digitalization helps farmers tackle the challenges they face. (Subsection 2.2.1)
3. Farmers are encountering a paradox: "Farmers would change, but often cannot" (Subsection 2.4.1)

Questions 2, 3, 4, 5, 6, 11, 12 and 13 are linked to farmers facing challenges.

Questions 8, 9 and 10 are linked to the use of digitalization.

Questions 7 and 13 are linked to the farmers' paradox.

The questions and answers can be found in Appendix 6 and 7.

B. Retailers

- Transparency poses a significant obstacle within the food industry. (Subsection 2.2.2)
- Digitalization can play a pivotal role in overcoming food waste (Subsection 2.2.3)

Questions 2, 3 and 6 are linked to both transparency within the food system.

Questions 4 and 5 are linked to the use of digitalization to help food waste.

The questions and answers can be found in Appendix 8 and 9.

3.7.2 Survey

A. Consumers

Based on the literature review, we came up with three main takeaways that we believe are important to analyze further through primary data:

1. Consumers are asking for more farm-to-fork traceability and transparency to increase awareness of what they are buying. (Subsection 2.7.3)
2. Technology has a positive effect on consumer consumption. (Subsection 2.2.4)
3. The price of healthy food is a crucial reason why consumers cannot afford sustainable purchasing behavior. (Subsection 2.5)

The questions we asked in the survey are the following:

1. What's your age range?
2. What's your current employment status?
3. What problems come first in your mind when you think of the food industry?
4. Would you be willing to pay more for food products that are produced sustainably and in a transparent way?

Choose from 0-5 (0 not willing - 5 extremely willing)

5. Before doing this survey, had you ever heard about the 17 SDGs?

Yes or No

6. In your opinion, which of the following SDGs is the most important for the food industry to address?

Rank options between:

- SDG 2: Zero hunger (here: end hunger, fight malnutrition, promote sustainable agriculture)
- SDG 3: Good health and well-being
- SDG 7: Clean and affordable energy (here: lowering CO2 impact, promoting renewable energy)
- SDG 12: Responsible consumption and production (here: food waste, preserving natural resources, less packaging…)
- SDG 13: Climate action (here: taking concrete initiatives to fight climate change)

7. Which of the following options influences your decision when buying products?

Choose one or more options:

Nutri-score/ Grading on citizen applications like Yuka or ScanUp/ Eco-score/ Price/ Company's overall environmental reputation or actions/ other

8. What digital innovation(s) that is/are already implemented do you consider as useful?
9. In your opinion, which of these digital innovations will have the greatest impact on the sector?

Rank the four different options:

- Universal platform to gather all the needed data across all the actors to build up the product's scores (Eco-score, Nutri-score...)
- 3D food printing (Meals made on demand with an automated additive process)

- Internet of Things (Food safety system to track the food through the whole supply chain to improve food quality and safety)
- Artificial intelligence and Machine Learning (Automating task to make them more efficient)

10. Based on your previous answer, what is the reason for your first choice? Can you also perhaps give other examples of promising innovations?

To link these questions with the three main takeaways from the literature review and discover if the primary data matches with the secondary data, we decided to regroup the questions:

Questions 3, 6, and 7 are linked to the takeaway regarding transparency and traceability to increase the consumers' awareness.

Questions 8, 9, and 10 are linked to the takeaway regarding technology.

Questions 4, 7 are linked to the price of healthy food and consumers' sustainable purchasing behavior.

The questions and results can be found in Appendix 10.

CHAPTER FOUR: ANALYSIS AND DISCUSSION

This section will be subdivided into three different parts:

1. Comparison of the secondary data collected through the literature review with the primary data collected in the interviews and the survey.
2. Technologies that we want to mobilize that will help the Belgian farmer to become more sustainable in their practices and tackle the challenges enumerated before.
3. Implementation plan with the concrete actions to undertake which actors to mobilize, what legal framework would be favorable, different aspects for the feasibility and the potential challenges we can encounter.

4.1 Comparison of the secondary and primary data

4.1.1 Qualitative data analysis

In this section, we will first compare the main takeaways from the literature review with the farmers' interviews. Followed by a comparison with the retailers' interviews.

A. Farmers' challenges regarding profitability and environmental uncertainties

From what we discovered in the literature review subsection 2.7 "Digitalization for the agriculture volatile market", farmers are under pressure daily as the market is very uncertain and cannot control external factors. As mentioned earlier in the subsection 3.5 "Sample strategy", half of Cédric's farm is organic, and the other half is conventional. Conventional farming uses chemicals, whereas organic (bio) does not, which is less sustainable. Cédric Dumont de Chassart, our interviewee of the farm, mentioned that consumers might be less inclined to pay for organic products. He confirms that and that the market is volatile by stating: "*Consumers are no longer interested in what they eat, they are more interested in organic nowadays. This is a problem because I must start producing today to sell next year. But the market is so volatile, I do not know if people want to eat organic food, I produce next year.*".

As mentioned in the literature review by Travelsafe-Abroad (2023) in the subsection 2.7 "Digitalization for the agriculture volatile market", farmers are struggling with profitability which comes from both environmental uncertainties such as COVID-19 or the Ukrainian war

and growing prices from raw materials. Cédric Dumont de Chassart adds that the profits made by supermarkets that sell his products are too high: "*Usually supermarkets are doing times 3 with the producers' price, therefore we are not reaching the fair price. The solution would be to tell consumers the exact price the supermarkets paid the producers to increase transparency and profitability for us.*".

The issue is that the lack of profitability could lead farmers to be less willing to pursue innovative initiatives to improve their production performance. The need for a framework where farmers are encouraged and helped to transition towards a more profitable and sustainable environment is crucial.

B. Digitalization supporting farmers' challenges

In the subsection 2.2.1 "The use of digitalization supports farmers", we found out that the crop intensity can be maximized using various digital tools. Fuglie (2016) adds that the use of such technology leads to a more productive and cost-effective work, which confirms what Cédric Dumont de Chassart mentioned during the interview: "*The use of robots and GPS helps us to plant the seed lines in perfect straight lines (...) and memorizes the location for when it is time to eliminate the weeds around the plants (...) which saves time, labor and fuel*". Next to that, Jana Du Bois, owner of a farm in Asse, adds the following: "*By developing certain technological systems, farmers can produce food in a more sustainable way, such as systems where they can generate their own electricity, purify water... After all, farms consume a lot of electricity and water.*".

However, Cédric Dumont de Chassart pointed out the fact that robots and technologies in general can have negative points too: "*For example, when sorting out the potatoes or other products to remove the ones that have another shape than the standard one, robots can be too disciplined and take out perfectly eatable products.*"

Another point that emerged from the secondary data regarding digitalization is vertical farming, as mentioned in the subsection 2.2.1, B "Vertical farming – controlled indoor farming in reduced spaces". Statista (2022b) pointed out that the vertical farming market is expected to grow immensely over the years and the market value will grow seven times. We believe that this type of farming would bring out many advantages thanks to the controlled environment.

This type of market necessitates the use of various types of technologies. Therefore, farmers might see vertical farming as a downside because it would require them a lot of changes. Moreover, they feel that they already have enough leftovers from their current production to bring a new concept of farming to the industry. It is a legitimate thought. However, with the growing demand and population (Ojo et al, 2018). We believe it would not be an issue. Cédric Dumont de Chassart mentioned: "*To produce in cities where you do not have a natural environment to do agriculture does not make sense to me as we already have so many leftovers. The cost would be huge*". We understand that this type of innovation can be seen as a threat, but the next generation of farmers might see it as an opportunity.

Talking about costs, both Cédric and Jane mentioned the fact that implementing new technologies is too expensive to do on their own. Jane Du Bois states: "*There is certainly a serious cost involved in implementing new technological methods. The lack of knowledge does also play a role here.*". She offers a potential solution: "*Possibly a joint purchase of these technologies with other farms to reduce the cost a bit. This would also encourage faster implementation of these technologies on different farms.*". Cédric is already part of such a collaborative and cost-effective group. "*Currently, we are already collaborating with farmers to exchange techniques, knowledge, and practices. Besides that, we borrow each other's machine if this one is needed for a very specific task, for amortizing the cost*." He also benefits from the help of the Centre d'Études Techniques Agricoles (CETA) which provides personalized technical assistance to farmers. Cédric says, "*It allows producers to reason his interventions and improve certain practices"*. The government also offers such support according to PwC (2023) in the subsection 2.6.1 C. "Human machine interaction", however, it seems like it might not be enough for all farmers as Jane Du Bois mentioned: "*The government could offer more guidance (at a reasonable cost) to farmers so that knowledge about the adoption of technologies increases.*"

C. "Farmers would change, but often cannot": Farmers' paradox

We had an interesting discussion with Cédric Dumont de Chassart who highlighted several key points, in his opinion to the paradox: "Farmers would change, but often cannot". Three different factors played a major role when coming to changing habits and adopting digital technology: external factors, financial and human factors.

External factors

We already talked about the uncertainty of the environment that implies that farmers can not have any control over it in a natural way. "*Concerning the external factors environmental climate, each farmer takes a gamble because it is a huge cost and can't control external factors*", said Cédric Dumont de Chassart. Since the geographical location of farmlands varies, there is no universal guideline or golden rule applicable to all farmers for effectively managing their soils digitally. The diverse conditions from one land to another necessitate customized approaches and strategies for optimal soil management. Many farmers would not know where to begin and which innovation would suit their businesses the most. As Blasberg et al (2022) mentioned, in subsection 2.4.1 "Farmers would change but often cannot", making shifting decisions is complex and could jeopardize all the previous efforts. Besides, external factors also include the legal framework having an enormous impact on consumer behaviors and therefore the agriculture industry as well. Politics have an important role to play in a more sustainable shift but often do not do enough to change things drastically. As Cédric mentioned: "*They usually prefer to have an impact on short-term measurable goals than to tackle global challenges such as sustainability. To give a concrete example, they could impose that 30% of the whole agricultural products in the supermarket should be organic. That would be a game changer for the bio farmers struggling. But the problem is that there are only 10% of the farmers that do organic products, which is only a small part of it, so politicians do not give priority to allocating the budget to this sector.*" That is a vicious cycle because that does not incentivize farmers to shift towards organic and could even have the opposite effect. Jana Du Bois agrees with this by saying: "*We are very much tied to regulations and applying for/obtaining permits and people are getting stricter on this every year. This restricts us from doing business.*". Politics should find ways to encourage people to consume bio, whether it is through financial or other means. But the problem is that if they are too much in favor of for example the bio, they will end up having against them all the companies that sell chemical fertilizers. "*For a small 10% of farmers or important companies, the government does not hesitate to choose a party, especially with the elections coming soon*" as Cédric states.

Financial factor

All the investments made by farmers individually are important and have consequences. They are usually bound to a loan from a bank. Therefore, they need to make sure to sell enough food to be able to repay this. The cost of the new machine in relation to the time and use is sometimes not worth it. Especially, when the machine is just put on the market, they are expensive. The farmers wait until it will be commercialized at a certain time and the price has become more democratic. Besides, Cédric mentioned the price unfairness and efforts not being compensated well enough. As mentioned above, he told us: "*The law of economics is that if it is profitable, you continue, otherwise you stop. With all that's going on, it is sure that some will stop. There is a concept called 'Fair price'. When the product is sold in a shop, it needs to be a fair price for the producer. However, usually supermarkets are doing times 3 with the producer price."*. He finds that unfair, therefore he would like to increase the transparency among the consumers so that they are also aware of the farmer's selling price which would put the supermarkets in a position to lower their prices and make it more equitable for everybody.

Human Factor

Humans fall easily into routines and stay stuck in them. They do not like it when there are changes and are usually satisfied with what they have achieved. Therefore, at the risk of failing, they prefer to do nothing. One could ask if this is the same when implementing new technology. Cédric pointed out the fact that "*We fought for a long time to have what we have today, the risk of failing can be seen as dangerous*". He also talks about standardization and the overuse of technology as "*the food industry is touchy because he works with living things that are influenced by so many external factors. There needs to be a certain margin, it is important to not standardize too much.*" That is why the human factor will always need to be present at a minimum level.

D. Lack of transparency within the food industry

In the literature review, subsection 2.2.2 "The use of digitalization makes the whole supply chain more transparent", O'hearn et al (2022) established that even though Environmental, Social and Governance reporting is being implemented in most businesses globally to benchmark companies' sustainable practices, this is not enough because social metrics (health,

nutrition...) are left aside. To give a proper measurement of the food business standards, new metrics need to be created. This will create more transparency between consumers and companies. This fact is supported in the interview of Veerle Poppe, sustainability strategist at Colruyt, "*Data overload and a lack of a standardized way to measure some concepts like the Life Cycle Assessment is a big concern, there are 38 different ways to assess it. We need quality, security and standardization in this industry to provide the consumers with relevant and easy information*." The lack of standardization also seems to be a problem for Geoffrey de Hennin, owner of an Intermarché, who says: "*I think it is necessary to have a standardized platform to communicate with each actor within the food chain."*. On the other hand, such a standardization platform already exists, it is called GS1. This platform generates barcodes and links markets and their suppliers to provide global standards for identification, data capture and sharing according to Veerle Poppe. She adds that "*Not everyone has access to it, the solution would be to have an all-in-one standardized platform accessible to everyone throughout the supply chain and user-friendly.*". In her point of view, the European Commission has a huge role to play in this process. It is their duty to impose and find a unified tool to gather all the different enterprises on one platform. Besides, once the data is gathered, one must draw conclusions from it and transform it into useful information. The lack of IT infrastructure and data knowledge is an important point as well to tackle. Not everybody has the required software and knowledge to do so.

As seen in the literature review, subsection 2.2.2 B. "Capability to conveniently trace the entire supply chain" by Costa et al (2012) barcodes could be replaced by RFID technology which would provide a platform with more accurate traceability and transparency for all the actors within the food chain.

E. Digitalization as a tool to overcome food waste

Yang et al (2021) state, subsection 2.2.3 "The use of digitalization helps fight food waste", that expiry dates create a race against time to sell products before they perish which is why they suggest adjusting products prices depending on the quality and freshness of the item. Geoffrey de Hennin makes use of this kind of strategy by using the platform Too Good To Go, explained in the subsection 2.2.4 A. "At-home consumption and production". Then he uses a software which allows him to know which product can go on sale on the Too Good To Go platform. "*We have a software that manages expiry dates. We encode dates to know when the products*

expire which makes our life much easier because before we had to encode everything by ourselves. (...) This allows us to reduce food waste, especially from the bakery and creamery.".

Another issue pointed out by Geoffrey de Henin is that sometimes they receive products from suppliers, but the expiration date is only 2-3 days away. The owner of Intermarché claims that this happens because of the number of stages in the supply chain and the time a product stays at each stage. The supermarket is then left with two choices: to sell it at a discounted price or to throw them away. Neither is positive for the supermarket. IEEE Explore (2020) and Van Geest et al (2021), subsection 2.2.3 A. "Smart Warehousing", brought an interesting solution to reduce the time taken at each step of the supply chain by improving warehouses with the help of Internet of Things. This would monitor and control the stages in the warehouses such as managing food inventory which would lead to reducing food waste, margins of errors and improving cost effectiveness.

4.1.2 Quantitative data analysis

We decided to create a survey to have an overview of the consumer behavior of a Belgian consumer. It is quantitative research that aims to collect and analyze the needed numerical data (Bhandari, 2023). As previously mentioned in the Methodology, in the subsection 3.7.2 A. "Consumers", this survey aims to tackle SDGs 2, 3, 7, 8, 12, 12.3 and 13 as they are the current SDGs that need the most attention. With the survey, we wanted to find out if they knew how digitalization can or is impacting the SDGs in the food industry. We established a user-friendly survey with 10 questions, it is mostly composed of closed questions (quantitative analysis) with the ability for the respondents to deliver additional information through open questions (qualitative analysis). The survey takes about 5-6 minutes to answer. Our survey was carried out through social media. We sent our survey on LinkedIn and Instagram. We gathered 101 responses, 50% of the age range was between 19 and 24, and the other 50% was above 24 until 64. We believe this is a good sample because the younger half of the respondents are directly concerned because they are tomorrow's consumers. Most of them included students or were employed. 60% of the total respondents already heard about Sustainable Development Goals before taking the survey.

A. Consumers' desire for more traceability and transparency

From the answers that came out of the open question three of the survey (Appendix 10), most of the respondents talked about a lack of knowledge regarding food traceability and food waste when thinking about the first problem they have in mind when thinking about the food industry. This is supported by Narayan (2022), subsection 2.7.3 “Farmers & consumers – lack of transparency and guidance”. According to him, if more information about the real value of the quality of a product is available, consumers might be more inclined to buy such high-quality products and make better-informed decisions.

In question six from the survey (Appendix 10), the results show that people put SDG 2 - Zero Hunger (end hunger, fights malnutrition and promote sustainable agriculture), as being the most urgent to address in the food industry. Based on the two pieces of information given here above, results from question seven of the survey (Appendix 10) are contradictory as 78.2% of the respondents showed that the price is a main factor of influence when doing groceries. This goes along with our finding in the literature review where a survey from Deloitte Belgium (2021) shows that healthiness and affordability are the two most important purchasing factors. Being more transparent could put the health factor way ahead of the price factor. The price aspect will be discussed later in the subsection 4.1.2 C “Impact of price on sustainable purchasing behavior”.

Moreover, respondents put SDG 13 - Climate action (talking about concrete initiatives to fight climate change) as being the least important when addressing issues in the food industry. Consumers might not see this as a pressing issue, however, as explained by Iizumi and Ramankutty (2015) in the subsection 2.7.1 “Agriculture - resource management and weather uncertainty”, climate change effects are getting stronger over time and directly impacts food production which would result in products shortages and prices increasing. Based on the result of our survey, consumers might think this is the less pressing Sustainable Development Goal to address, however, it has a direct impact on their purchasing behavior.

The interview with Veerle Poppe informed us that there is a noticeable dilemma between being transparent with the consumer and keeping its competitive advantage secret. Her job is to oversee the eco-score. To make a long story short, the eco-score aims to help consumers become active buyers who are aware of the ecological impact their bought products have.

Whereas the Nutri-score helps the consumer be aware of the healthiness of the product. They both use letters to express the low or high impact behind the production (BeCPG, 2022). Therefore, we decided to mention this in our survey through question seven (Appendix 10). The results show that Nutri-score and Eco-score are important purchasing factors after price. Consumers seem to be looking for such information, this supports the fact that people are looking for more transparency throughout the food chain.

B. Technology as a positive effect on consumers consumption

Respondents to our survey are already aware of the most famous digital platforms as question 8 of the survey (Appendix 10) can attest. Those match with the ones found in the Literature review in section 2.2.4 A. "At-home consumption and reduction" as respondents mentioned the same platforms as we found. Through the use of applications, consumers can easily help fight food waste (Too Good To Go) or become more aware of what they are buying (Yuka).

In question 9 of our survey (Appendix 10), respondents ranked from one to four digital innovations that will have the greatest impact on the food industry. They ranked the Internet of Things as being the most important digital innovation. This makes sense because as Natalia Serbulova et al (2019) mentioned, subsection 2.3.1 B "Data and connectivity", Internet of Things optimizes and automates every process within the supply chain which generates time and cost efficiency and most importantly, more transparency. This allows products to be more traceable which is what consumers are seeking based on what has been explained in subsection 4.1.2 A "Consumers' desire for traceability and transparency". 3D Printing was ranked as the least impactful digital innovation which can be seen as a lack of knowledge from the public regarding this technology. However, according to IEEE Xplore (2019) 3D Food printing brings out many advantages such as reducing harmful emissions, decreasing food waste, and shortening the food chain.

C. Impact of price on sustainable purchasing behavior

As mentioned above, price is the main purchasing factor for consumers. In question four of our survey (Appendix 10), a clear majority of the respondents are in favor of paying more for food products that are produced in a sustainable and transparent way. As of now, healthy products are a bit more expensive and as pointed out by the World Organization of Health (2021),

subsection 2.5.3 “Food Insecurity and unhealth (consumer)”, the price of sustainable food can lead consumers to choose unhealthy food and thus malnutrition.

Hence, it is evident that sustainable practices hold increasing significance for consumers, but price is still a major factor that can influence people especially with what is happening nowadays in the world.

4.2 Regenerative and greenhouse farming supported by digital innovations

From all of the innovations enumerated in the Literature review section 2.2 “How are digital innovations helping the food industry?” and in “the comparison of the analysis of the qualitative and quantitative research” section 4.1, we decided to select regenerative farming and vertical farming in the form of urban greenhouse supermarkets. To overcome the challenges outlined in the chapter "Digitalization for the Agriculture Volatile Market," the establishment of urban greenhouse supermarkets is a viable solution. However, due to the substantial upfront investments and preparation, a quicker response was necessary to address the urgent situation. Hence, regenerative farming emerged as a parallel solution to tackle the challenges promptly.

Therefore, our solution will be **twofold** with distinct goals, yet complementary. The first goal is to make sure that Belgian agriculture embraces **regenerative farming on the existing fields**. Belgian soil erosion is a major problem and will even become worse with climate change (ILVO, 2023). That is why regenerative farming is a solution. Agricultural technologies and precision farming plays a crucial role, especially in Wallonia which is lagging behind. In 2019, there were still 37% of Walloon farmers not connected, among which only 22% used new technologies like GPS, connected sensors, connected weather sensors, or robots. The majority used only traditional tools including the Internet, e-mail, and social networks. Besides certain reluctance to change, the reasons behind this low adherence are cost, lack of time, data-protection issues, and the complexity of connected tools (Brussels Times, 2019). Belgium politics need to make a great effort to make this digital transition towards sustainable practices as smooth as possible for the future generation. Regenerative farming with the support of precision farming and agricultural technologies will allow Belgian farmers to increase the on-field production of the crops that need a large area to grow like wheat, sugar beet, potatoes, and maize in which Belgium is specialized and represent the largest harvest (Statbel, 2022b).

In the second stage, we want to implement **urban greenhouses supermarkets** that would be used as a place where the crops can grow indoors in a controlled environment as well as crop supermarkets where people can directly harvest their crops according to their needs. In this case, the preferred crops are the ones edible on the spot which are the same as the ones in vertical farming. It will tackle the farmers' challenges of environmental uncertainty and scarcity of natural resources and at the same time provide a solution to unfair sales prices by cutting the middlemen and directly selling it to the end consumer. Additionally, it will supply the consumers with healthy pesticide-free crops near to their houses ensuring transparency requested about the origin of the crops. The products will be 100% fresh, local, and organic products avoiding food waste and profitability loss through middlemen.

4.2.1 Regenerative farming

Belgium uses twice as much fertilizer as France, which ranks first in European agriculture (TheGlobalEconomy.com, 2021b). The main goal for farmers when using regenerative agriculture is to have more sustainable practices by aiding in the **restoration** of agricultural lands, and replenishing the soil after it has suffered damage from traditional agriculture's intensive chemical use. With the final aim of improving resource management and increasing profitability, a positive consequence for farmers will be the optimization of cropping intensity as they will be able to generate more output in the same area thanks to healthier soil as well as the decrease of emissions (Focus on Belgium, 2023). Regenerative farming has the capacity to help with climate issues at the level of SDG 12, SDG 13, and SDG 15 (EIT Food, 2021).

At the moment, regenerative farming is increasingly popular and is seen as one of the most promising opportunities to help out farmers as well as respond positively to SDGs (EIT Food, 2021). While regenerative agriculture is in its infant period, it is **growing in Belgium** supported by organizations such as the Food and Agriculture Organization and the Intergovernmental Panel on Climate Change. In fact, it has been said that out of all the Belgian agricultural lands which are approximately 1.3 million hectares, an average of 50 000 hectares will be allocated to regenerative farming by 2025 (Focus on Belgium, 2023).

Agricultural **technologies** play a pivotal role in supporting and promoting the adoption of regenerative farming practices, with a primary focus on automation, which will be discussed further in the section. It becomes an essential component in optimizing operations and

empowering farmers to succeed. According to the report *Cultivating farmer prosperity: investing in regenerative agriculture*, the findings were very promising for regenerative agriculture. Even if shifting to regenerative agriculture requires important upfront investments for farmers because they first reach a loss of over $100.000 (Petry et al., 2023). In the long term, using regenerative farming practices instead of traditional practices seems to result in an increase in profitability by over 120% (ATTRA, 2023).

In the case of Belgium, the agricultural **soil** is in some parts fragile or cannot be used at its full potential. This fragility is caused by erosion which is the phenomenon where soil or other materials on the land are moved away and transported toward another place due to wind or water. In Flanders, this phenomenon is mostly present in the southern part since it has more hills. Wallonia boasts a diverse range of landscapes and terrains, resulting in the existence of thirteen distinct soil combinations. Despite having more soil types compared to Flanders, Wallonia faces similar threats to its soil quality and health. Moreover, in Belgium, there is a drop in soil organic matter, the part of the soil that is surrounded by plants and animal residues in various stages of decomposition. This is another threat to the soil because it affects the soil quality since soil organic matter creates carbon which generates nutrients for organisms in the soil (eip-agri, 2016), (Gentile et al., 2009).

A. Agricultural technologies and precision farming as support

To reduce and control soil erosion and its decreasing quality because of the erosion and diminishing organic matter, there are several regenerative farming techniques that can be used to combat those threats. That is mentioned in subsection 2.2.1. “Regenerative Farming”. In addition to regenerative farming techniques aimed at preserving soil health, the utilization of **agricultural technologies and precision farming** are used as important complements to go from traditional towards sustainable practices.

The agricultural technologies that can help with most regenerative techniques are the Internet of Things, Artificial Intelligence, Drones, Robots, and Satellite Technology. These **agricultural technologies** are frequently used and valuable because they enable farmers to optimize the use of the data they collect. Moreover, they ease the implementation of customized and sustainable farming practices (Fruit Growers Supply, 2023). Two main agricultural technologies that significantly impact regenerative farming practices are the following:

The first technology is **Smart greenhouses**. They offer a remarkable advantage by minimizing the need for pesticides and harmful chemicals as well as reducing waste. The controlled indoor environment facilitated by these technological advancements allows for precise regulation of external factors, ensuring an optimal growing climate. As a result, the reliance on damaging chemicals becomes unnecessary. Through the collective integration of these regenerative practices, the soil in Belgium can progressively restore itself. Further insights regarding greenhouses will be discussed in subsequent sections (Miskinsis, 2018).

Another important technology to implement in Belgium is **Smart irrigation systems**. In Belgium, the duration of drought periods is progressively extending, posing a challenge to the essential water needs of the lands and crops. However, the cost associated with providing water poses a financial burden for farmers. Hence, it is imperative for farmers to effectively manage their water resources. This can be achieved through the adoption of smart irrigation systems, an agricultural technology that ensures secure and high-quality yields (Valeria, 2021). Smart irrigation systems encompass various components that contribute to the optimal growth of crops. Firstly, precision irrigation ensures that the crops receive the precise amount of nutrients and water necessary daily, facilitating their optimal development. Additionally, sensor technology, which aligns with precision farming, provides real-time data and information derived from the yields. Sensor technology is very useful to keep a high-quality of the crops because any changes or anomalies will be immediately detected by those sensors. Moreover, smart irrigation systems will give the crops the right amount of water at the right time. The crops will be perfectly irrigated. This automated approach not only promotes water conservation but also leads to significant cost savings for farmers (DMahbub, 2023).

As highlighted in the subsection 2.2.1 C. “Regenerative farming”, Belgium is set to experience significant growth in the field of regenerative farming. As a result, **precision farming** using agricultural technologies like GIS (Geographic Information System), GPS (Global Positioning System), and VRT (Variable-Rate Technology) is expected to increase soon. This trend will be particularly noticeable in Wallonia, where farmers have been slower to adopt these tools. The main reason for this lag is that the average farmer in Wallonia is less inclined to use advanced technology compared to younger farmers who are more accustomed to it (The Brussels Times, 2019). The following precision farming tools play a vital role in equipping farmers with the

necessary data to make informed decisions to effectively manage their resources, reduce their environmental impact and promote regenerative farming practices.

First, we have a **Geographic Information System (GIS)**. One of the pivotal precision tools employed in Belgium is Geographic Information System (GIS). GIS technology is increasingly utilized to ascertain the spatial distribution of pesticides. This application is of utmost importance in Wallonia, as there has been a lack of understanding regarding pesticide levels in the environment until now. Research has revealed that pesticides are predominantly concentrated in orchards, potato fields, and beet crops within Wallonia (TheGlobalEconomy.com, 2021b). Remarkably, these areas constitute a mere 10% of the total agricultural land in Belgium. In contrast, grasslands, which encompass 50% of the agricultural areas, exhibit the lowest pesticide presence. Consequently, the adoption of sustainable farming practices is steadily gaining momentum in Wallonia. In 2017, the proportion of regenerative crops reached 9%, and it is projected to further expand to 18% in recent times, as mentioned earlier (Habran et al., 2022).

Secondly, Belgium needs to make use of **Satellite navigation sensors and Global positioning systems (GPS)**. In the Netherlands, one of the most technologically advanced farms is known as Van den Borne. Since 2006, Jacob Van den Borne has been an avid investor in precision farming, and this commitment has persisted to the present day. Precision farming encompasses various technologies, including satellite navigation sensors and global positioning systems (GPS). Notably, Jacob Van den Borne employs a technology called EGNOS in his tractors. EGNOS utilizes a system that incorporates three satellites, enhancing the accuracy and performance of global navigation satellite systems like GPS (EUSPA, 2023). This cost-effective solution provides precise positioning capabilities. EU farmers are increasingly embracing EU space technologies like EGNOS as they offer valuable support and data, enabling more sustainable agricultural practices (EUSPA, 2023a). However, specific information regarding the extent of technology adoption in Belgium is currently unavailable but this could be very valuable to the country.

Finally, **Crop monitoring technologies / variable-rate technologies (VRT)** are of utmost importance for supporting regenerative farming. In the 2000s, Belgium was considered a relatively modest agricultural producer within Europe, and this remains the case due to the country's small size. Consequently, the production forecast has been relatively limited, if not

negligible. However, this situation can be advantageous in addressing the challenges encountered by Belgian agriculture, such as weather management and resource utilization for production (Belgian Earth Observation, 2000). Presently, with the increasing influence of technology, the adoption of crop monitoring technologies, also known as variable-rate technologies (VRT) as referenced in the literature review, has proven highly beneficial for Belgium. Crop technologies consist of drones, satellite imagery and soil sensors (DMahbub, 2023). They play a crucial role in facilitating precise control over farmers' fertilization and flooding systems. These technologies provide real-time data, predominantly in the form of images, allowing for comprehensive analysis of various crops and the identification of any irregularities within the fields. The imagery generated by these technologies provides ultra-high-resolution images that effectively identify soil-related issues. Additionally, drones serve another purpose by enabling precise spraying of fertilizers, pesticides, and water. Their capabilities ensure a high level of precision in the application of these substances (World Economic Forum, 2022). However, relying solely on images may not suffice to transform the collected data into valuable information. Hence, additional precision techniques, as mentioned above, are required to foster increased crop production in Belgium (Janssens, 2020).

Overall, there is a growing need to expand regenerative agriculture practices in Belgium, to align with the evolving technological trends that are reshaping the agricultural landscape. This shift is crucial for addressing the farmers' challenges and embracing more sustainable practices that align with the Sustainable Development Goals.

4.2.2 Urban Greenhouse Supermarket

A. Indoor controlled environment selling natural local crops

The second concept that would suit Belgium is the urban greenhouse supermarket. Commercial greenhouses are already well settled in Belgium and is a concept that works as the following project illustrates. The most famous greenhouse rooftop in Belgium is without any doubt the one in Roeselare called Agrotopia (Inagro, 2022). This 9,500 square meters greenhouse is designed by Meta Architectuurbureau and Van Bergen Kolpa Architecten and is Europe's biggest public building for urban food production and used at the same time for educating people about agriculture (Aouf, 2022). Another example of a rooftop greenhouse project is called Groof, already mentioned before. The prior aim is to incentivize a cross-sectoral

approach to diminish CO2 in the construction and agriculture sectors by mixing energy sharing and local food production. Using the energy produced by the building for heating the greenhouse on the building and thus for growing crops (Groof, 2021).

While greenhouses are widely known, the mix with a supermarket is not introduced yet in the country. With the arable land decreasing and urbanization growing, the country needs to adapt by implementing an urban solution with higher cropping intensity[7]. The purpose would be to offer consumers directly edible, naturally grown crops sourced from their own city in a 100% controlled environment increasing tremendously the yields utilizing unused flat roofs of existing or vacant buildings. The commercial greenhouse market is a promising business since the global CAGR is expected to grow by 10.6% from 32.97 US$ in 2023 to 49.26 US$ in 2027 (Research and Markets, 2023). With its variable climate, Europe is among the largest adopters in the world (Markets and Markets, 2022).

B. How it tackles our challenges

The project has many important benefits. We follow the **urbanization trend** of the citizens by reducing the distance between the production and consumption places. In 2021, 98% of the total Belgian population was living in urban areas (World Bank, 2021d). The spots where to implement those urban greenhouse supermarkets would be chosen wisely including a central one with the largest surface area and others that would be smaller on unused urban surface areas to increase the number of locations where people can harvest 100% local and natural crops as if it was their own. In addition to reconnecting citizens with nature and sensitizing them to sustainable and local consumption, the proximity reduces the transport carbon footprint and risk of damaging the crops (Hortica, 2022).

Besides, the use of a greenhouse allows us to lower or even eliminate the **impact of the external environment on the crops**' growth process. Indoor farming's main advantage is the controlled environment. That implies many benefits: no seasonal constraints allowing harvest during a longer period or even throughout the whole year, prediction in the production, and weather or climate have a restraining impact.

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[7] Yields per given surface area.

Next, it improves **resource management**. Our indoor farms will use soilless hydroponics. Thanks to the fact that hydroponics uses water instead of soil, nutrients are put in the water and hence immediately absorbed through the roots. Having a closed-water irrigation system implies two things: no resources are lost in the environment polluting the environment and no waste of resources since they are kept in the system until they are absorbed. On average, this type of irrigation can save up to 98% compared to traditional agriculture (Hortica, 2022). In the figure below, you can see the process behind this system. The country that masters greenhouses more than any other is the Netherlands. They knew the potential of these infrastructures in their early stage and took rapid advantage of them. At optimal growing conditions, the yields of lettuce can be ten times higher, and chemicals used cut by 97% (TheCivilEngineer.org, 2018).

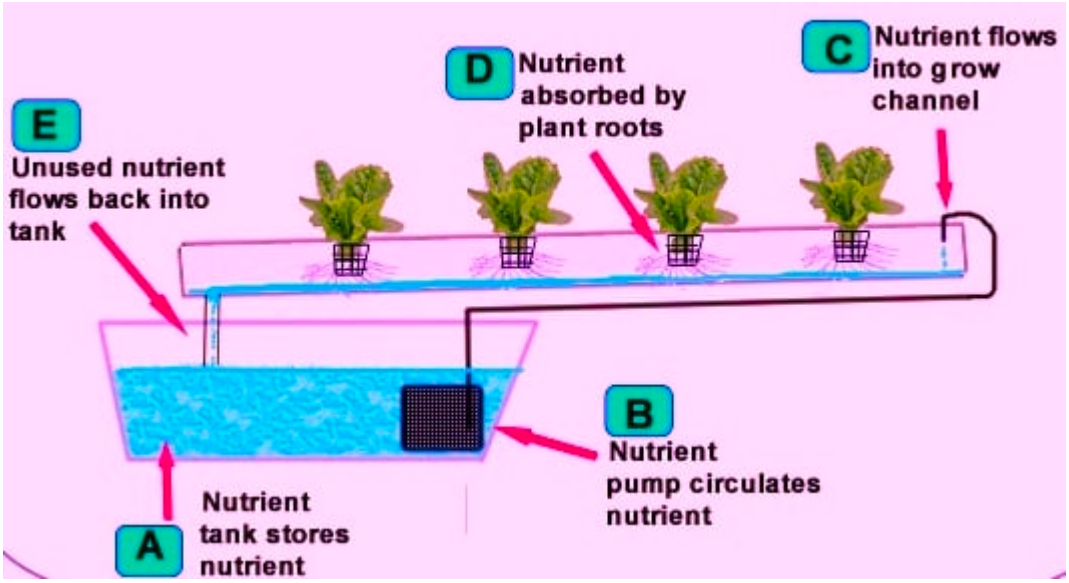

Figure 8: Hydroponics Farming Information Guide (Jagdish, 2018)

The last main benefit is related to the choice of making it a **public supermarket**. The farmers would be responsible for the maintenance of the greenhouse and preparing the crops in the morning, while the consumers could come in the afternoon to buy their products in the greenhouse itself. It would be seen as a giant living supermarket where everyone is allowed to harvest the ripe produce spotted by Artificial intelligence, sensors, and cameras and they would be automatically charged at the exit of the greenhouse according to what the consumer has in their shopping cart. Allowing consumers to go buy their crops at the precise place where it grows makes it a farm-to-fork supply chain. It tackles the **farmer-consumers' challenge** regarding health and willingness to buy in a more informed way. This challenge is covered in

the chapter “Digitalization for the Agriculture volatile market” and “Current Challenges regarding the SDGs”.

Nowadays, there is an increasing awareness about the benefits of eating healthy and locally. In that context, greenhouses have an added value since no or limited pesticides or herbicides are used, and the crops are produced near the consumption place. In addition, it tackles the farmer **- retailer challenges** by cutting the middlemen, farmers will have a greater share of the end price increasing in this way their profitability. Finally, with fewer intermediaries’ food waste will decrease tremendously. Thanks to the technologies used, the ripe crops will be put in evidence so that the consumers can see them in an obvious way. More details will be explained in the following sections.

C. Types of crops

One must be aware that it does not have the same scope as the previously mentioned farming. While the regenerative practices remain outdoors, greenhouse farming happens indoors. Also, the types of crops are different. The preferred indoor crops are the ones that require specific conditions to grow such as strawberries, the ones that do not take as much space as microgreens or grow quickly like leafy greens or herbs (Light Science Technologies, 2021). Vegetables and fruits are the most popular crops like cucumbers, tomatoes, and melons. We seek a mix of different species. In summary, the most cost-effective crops to put in greenhouses are the ones with the maximum number of edible parts, fast-growing, and with a high market value. The crops that Belgium produces the most such as potatoes, cereals, or wheat are not suitable for this kind of farming since these need more space (European Parliamentary Research Service [EPRS], 2022). That is why both types of farming, regenerative and greenhouse, are complementary. While precision farming supporting regenerative on the field will provide Belgium with accurate real-time information to make data-driven decisions for robust crops requiring rural wide spaces, greenhouse indoor urban farming will ensure better protection against the undesired environmental aspects of crops having a short growing process. As reported by USDA data, the average yield for tomatoes that grow in greenhouses with hydroponics in 2020 was 10.59 pounds per square foot (≅ 51,7 kilograms per square meter) against 1.85 pounds per square foot in traditional farming (≅ 9,03 kilograms per square meter) (Markets and Markets, 2022).

D. Technology-driven

Technology will play a key role in this project for the greenhouse part but also the supermarket aspect.

Regarding the technology that will manage the environment of the **greenhouse,** according to the Commercial Greenhouse Global Market Report 2023, this is mainly the Internet of Things, automated irrigation systems, pH sensors, climate control software, and artificial intelligence (Research and Markets, 2023). The purpose is to offer the crops the best-growing conditions regarding moisture, temperature, fertilization, humidity, and irrigation for them to grow as fast and healthy as possible (Markets and Markets, 2022). The software will additionally enhance crop planning and tracking and allow the facilities to be managed remotely. Manual intervention will gradually be replaced (Spherical Insights, 2023). Also, the fact that it will be on roofs, all the water that will fall on the greenhouses would be re-irrigated into the system for the indoor plants and the building heat underneath will be used to inject into the greenhouse.

In parallel with environmental factors management, technology will support the whole **commercial part** too since farmers are not specialized in this domain. As briefly introduced above, Artificial intelligence, sensors, and cameras will be of great importance. The aim is that farmers only support the agriculture part of the project, that is the greenhouse maintenance and ensure the good development and harvest of the products. All the sales would be covered by an application, automation, and Artificial intelligence that will ensure the smooth running of the customer experience.

To have access to the greenhouse the consumer must download the app beforehand to encode his banking information. Once the account is set up, it will be linked with a QR code that will have to be scanned for the doors of the greenhouse to open. The app will guide the consumers to the ripe products spotted thanks to 3D camera technology and sensors. In 2015, it was Lincolnshire that led this technology to help farmers know when their broccoli was ready to harvest (GOV.UK, 2015). Each time the consumer puts a crop in his basket, AI recognizes the product and its pricing. The consumer can have a real-time overview of their shopping cart's value. When walking out of the greenhouse, the same individual QR code will need to be scanned, the app will charge the customer account by the amount of the cart. This cashier-less supermarket functioning is based on the Amazon Go Grocery stores launched in 2018

(Amazon, 2023 and “Amazon Go Opens, Promises to Revolutionize Brick-and-morter Shopping,” 2020).

E. Inventory management

The coming challenge of these urban greenhouse supermarkets will be to supply enough crops for the demand and people coming weekly to this living supermarket.

First, the greenhouses will stack several **vertical layers with valuable plants**. According to the well-known greenhouse firm Gothic Arch Greenhouse, the most profitable products for greenhouses are tomatoes, lettuce, peppers, cucumbers, spinach, herbs, microgreens, and strawberries (Gothic Arch Greenhouses, 2017). They are selected for their fast-growing process, high demand, or for the added value for which they can be sold. Others such as onions, garlic, pea plants, or beans are chosen for their high resistance to colder environments and grow all year through (Vilar, 2023). If the customer flow is too heavy for the available crops, we can increase the vertical layers while paying attention to not putting shade on the layers of plants below to prevent the use of artificial lights which would require a large amount of electricity.

Another option for inventory management is to restrain the incoming customers per period by adopting a **subscription** business model. L[ag]UM which is an educational and experimental market garden in collaboration between the Commune of Ixelles and the ULB operates this way. They open their market garden from the beginning of May until December which allows their members to come every day to harvest crops after having followed a workshop on how to properly harvest a crop. For the 31 weeks of membership, different prices are settled according to your status: The 2023 fee is €310/year per adult/teenager and €155/year per child (under 12). The idea is for the whole family to sign up, as the fixed price is calculated for one person and places are limited (L[ag]um, 2023).

4.3 Go-to-market strategy (implementation)

Once both concepts are explained, we will expose the next steps for both regenerative agriculture as well as urban greenhouse supermarkets to include **managerial aspects** to our master thesis. Both require a different approach since they are at different phases of maturity in the country; While regenerative agriculture is already slightly introduced in our country, these practices need drastic incentivizing actions to increase the adoption rate of it among farmers. In parallel, urban greenhouse supermarkets need to be launched from scratch and brought into the urban consumers' habits. A strong focus on adequate communication is required in both situations, whether it is farmers' or consumer wise.

Two stages according to the need for digitalization:

4.3.1 Regenerative farming

Transitioning from conventional farming to regenerative farming requires more than just providing agricultural technologies and precision farming. It calls for guidance and specific requirements from various stakeholders in Belgium to support farmers in making this transition. The following section will elaborate on these aspects.

A. Current legal framework and projects

The European Commission consistently allocates funding to projects that align with the objective of addressing environmental challenges that are important for the country.

Farmers must adhere to three rules about sustainable practices to be eligible for **funding** from the European Union. Firstly, there is the rule of crop diversification, which entails cultivating a range of different crops. Secondly, farmers must preserve permanent grasslands as it facilitates carbon sequestration and safeguards biodiversity. Lastly, it is mandated that 5% of arable land be set aside specifically for promoting biodiversity. Those who do not comply with those sustainable rules get less funding. Furthermore, national governments have the authority to impose additional administrative penalties, next to those related to sustainable practices (European Commission, 2023).

In the previous year, the European Commission introduced a new project proposal aimed at verifying high-quality carbon removals. This initiative encompasses a voluntary framework that seeks to highlight the advancements in carbon removal technologies. The project aims to promote the adoption of innovative approaches that contribute to carbon sequestration, facilitate the transition towards more sustainable agricultural practices and play a major role in resolving climate and environmental goals (European Commission, 2022a).

Next to this initiative, the **Green Deal** encompasses a vital objective of reducing greenhouse gas emissions by 55% by 2030. Reaching this objective includes the creation of a regulatory framework for the certification of carbon removals. In simple terms, regenerative farming closes off millions of tons of carbon dioxide, this is positive because it means that this amount of carbon dioxide is not going into the atmosphere. By actively engaging in these sustainable farming methods, the agricultural sector can contribute significantly to the EU's efforts in reducing climate change and promoting environmental sustainability (Mehta, 2022).

Regarding **Belgium**, on one hand in Wallonia, the minister of Agriculture has taken proactive measures by introducing the Plan Bio 2030 in 2021. The primary objective of this plan is to achieve a significant milestone of 30% organic land out of the total agricultural land. It is noteworthy that the European Commission's ambitious target, the European Green Deal, aspires to 25% organic land by 2030 (Biowallonie, 2021). On the other hand, Flanders has set its sights on becoming one of the leading bioeconomic regions in Europe. This entails the daily utilization of renewable biological resources. To realize this vision, Flanders is committed to making substantial investments in research and development (Poumpalova, 2022).

B. Stakeholders to mobilize

Several key actors have been identified as of great importance in assisting farmers in achieving more sustainable farmland practices. Firstly, **farmers' organizations** represent the farmers and their needs on a daily basis. Secondly, **agricultural advisory services** and **civil society** play a pivotal role by offering valuable guidance and support to farmers in adopting regenerative farming methods. Thirdly, **governmental organizations** are actively engaged in promoting sustainable agriculture, driven by their policy objectives related to climate change mitigation. These organizations possess the authority to develop new policies and revise existing ones to align with their goals. Fourthly, **research institutions** provide valuable insights and expertise

to farmers, aiding them in navigating the transition from conventional to regenerative farming with minimal losses. Lastly, **private organizations** have the potential to contribute by offering financial support to farmers (ILVO, 2023).

C. How stakeholders can proceed with joint efforts

Like previously said and illustrated, the food industry is very much interconnected between all the stakeholders. Whilst many relationships are hidden, they still have a great impact on one another. That is why several stakeholders must be taken into account when shifting practices and a holistic view is required. The needs, goals, expectations, and motivation differ according to the networks which makes it a complex puzzle.

To disentangle the whole environment, we grouped the stakeholders by common aims: connectivity, knowledge, and finance support. The first ones need to coordinate and connect stakeholders at the local and continental levels to ensure alignment through clear communication and actions. The second is in charge to accompany farmers in their technological shift by assessing the feasibility of the project on their case specifically and providing them with sufficient knowledge to operate independently. This group is also synonymous with continuous research and development for the methodologies' improvement. The last network built up an innovative financially profitable environment for farmers to ensure them stable revenues and fair returns on investments.

The structure that follows is introduced each time by one of the three goals explicitly and below the concrete actions that one can come up with to achieve this goal.

<u>Goal 1. Interconnectivity between governmental organizations and organizations that support farmers towards regenerative practices (awareness)</u>

As Cédric Dumont de Chassart and Jana Du Bois made clear in subsection 4.1.1 C. "Farmers would change, but often cannot: Farmers' paradox", in Belgium, there exists an inconsistency between the level of support provided to farmers and the legal framework. This difference highlights the need for enhanced alignment between governmental organizations and organizations that support farmers for their regenerative practices. It is crucial to bridge this gap and create a cohesive approach that addresses the objectives of environmental issues such

as climate change and governmental objectives such as the Green Deal. Such alignment would ensure that farmers receive the necessary backing and resources to adopt and implement regenerative farming practices effectively.

To create awareness among government organizations different goals and actions need to be followed:

- Belgium and the other EU countries need to have a unified approach towards regenerative farming

A unified and comprehensive approach is necessary because, without demand from retailers or consumers for sustainable farming practices, there is a risk that farmers will return to conventional methods, undoing any progress towards sustainability. Retailers in France, for example, are increasingly supporting regenerative farming practices by setting goals to source a certain percentage of their product from this type of farming. Danone's French subsidiary has set a goal to exclusively procure 100% of its ingredients from regenerative agriculture practices in France by 2025 and Nestlé wants to reach 50% by 2030 (Girard, 2022). The whole potential of regenerative agriculture will be unlocked when agrifood companies change their food sourcing strategies. Initiatives like these have the potential to inspire retailers in Belgium to follow suit.

Furthermore, as previously mentioned in subsection 4.3.1 A “Current legal framework and projects”, the European Commission is increasingly providing funding for such projects due to their significant contribution to addressing climate change and environmental concerns. Hence, an increasing number of food companies are recognizing the importance of adopting regenerative practices in the EU. However, the transformation must originate at the farm level. It is crucial for farmers to modify their practices, and they require financial support and supportive legislation to facilitate this transition. We agree with Stefania Avanzini, the director of One Planet Business for Biodiversity, who emphasizes the need for a unified approach, stating, "A farmer doesn't have one field for Nestle, one field for McCain." (Mehta, 2022: online) The farmers cannot meet the unique demands of every retailer. Therefore, it is crucial to establish a comprehensive framework that encompasses governmental organizations, retailers, farmers' organizations, and agricultural advisory services, with the aim of prioritizing the best interests of farmers. This framework should include the development of policy

measures and financial incentives to provide a supportive environment for regenerative farming practices. By doing so, stakeholders can work collaboratively towards achieving sustainable agriculture goals while addressing the needs and challenges farmers face. Additionally, a clear definition of regenerative farming practices is essential, as the absence of such clarity can lead to greenwashing for food and beverage companies (Mehta, 2022).

- Coordination of individual actions

As we have established, farmers often encounter challenges related to profitability, leaving them uncertain about the right decisions to make concerning their lands. As a result, farmers face complexities in managing various aspects independently, including addressing crop issues and adopting new technologies for transitioning to regenerative farming. From our perspective, fostering coordination among all local actors is essential. This collaboration would give each farmer the support needed because everybody will share their knowledge and experiences. The goal is to create a network, the actors that would be included are the following: farmers, agricultural advisory services, farmers' organizations, and research institutions. This network will assist farmers in addressing their day-to-day challenges and provide them with a sense of assistance during the entire transition process.

- Continuous support to farmers

A collaborative plan is essential for farmers who are hesitant to transition from conventional to regenerative farming. This plan would outline the short- and long-term benefits and objectives of adopting regenerative farming practices. It would be developed in partnership with agricultural advisory services, as they are well-suited to assist with the implementation process and monitor the outcomes to ensure the desired results are achieved.

<u>Goal 2. Organizations share knowledge with farmers from conventional to regenerative farming (knowledge)</u>

We place a strong emphasis on the significance of knowledge sharing. As highlighted in the interview with Cedric, farmers face challenges in being heard and expressing their desire to share their concerns and issues. Being able to share all of that with external stakeholders to enhance their knowledge base becomes crucial.

Knowledge sharing comes in different forms:

- Technical support on the field

The inclusion of an expert specializing in farmland analysis is crucial for farmers to assess the viability of integrating agricultural technologies and implementing regenerative practices within their existing infrastructure. Furthermore, the expertise of this individual would enable them to guide farmers toward the appropriate agricultural advisory service that can facilitate the transition. By receiving confirmation and recommendations from a knowledgeable professional, farmers would gain the confidence to make necessary changes, knowing that they have received the green light from someone with technical expertise.

- Continuous R&D in line with market needs

In order to achieve the sharing knowledge objective, it is essential to establish a direct line of communication between research institutions and farmers. When farmers encounter an issue and seek to find the most effective resolution, it is crucial for them to share that information with research institutions. In turn, these institutions will independently explore potential solutions and propose them to the farmers, aiding them in overcoming their challenges. In addition, research institutions also need to share their technical knowledge with farmers. This is very important since the expertise provided will help farmers gather and analyze data.

Goal 3. Financial support to increase regenerative farming

We see the importance for farmers to build an attractive environment to adopt regenerative farming, to make it an opportunity instead of a burden. To reach that farmers need to be incentivized in various ways.

Most importantly, as we have discussed, farmers' profitability is low. The idea is to get farmers more money and this is possible with the following:

- Subsidies and funding from the European Commission

In Belgium, the new common agricultural policy emphasizes the adoption of regenerative and precision farming practices. This policy also includes funding provisions, ensuring a more

equitable distribution of resources across farms in Belgium. On average, Flanders will receive 1.3 billion euros, while Wallonia will be allocated 1.8 billion euros. Both regions have set specific objectives on how to utilize these funds effectively (World Economic Forum, 2022).

Flanders is determined to provide enhanced support and security to farmers, with funding allocations tied to the adoption of sustainable practices such as regenerative farming. The more extensively Flemish farmers embrace these practices, the greater their funding benefits. Additionally, a portion of the funds will be directed toward initiatives aimed at reducing greenhouse gas emissions and improving soil quality. A pivotal aspect of the plan involves transitioning over 30,000 hectares from conventional practices to regenerative farming methods. The funding not only aids young farmers but also stimulates the creation of over 1,500 jobs (European Commission, 2022c).

In Wallonia, there is a strong emphasis on increasing protein yields in agricultural production. Consequently, farmers engaged in this activity will receive financial support and assistance. Similar to Flanders, a significant portion of the funding is dedicated to initiatives that promote climate and biodiversity preservation. The adoption of regenerative and precision farming practices in Wallonia is expected to encompass 18% of the land, and this figure is projected to continue rising. Moreover, the plan aims to support young farmers and foster gender equality by facilitating more inclusive events and opportunities for women in agriculture (European Commission, 2022c).

In relation to financial support for farmers, it is worth noting that certain laws mandate the provision of funds from the EU, commonly referred to as "income support" or "direct payments". These payments are allocated to farmers based on the size of their land holdings. Moreover, both Belgium and other EU countries receive a basic payment, along with an additional payment for adopting sustainable practices, it is noteworthy that 30% of the funding is specifically assigned for this purpose. Furthermore, young farmers are provided with support and also receive a specific payment (European Commission, 2023b).

- Foster and support start-ups in their innovation of agricultural technologies.

We firmly believe that the greater the number of start-ups dedicated to this field, the more diversified the risks will be, ultimately leading to the creation of more affordable opportunities for farmers by creating a competitive environment.

D. Challenges

To reduce difficulties in implementing precision farming, one must consider some factors related to the country's connectivity and all the aspects and investments that precision farming requires.

In fact, while Belgium was digitally advanced compared to other EU countries, in the 2022 DESI report the country has lost many places in the ranking scoring. Including the four factors (human capital, connectivity, integration of technology, and connectivity) Belgium ranks 16 out of 27. Analyzing it more in-depth, two factors stand out: connectivity and the integration of it. An interesting fact is that the integration of technology and connectivity is high since it takes the 6th place, but the connectivity is the worst among EU countries. This is mainly due to the restraint 5G coverage[8] where Belgium scores 4% while the EU has 66%. Belgian authorities do not give the 5G spectrum licenses as fast as other countries; there are differences in rules on Electromagnetic Fields (EMF) resulting in a slow 5G rollout (European Commission, 2022d). To have a smooth running of regenerative farming through precision farming that relies on the connectivity between the tools, Belgium will need to improve its urban and rural connectivity (European Commission, 2022c).

Farmers will encounter other types of challenges in the integration of regenerative farming practices. A second potential challenge that farmers may encounter when adopting regenerative farming practices is the presence of financial constraints. The initial investment costs associated with transitioning to regenerative agriculture, particularly when incorporating agricultural technologies, can be substantial. Farmers are faced with the task of making informed decisions to ensure that the investment is worthwhile in the long run.

Finally, a third potential challenge that farmers may face is the abundance of different types of digital innovations, as previously mentioned. It can be overwhelming for farmers to navigate

[8] % populated areas (European Commission, 2022)

through the numerous options and select the most suitable technologies for their specific needs. In many cases, farmers may require expert advice to make informed decisions, but they often struggle to identify the appropriate sources of guidance (Patteri, 2017).

4.3.2 Urban greenhouses supermarket

The concept of combining a rooftop urban greenhouse and a supermarket does not exist yet. However, rooftop greenhouses are already existing and could be taken as an example for the implementation phase of our project. The examples were mentioned before in the section 4.2 “Regenerative and greenhouse farming supported by digital innovations”: Afrotopia and Groof.

Similarly, to regenerative farming, digitalization has an important role in this project and has numerous benefits, but only if well implemented taking all the stakeholders on board. If the contrary happens, digitalization can divide the country even more between those with access to cutting-edge innovations and those without.

Since this concept needs to be launched from scratch in Belgium, a great project management is needed taking numerous aspects into account: the project outline, technical feasibility, legal feasibility, and social feasibility.

A. Project outline

The creation of urban greenhouses aims to achieve two primary objectives.

- Farm-to-fork traceability for consumers

As previously mentioned in the literature review, in the section 2.7.3 “Farmers & consumers - Lack of transparency and guidance” more precisely, consumers are increasingly seeking greater traceability to make more informed and conscientious decisions regarding the products they purchase. The urban greenhouse project aims to address this demand by providing the transparency and farm-to-fork traceability that consumers are actively seeking. By doing so, this initiative not only meets consumer expectations but also creates a more sustainable food production process.

- Improve profits and resource management for farmers

The establishment of urban greenhouses also presents significant advantages for farmers. As previously highlighted, farmers often struggle with profitability, with retailers exploiting their products by purchasing them at low prices and reselling them at significantly higher rates. However, through the implementation of this project, farmers would bypass the involvement of retailers in the selling process, thus eliminating exploitative practices. This direct connection between farmers and consumers would not only ensure fairer prices for farmers but also help reduce food waste that typically occurs at the retail stage.

The urban greenhouse project must capitalize on the building in which the crops are cultivated. It is crucial to establish synergies between the greenhouse and the host building. These synergies encompass various aspects such as energy costs, water conservation, and more.

Besides, for our greenhouse, there would be no use of LED lights in comparison to regular vertical farming. The reason is simple, there is an urge for a sustainable generation of electricity and improvements in battery storage.

B. Technical feasibility

The objective is to construct a greenhouse that can withstand various external conditions and is in line with the current building regulations. Like mentioned above, the architects involved in the project must be able to justify their choices regarding the materials and technical equipment selected for the greenhouse depending on the type of building and the degree of use.

To achieve that, a comprehensive study will be required to assess the feasibility of implementing the urban greenhouse on a particular building. This study will involve calculations and hypotheses made in collaboration with designers, architects, engineers, the building owner (private or authorities), and the future greenhouse supermarket owner. The building should have, for example, a high bearing capacity capable of managing high loads, but also able to cope with lifting forces triggered by the wind on the greenhouse (Bin, 2021).

In our case, the greenhouse should provide sufficient space to accommodate both the planting area for diverse crops and the technical equipment required for its operation. For example, the project of Agrotopia is built around four types of climate zones allowing different fruits and vegetables to grow in their optimal environment (Aouf, 2022). Additionally, it should be

spacious enough to accommodate customers, allowing them to explore and engage with the greenhouse environment.

C. Legal feasibility

First and foremost, one needs to make sure that the government allows using the flat roofs of existing or vacant buildings. Clear guidelines need to be developed to ensure the **safety** of the space on which the greenhouse will be settled. It needs to be technically possible to grow many crops and at the same time a customer-friendly environment. For example, some buildings may be in poor condition or may not be structurally suitable for supporting the weight and infrastructure of a greenhouse on their roof.

Presently, some existing **regulations** in Belgium govern the construction of greenhouses such as The maximum constructible height depending on the size of the building, Building permits and controls, Health regulations… (Urbanfarming-greenhouse, 2021) To ensure compliance and approval for the urban greenhouse project, it is advisable to contact the local municipality. This step is crucial for both the Wallonia and Flanders regions, as regulations may vary between them (Euroserre, 2021). Therefore, it is important to ensure that the project aligns with building regulations and standards.

In parallel with adjustments regarding the buildings, other laws need to be introduced to incentivize people to buy more products coming from sustainable practices.

Besides, Farm-to-fork is at the center of the **Green Deal** of the European Commission. In line with this, a legal framework for sustainable food systems will be created which will help for the creation of a sustainable food policy. To enhance food security, the development of a contingency plan will be generated. Just like with farmers, there are several players that can be reached for offering support to initiatives such as the urban greenhouse project. Various organizations such as advisory services, private organizations, and research institutions can provide valuable assistance and support (European Commission, 2023a).

In line with our perspective, we firmly advocate for government support in **educating customers**. Such support can manifest through various means, including assistance in raising awareness through impactful marketing campaigns. Given the government's inherent authority,

it possesses a unique capability to influence and persuade consumers to alter their purchasing habits.

D. Social feasibility

Urban greenhouse supermarkets are currently absent in Belgium, requiring some shifting behaviors coming from the consumers and farmers. Similarly, to regenerative farming, several stakeholders are involved and require joint efforts to make this kind of project come true. A great **stakeholder management** begins by mapping them all out and next assessing what actions need to be undertaken according to respective power and interest in the project.

- Local community/consumers

These citizens will be the first target consumers of the project since they live in the neighborhood. The first communication is towards them announcing that this urban greenhouse market is about to open and explaining to them all about it. The purpose is to make them feel part of the project and incentivize them to take the opportunity to consume locally, naturally, and have a positive impact.

Currently, consumers are accustomed to their routine of purchasing from traditional retailers. Grocery shopping is majorly seen as a weekly task that people want to be done with as fast as possible. Urban greenhouse supermarkets will help people enjoy this time in the greenhouse by putting the focus on the experience rather than only the products they are buying. It aims to sensibilize people about all the growing processes behind the regular crops sold in supermarkets and to reconnect urban citizens with nature as they harvest their crops themselves. In a fast-moving world where almost, everything is reachable within a short time period, this urban greenhouse supermarket will make people more conscious that natural, local and healthy crops need more time to grow and that not every type of it is available all year long. Changing consumer behavior and mindset is thus needed, moving the focus to quality rather than quantity.

It is crucial to raise awareness and educate consumers about urban greenhouses. Raising awareness can be done through campaigns, workshops, and visits showing consumers the many advantages of buying products at urban greenhouses instead of retailers.

- Urban farmers – producers

Either becoming farmers or current farmers who want to expand their business in cities. They will closely work with the architect in designing the building if possible. Both have valuable knowledge, on the one hand, farmers know best what area is needed per type of crop according to the size and the requirements of the market. On the other hand, the architect can advise accordingly on the feasibility and what suits the building the most.

Analogically to the consumers, shifting behavior from the farmers must happen as well for the project to succeed. Generation upon generation we have been taught that agriculture only takes place in wide fields in rural areas. But we are at a turning point where digitalization takes an increasing place in our society, making exponential progress in the last decade. This may be disturbing and scary at first sight. This is why great support for farmers is required through workshops, expert advice, exchanges among them, training…

In the long run, two categories of farmers will distinguish themselves from each other, yet will jointly represent the global supply chain of food. The first category pertains to field farmers. As highlighted in our thesis, the integration of digitalization is steadily growing. It is essential for field farmers to seize the opportunities presented by this technological advancement and collaborate closely with innovative solutions to address the challenges they face and enhance overall profitability. The second category, we call them the urban farmers. This team will primarily consist of experienced farmers who possess the necessary expertise in crop cultivation and greenhouse management. The urban farmers are an essential component of the team due to their familiarity with working with crops and understanding of agricultural practices.

- Roof owners and/or governments

Many buildings have flat roofs that could be eligible for this project. Negotiation and analysis should take place with this roof owner to explain the benefits of this collaboration and to assess if the building is suitable for it.

Alternatively, the project also can take place in vacant or abandoned places and give them a new use. In 2021, Brussels had over 700 infrastructures which equaled approximately 1 million m2 (The Brussels Times, 2022). Currently, the City of Brussels has deployed a special unit in charge to find solutions for these kinds of buildings. It would be interesting to analyze with

them what buildings can be allocated to make the city greener with this project. Brussels is only an example; other cities have for sure vacant usable buildings as well.

- An architect, an engineering office

This actor will be in charge of designing the urban greenhouse supermarket in a way that is sustainable and technically, economically, and thermally efficient. This project needs to be viable over time. Once he/she agrees that the building is adapted for such use, the architect must think of the material, budget constraints, and local regulations to take into account the structure, and the most adapted design to enhance the customer experience in the greenhouse supermarket.

- Investors and Financial Institutions

Such a project has important upfront investment costs. Funders will have a crucial role in financially supporting the project. The typical profile would be someone who takes the bet to invest in new promising sustainable concepts that will help Belgium foster its economy and lower its carbon footprint.

- Researchers and Universities

Researchers possess the necessary expertise in crop cultivation and greenhouse management. Farmers are an essential component of the team due to their familiarity with working with crops and understanding of agricultural practices. However, since urban greenhouse cultivation involves unique challenges and techniques, it is imperative to provide them with adequate training and guidance from researchers who specialize in urban farming. Since the project will be brand new, continuous improvements are needed to permanently enhance the efficiency of the practices.

- Local Businesses

These are not key stakeholders, but they have some influence in promoting the project in the neighborhood. Word-of-mouth has a great impact on a business and is an easy way to reach a larger scope of consumers. They are seen as strategic partnerships with the project.

- Environmental Organizations

Similarly, to local businesses, environmental organizations would help the project increase in visibility and exchange of practices and knowledge. They are more involved in the project than the local businesses.

To disentangle this complex network of stakeholders, a **stakeholder matrix** is useful to properly understand all the stakeholders' interests in the project, see below Figure 9. Next, it is also important to identify their power and influence between them to assess a priority list and actions that need to be taken accordingly.

Figure 9: Stakeholder matrix (source: authors,2023)

- Local Community/consumers: The local community would typically fall into the "high influence, high interest" quadrant as they have a significant impact on the success of the supermarket and are highly interested in the availability of fresh, sustainable produce.
- Farmers: Suppliers and farmers can be placed in the "high influence, high interest" quadrant. They have a direct influence on the supply chain and success of the supermarket but may have varying levels of interest depending on their business priorities.

- Government Authorities: Government authorities usually hold a "high influence, low interest" position in the matrix. While they have significant regulatory power and can impact the supermarket's operations, their direct interest may be lower compared to other stakeholders.
- Environmental Organizations: Environmental organizations tend to have a "low/medium influence, high interest" position. They are actively interested in promoting sustainable practices and may have some influence in shaping public opinion and advocating for environmentally friendly initiatives.
- Research Institutions and Universities: Research institutions and universities often hold a "low influence, high interest" position. While they may not have direct control over the supermarket's operations, their expertise and research can be of great interest and value to improve and innovate within the business.
- Local Businesses: Local businesses would typically fall into the "low influence, low/medium interest" quadrant. While they may have an interest in collaborating and supporting the supermarket, their influence may be relatively limited compared to other stakeholders.
- Investors and Financial Institutions: Investors and financial institutions generally hold a "high influence, low interest" position in the matrix. They may have a financial stake in the success of the supermarket but may not be actively involved in day-to-day operations or have a significant interest beyond their investment.

E. Challenges

Similar to the challenges encountered in regenerative farming, the establishment of an urban greenhouse supermarket also presents certain complexities. As previously discussed, managing such a facility involves addressing issues related to **inventory management**. Ensuring a consistent balance between supply and demand can prove to be a challenging task. Keeping a steady flow of demand and offers might be tricky. Consumers might want more products than the crops can produce and offer at the time.

Another challenge to consider is the **initial investment** required to launch the project. Establishing an urban greenhouse supermarket entails significant financial resources to secure an appropriate building, acquire necessary equipment, implement relevant technologies, and

obtain specialized expertise. But, on the other hand, “traditional” farmers also have investments in machinery for the large fields and need a higher quantity of inputs.

Finally, there is a challenge pertaining to **competitio**n. The urban greenhouse supermarket faces direct competition from traditional supermarkets and established food retailers. These competitors wield considerable bargaining power and have already garnered a significant customer base due to their well-established presence and brand recognition. Consequently, attracting and retaining customers for the urban greenhouse supermarket can prove to be a daunting task, as it introduces a new concept to consumers.

4.3.3 How do these projects tackle the SDGs?

Remaining the main focus of our master’s thesis, we aim to find out how digitalization can help the agricultural industry to manage this volatile environment and be more sustainable. We recall in this section the current challenges in the food industry seen in the literature review that are: natural resources management, food waste and food insecurity and unhealthy and Fair distribution of product value (Farmers). Per challenge, we will cover how both of our projects are tackling these challenges jointly.

A. Natural resources and pollution

In this section the SDGs concerned are: **12 - responsible consumption and production, 7 - clean and affordable energy and 13 - climate action.** This involves mainly the resources such as land, soil, water, biodiversity, minerals, biomass, and fossil fuels.

Regenerative farming supported by agriculture technologies and precision farming is mostly aiding soil erosion in the country that deprives the soil of its natural minerals. Beyond the fact that these practices have no negative impact on the environment, they have on the contrary positive ones by restoring harmful processes of traditional agriculture.

Urban greenhouse supermarkets allow better natural resource management in a broader way. Having a quasi-fully controlled environment enables the allocation of resources. It diminishes for example water, fertilizer, and pesticide use tremendously which causes the most negative effects. That is in line with Europe’s 2030 aim to cut its chemical pesticides by 50% which means that Belgium will need to reduce it by 58% (L’Echo, 2022). Currently, Belgium appears

to be the country with the highest percentage of contaminated fruits and vegetables by toxic pesticides on the continent. According to the Pesticide Action Network Europe (PAN) report, it would reach 34% (The Brussels Times, 2022a). That not only results in chronic diseases such as cancers, cardiovascular problems, and diabetes but is also highly toxic to the environment, poisoning rivers, and other important ecosystems. As mentioned in previous sections, the fact that our project will use hydroponics that has a closed water irrigation system, no water is lost and wasted in the environment.

B. Food waste

SDG 12, but more precisely the **goal SDG 12.3** tackling food waste, is mainly happening between the farmer and retailer level. According to BCG, the coming main challenge is not about producing enough food but rather remains in the storage and distribution of the food where needed (Cousin et al., 2022). “Numerous start-ups are inventing daily technical innovations, more efficiently one than another to help farmers to produce more with less, but if the crops are not sold and shipped on time, all these efforts and food are lost”, highlighted Cedric Dumont de Chassart in his interview.

The urban greenhouse supermarket is a solution for this. Having in the same place the production and the sale enables cutting out the middlemen avoiding in that way all transport costs and CO2 emissions related and reducing the food waste almost to zero since no crops will be damaged during transport and it will be directly sold to the end consumer.

Another solution that contributes is regenerative farming, the use of chemicals is being reduced drastically which helps towards achieving SDG 12 Responsible Consumption and Production and 13 Climate Change.

C. Food insecurity and unhealthy

This is the scope of **SDG 2 (zero hunger and malnutrition)** and **SDG 3 (good health and well-being)**. Consumers have the growing urge to know the source of their food and to pay attention to their environmental impact. That requires strict control and traceability of the product's inputs which can be quite challenging when several players are involved, as mentioned by Veerle Poppe representing Colruyt and the Eco-score.

Regenerative farming is a solution that will directly contribute to the achievement of SDG 2, the enhancement of soil health within the farms strengthens their capacity for sustainable food production. This will not only increase the number of crops but also the amount of food.

In parallel, the farm-to-fork concept of the urban greenhouse supermarket tackles both challenges: the urge for healthy and sustainable food as well as for transparency concerning the crops' origin and growth process. Thanks to the fact that it is an open supermarket where one can see how the crops are growing, it will raise awareness about how to properly make crops grow without or with a restraint use of chemical pesticides.

D. Fair distribution of product value (Farmers)

As seen in the literature review, only fifteen percent of the end product price reaches the farmers, while they are doing the greatest efforts. Not generating a large profit, employment in the agricultural industry is tremendously decreasing over the years. Our project of urban greenhouse supermarkets offers a place where the crops both can grow and be sold, with no need for middlemen anymore. That tackles **SDG 8 - Decent work and economic growth** aiming to offer a good work environment fairly rewarding the employees for their effort.

As farmers are not specialized in marketing and the sales aspect, it will also be supported by technology with client recognition at the entry and exit of the supermarket automatically charging them according to what they have bought. Therefore, once they have broken even from their initial investments all profits are 100% for them.

4.4 Change management

Such important transformational changes need some managerial implications at the consumers' sides. Shifting from a fast way of grocery shopping where mostly all crops are available towards a slower business model where patience is key, requires acceptance and indulgence. As we saw in "the three paradoxes" section 2.4, although consumers support sustainable initiatives, their actions do not always reflect the same. That is called the "attitude–behavior gap" and represents an important challenge for the business, marketers, NGOs, government... It is not enough to only convince consumers, one must also ensure that action follows (White et al., 2019). That is why a sustainable consumer behavior change is preferred with a long-term view, whether it is regarding sustainability, but also in consumer behavior management in general.

That is what the **SHIFT framework** aims to do, enlightening several factors that influence long-lasting consumer behavior changes: **s**ocial influence, **h**abit formation, **i**ndividual self, **f**eelings and cognition, **t**angibility (White et al., 2019).

4.4.1 Social influence

Humans are very much influenced by what others do and expect. If one wants to change how someone behaves, one needs to change social norms, social identities, and social desirability.

The **norms** for example, refer to the accepted and culturally endorsed beliefs and behaviors within a specific context that dictate what is considered socially appropriate or approved of (Cialdini et al. 2006). In our context, we would aim to create a social norm of eating local and sustainably sourced food. It would be mainstream to eat seasonal crops coming from a greenhouse in your city instead of craving for kiwis in the middle of the winter coming from New Zealand.

The influence of social factors is contingent upon individuals' "social **identities**," which arise from their affiliations with various groups. For instance, consumers are more inclined to adopt sustainable behaviors if they observe fellow group members engaging in such actions. (Tajfel and Turner 1986). The groups can be based on location like regions or cities, but also more widely taken as local consumers. If the norm of the group's switches, the members will follow.

In addition, most of the time, there is a kind of competition between the groups of who is going to outperform the other. Emphasizing a common, overarching ingroup identity can enhance the receptiveness to information concerning sustainable actions, particularly among individuals who strongly identify with the ingroup (Schultz and Fielding 2014).

In the same perspective, social **desirability** is also key and influences behaviors. The goal is to make sustainable grocery shopping and consumption appealing and desirable for the consumers making a positive impression on other people. The desire for social approval is such that It even appears that consumers tend to exhibit behaviors aligned with societal expectations when they are in public settings where their actions can be observed and evaluated by others(Green and Peloza 2014). That is why putting the greenhouses in central, iconic places could have a positive effect.

4.4.2 Habit formation

Habits are actions that endure due to their automatic nature, developed over time through repeated exposure to specific contextual cues (Kurz et al. 2014). Our habits individually do not have great impact, but as mentioned they are repeated, and all the consequences are thus summed up. To initiate new positive habits and get rid of the negative habits, the government will need to implement a punishment-incentive system (White et al., 2019). Whether it is increasing taxes on products with a low eco-score or implementing monetary incentives when shopping in the greenhouses.

4.4.3 Individual self

Obviously, the person must be in line with sustainability as an individual person too, not only as part of the group. The consumer must like the personality that he/she reflects towards the other without losing its own identity. They need to find the right balance between adopting sustainable practices and not crossing their own personal limits to avoid this “attitude–behavior gap”. Make people commit to some changes, but to a reasonable extent to stay consistent for the long term (White et al., 2019). Here we could propose people to not only do their grocery shopping in the greenhouses but at the beginning one week out of the two.

4.4.4 Feelings and cognition

Emotions and feelings are closely tied to our actions, whether they are positive or negative. These emotions play a substantial role in influencing our behavior.

To address the challenge at hand, it would be beneficial to associate purchasing products in supermarkets, having bad environmental impact, with **negative emotions** like guilt, sadness, or even fear related to the detrimental effects it has on the planet's gradual decline. Of course, we avoid triggering overly intense negative emotional states. But a more subtle activation of negative emotions influences behavior (Meng and Trudel, 2017).

While triggering negative emotions prevent nefarious actions, **positive emotions** on the other hand, enhance pro-environmental actions. After buying in the local urban greenhouse supermarkets, the consumer should feel the joy and pride to have contributed to a sustainable business. It needs to be a great experience to be in the greenhouse and a moment of relaxing. The feeling of hope can be emphasized as well, the hope that all our individual small pro-environmental actions can slowly replace our bad habits. Besides emotion during the moment of buying, since natural crops are much tastier than the ones bought in the supermarket, that relieves also positive emotions.

Communication and awareness are hence important. Transparency towards consumers for example is highly required about all the negative consequences of buying cheap products all year through without knowing from where it comes nor in what environment it grew.

4.4.5 Tangibility

If the outcome seems vague and distant, consumers will have the urge to act quickly, and our project will not be their top priority. Sustainable behaviors are triggered by creating **proximity** between the consumer and the problem, involving people and making them count (Spence, Poortinga, and Pidgeon 2012). While we often talk about the future when it comes to sustainability, the consumers are present-driven. This **temporal mismatch** needs to be tackled as well. On the one hand, sustainable milestones need to be reachable and visible in a shorter time span and on the other hand, consumers must be sensitized that all their efforts are not lost but will be part of their legacy for future generations (Reczek, Trudel, and White 2018). In this

case, **concrete results** can be shown at the entrance of the greenhouses of how much CO2 the greenhouses have saved, how many crops were already harvested by their own consumers' hand, how many resources have been saved so far, how many consumers participate in this project… That is what Guy de Hennin told us they are doing in his supermarket Intermarché: "*We even installed a TV screen that shows how much energy and electricity was returned to the shop thanks to the solar panels. The purpose of this screen is to show the consumers that we are careful with our electricity consumption*".

CHAPTER FIVE: CONCLUSION

In this master thesis, we investigated and answered the following question: **How can digitalization help the agricultural sector to achieve Sustainable Development Goals (SDGs) in the case of Belgium?**

After conducting a comprehensive analysis of the subject matter, this master thesis has yielded significant insights and findings in the literature review that effectively address the main research question.

The thesis started by delving into the role of **digital innovations** in revolutionizing the food industry. With this analysis, it became evident that technological advancements have a profound influence on the food industry in four distinct ways. Firstly, digital innovations allow farmers daily to make better-informed decisions with tools that help them analyze their data more efficiently and monitor their crops in real time. Secondly, digitalization has greatly benefited the entire supply chain by fostering transparency and traceability. The implementation of technologies such as the Internet of Things has facilitated seamless tracking and monitoring of products throughout their journey from farm to fork. Thirdly, digital solutions have emerged as powerful allies in the battle against food waste. Numerous digital platforms, coupled with the utilization of Artificial Intelligence find innovative solutions to reduce the amount of food thrown away. Finally, digitalization plays an important role when it comes to consumer behavior. By leveraging technology, individuals have a certain way to make consumers more aware of environmental challenges facing the food industry and contribute towards changing consumer habits.

After having gained a comprehensive understanding of the benefits digitalization can offer to the food industry. We uncovered the presence of **three paradoxes** within the food system. These paradoxes serve as significant barriers despite the considerable efforts made by organizations to transform the food industry. Moreover, they act as underlying reasons why the desired changes are not being achieved as expected.

Finally, we noticed that Belgium has a medium to high **degree of implementation**. This means that there is still room for improvement to help the food industry.

Given the vastness of the food industry, we chose to put our attention on the **agricultural sector** but still take into account the relationships they have with the other stakeholders. Through our research, we discovered that farmers encounter daily struggles related to resource management and unpredictable external conditions, hurting the farmers' optimal performance. Tensions also exist in the relationship between **farmers and retailers**, as farmers often experience unfair wages and substantial food waste occurs along the supply chain. Furthermore, **customers** lack awareness of the tireless efforts made by farmers in producing the products they purchase, leading to a lack of transparency from farm to fork.

Last but not least, we provided an analysis that consists of **two main solutions** to answer the agricultural challenges, the analysis connects our gathered data from Belgian farmers, retailers and consumers and the findings and insights from the literature review.

One of the solutions we identified is **regenerative farming that entails** practices that are entirely sustainable. The chemical-intensive approaches of traditional practices are being replaced by new regenerative farming practices. We found out that regenerative farming is one of the most promising opportunities to help the agricultural sector out and to respond positively to Sustainable Development Goals. This solution is closely linked with agricultural technologies and precision farming tools which provide digital opportunities for farmers to transition more seamlessly from traditional agriculture towards regenerative agriculture. Moreover, agricultural digitalization will help farmers resolve the challenges mentioned above as well as make better-informed decisions since they will have more accurate data to analyze.

The other solution we identified to help the agricultural sector achieve Sustainable Development Goals through digitalization is the concept of an **urban greenhouse supermarket**. This holistic solution tackles challenges at all levels of the supply chain. From an agricultural perspective, the indoor controlled environment allows to reduce the environmental uncertainty and handle the natural resource with care thanks to the use of hydroponics. Moreover, it relies on the farm-to-fork concept of having a growing and selling place in the same area. That tackles the challenges the agricultural industry has with the other actors: reducing food waste by directly selling to the end consumers, increasing the part of the end value going to the farmers by cutting the middlemen and offering naturally grown crops locally satisfying in that way the consumers' willingness to have more transparency concerning the products. The use of Artificial intelligence is highly present and contributes to controlling

the environment. It also aids the supermarket because most of the processes are automated, for example, customers can enter using a QR code.

Although these projects are promising, numerous obstacles can be in the way when it comes to the **implementation**. While regenerative farming is already known in the country but needs to expand, urban greenhouse supermarkets are to be launched from scratch. Since the goals differ, the strategies to achieve it too. On the regenerative farming side, stakeholders must join their effort to ensure awareness, research, and financial support. Regarding the urban greenhouse supermarket, the feasibility must be assessed: social, legal, and technical. Besides, not only the food supply has to change methods for a sustainable future, but also the demand. That requires a coherent **change management** at the consumer's side. The consumer behavior needs to prefer slow, local, and natural crops over the ones bought in regular supermarkets for the urban greenhouse supermarket to work. We suggest doing it via the SHIFT framework: social influence, habit formation, individual self, feelings and cognition and tangibility.

Although this master's thesis covers the implementation of these projects, there is still a lot of room for **further research** into both solutions. Firstly, it would be interesting to dig deeper into the feasibility aspects of the urban greenhouse market. Since it is a project starting from scratch it would need deeper expertise to assess the feasibility and scope that this can have. Especially for the financial feasibility. We chose to leave this aspect out, since there are too many factors that would influence the outcome. Secondly, it would also be interesting to investigate the financial aspects of regenerative farming. As implementing technologies is expensive, it can be valuable to assess the investment costs of each technology that the farmer wants to implement.

One of the **limitations** during the writing of the thesis was the lack of expertise concerning how the urban greenhouse supermarkets can be implemented the best. Many factors need to be considered. This could be the subject of a master's thesis on its own and can be done by studies that are teaching how to build a start-up requiring students from civil engineering, bioengineer, and law, especially to complement our researchers. Another significant limitation is the complexity associated with analyzing the implementation of technologies. Gathering accurate data on the extent to which a specific technology is adopted within a country, especially Belgium, was a challenging task.

Internal challenges that we encountered were small yet existing. The first step was to find a relevant subject for the thesis. The initial subject was to analyze the food industry. We rapidly realized that the scope was too wide and had to narrow it down by choosing to focus only on the agriculture industry. The search for the subject was not straight-lined but got defined all along the thesis as our knowledge about the subject sharpened. Next, the location of our respective years challenged the schedule and organization. The fact that one of the students was in Chile during the first semester and the other student was in the US on an exchange program during the second semester added to the jetlag complexity for the meetings. Along with the time-consuming business project we had during the whole semester it contributed to the slight delay of our thesis' deposit.

In conclusion, to **answer to our research question**, the implementation of regenerative farming practices, bolstered by Agtech and precision farming techniques, combined with the integration of Internet of Things and Artificial Intelligence in urban greenhouse supermarkets, will contribute to the enhancement of natural resource management and pollution control in the Belgian agricultural industry (SDG 7, 12, and 13). Additionally, this approach will aid in reducing food waste (SDG 12.3), addressing issues of food insecurity, and promoting better health (SDG 2 and 3), and ensuring equitable distribution of the value generated by agricultural products (SDG 8).

CHAPTER SIX: BIBLIOGRAPHY

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CHAPTER SEVEN: APPENDICES

Appendix 1 : The 17 Sustainable Development Goals

Appendix 2: Overview of the use of technology to help farmers

	Focus	Spatial consideration	Technologies	Benefits
Precision farming	Optimizing crop production within existing agricultural fields	Within traditional agricultural fields	GPS, GIS, and remote sensing to identify and manage variations in soil	Minimize input waste, reduce environmental impact, and enhance overall

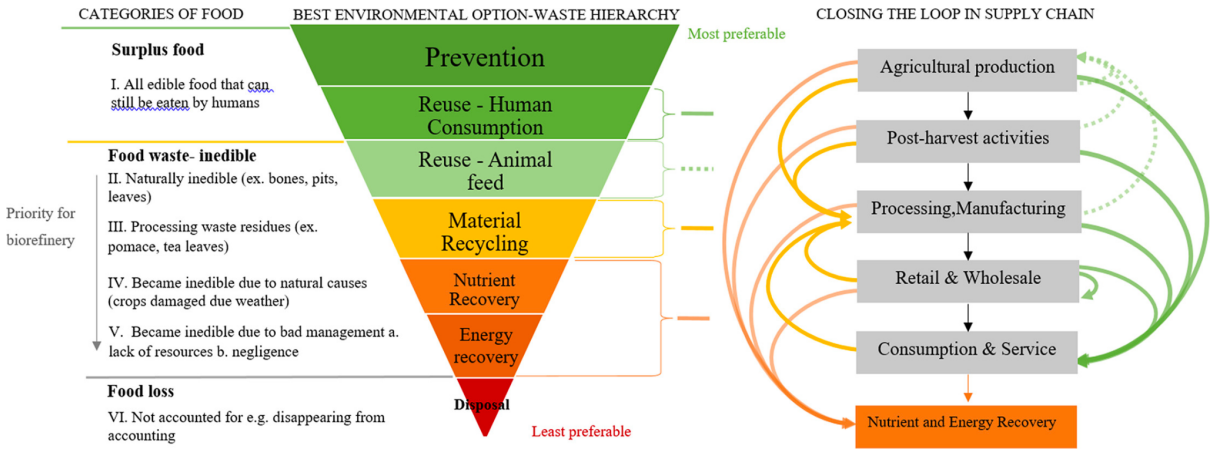
			quality, moisture levels, and other factors	farm profitability
Vertical	Creating optimal growing conditions for plants indoor	Indoor in vertically stacked layers in urban environments or areas with limited arable land	artificial lighting, hydroponics or aeroponics systems, and precise climate control	Overcome limitations associated with traditional agriculture, such as land availability, climate constraints, and transportation distances
Regenerative	Aims to restore and enhance soil health, biodiversity, and ecosystem functioning	On field	Internet of Things Satellite Artificial Intelligence	More sustainable practices, more output with fewer resources spent
Web of connections	Creating a network for farmers	Online	Digital platform Artificial Intelligence	Shared expertise among farmers and easiness of ordering farmers equipment

Twin farming	Virtual copy of all farmers' operations to track and inform faster	Online (and on field)	Internet of Things Sensors Satellite Artificial Intelligence	Turning data into valuable decisions and faster decision-making

Appendix 3 : Fixing our food system depends on solving three paradoxes

Source: Bain & Company

Appendix 4 : Best environment option-waste hierarchy



Source: Teigiserova, 2020

Appendix 5: Overview of the degree of implementation in Belgium

Digital innovations	Degree of Implementation
Data and connectivity	

Internet of Things	high
Cloud technology	medium
Drones	low
Satellite imagery	high
Wireless sensors	medium
Advanced analytics	
Artificial intelligence	high
Big data & analytics	medium
Machine Learning	high
Human-machine interaction	
Robotics	medium
AR/VR	high
Improvement in robotics	
3D printing	medium

Appendix 6: Interview Farmer, Cédric Dumont de Chassart

1. Can you quickly present the firm and how you differentiate yourself from the others?

I have a classic SB farm with a few cattle. I have had an organic meadow since the 2000s for organic food that I sell to supermarkets such as Delhaize.

I have converted half of my farm to organic, although I have kept some conventional in case organic does not sell anymore (although it has been evaluating to organic gradually since the 2000s). I mainly focus on organic vegetables for organic.

Export of products: so first I produce them and then I market them (i.e., I do the packaging, distribution...)

Our customers are the supermarkets.

2. What are the current challenges regarding sustainability in the food sector or yourself?

Before we had production problems, that is to say with the volume we produced. But now we are in a difficult period for marketing. Consumers are no longer interested in what they eat, they are more interested in organic. And this is a problem because I have to start producing today to sell next year. But the market is so volatile, I do not know if people will want to eat organic next year. You have to hold on commercially to be able to sell tomorrow. You really have to ask yourself the right questions about organic and this can be influenced by the government as well. Moreover, the covid crisis and the war between Ukraine and Russia make it even worse to sell bioproducts because people are more worried about other things such as dealing with increasing prices and bio products are usually a bit more expensive.

3. What do you understand about “bio”?

The production method that excludes all chemical and mineral interventions (no vaccines for poultry, no antibiotics, no mineral fertilizers for crops) is organic yes, but it must come from extensive or organic farming. Means are reduced because they are not conventional.

There are two types of agriculture

- Conventional agriculture: works with 'chemicals
- Organic farming: does not interfere with humans and works with nature

4. Do you think you are being paid enough for your efforts?

No, the law of economics is that if it is profitable, you continue, otherwise you stop. With all that's going on, it is sure that some will stop. There is a concept called ‘Fair price’ = the product sold in a shop, needs to be a fair price for the producer.

However, supermarkets are usually doing times 3 with the producer price. Therefore, we are not reaching a fair price.

The solution: telling people the exact price the supermarkets paid the producers (INCREASE IN TRANSPARENCY TOWARDS THE CONSUMERS)

I have in total 4 fixed employees + seasonal/temporary workers per 100 days (do not need more)

5. How does your organization currently address sustainability concerns in your operations, supply chain, and products?

Integration to shorten the circuit (reach the consumers more easily)

Problems with potatoes, easy enough to market via a vending machine → another business than production (profitable investment or not? Costly to put in vending machines? Is it not easier to just sell to supermarkets)

Short term solution and adaptability

6. What are you doing when overproducing?

There are many reasons that lead to overproducing.

- Bad market (conditions).
- Working with clients that might not be trustworthy. If they cancel, there are too many products which means inventory and storage, and this increases costs.

Each market has its own process:

- Fresh market (producing day-by-day that we send to the client daily) , therefore stock and inventory is needed (for example carrots or potatoes)
- Industry market : fixed contract (ask for huge quantities) → goes to the factory

Sufficient volume for the industry's needs

Tame chains must be able to take these products (if there are too many products, the farmer needs to reduce prices drastically to avoid throwing them away).

The 2nd quality products are not fresh; therefore, they do not have the same value. This can be the food for the animals.

7. Do you agree with the farmer's paradox ?

Most of the time, farmers work individually. Especially after the covid crisis, the agriculture sector only makes a small margin on each product and are dependent on several external factors such as the climate, quality of soils, pollution, government… In this domain, the exposure of a bad year is very high. Therefore, even though they want what is best for the perpetuation of the activity to hand it across generation, making shifting decisions is complex. A misjudged choice can jeopardize all the previous efforts

It is important that the offer is not greater than the demand, otherwise, the farmer needs to stock, which is costly. Concerning the external factors Environmental climate : each farmer takes a gamble because it is a huge cost and can't control external factors. The geographical location (land dependent)

- Monetary/financial factor

Investment and if there is anything left over afterwards it is for them >< loan company but profit at the same time:10 15 20 years of machine

Hangar wants 10 years, but banks want 20 years to be sure if there is a bad year

Constrained with this tax scheme

- Human factor

Human phenomenon = routine does not change (do not change everything either)

Impact more on young people than on old people

On the other hand, at the risk of failing, dangerous we have already fought for a long time to have this

→ do not want to change, will implementing technology be beneficial or is it a risk too

8. What digital technologies do you already use daily ?

Robot, GPS rtk. This technology helps us to plant the seed lines in perfect straight lines. When it plants the seeds, it memorizes the location so that when it is time to eliminate the weeds around the plants, it knows exactly how to distinguish the plant form the weed and only burns the weeds. That saves time, labor and fuel.

9. What specific digital technologies do you think to hold the most promise for improving sustainability in the food industry?

The robots are very promising to be more efficient. But it has its negative points too. For example, when sorting the potatoes or other products to remove the ones that have another shape than the standard one. Robots can be too disciplined and take out perfectly edible products. Standardization in the food industry is very touchy because you work with living things that are influenced by so many external factors.

We must be careful to not standardize too much and leave a certain margin.

10. What do you think about vertical farming?

Producing in cities where you do not have a natural environment to do agriculture does not make any sense to me. We already have so many leftovers. The cost would be huge.

11. What challenges do you face in implementing digital technologies for sustainability improvements in the food industry?

The price of the new machines and the R&D behind it. The ROI is very bad. The cost of the new machine in relation with the time and the use that we have of it. Especially, when the machine is just put on the market, they are very expensive. Personally, I will wait until it is commercialized at a certain time and the price has become more democratic.

12. What partnerships or collaborations with other organizations could help your organization to implement digital technologies for sustainability improvements in the food industry?

Currently, we are already collaborating between farmers to exchange techniques, knowledge and practices. Besides that, we borrow each other's machine if this one is needed for a very specific task, for amortizing the cost.

Also, there is the CETA that exists and stands for " Centre d'études techniques agricoles". It is an association created and managed by farmers wishing to benefit from personalized technical assistance to improve their production practices and performance. A technical advisor ensures

regular follow-up of each farm (crop visits, emergency interventions, specific information...), which allows the producer to reason his interventions and improve certain practices.

External partnerships are to be avoided, especially the commercials since they take a huge margin on the product and reduce ours.

13. What role do you think policy and regulatory frameworks can play in supporting the use of digital technologies for sustainability improvements in the food industry?

Politics have a huge role to play, but often do not do enough to change drastically things. They are under pressure from the budget, upcoming elections… And once they have some power, since they are only there a few years, they usually prefer short term changes that require more energy to change things, like ecology and the whole way of the economy is working.

To give you a concrete example, they could impose that 30% of the whole of agricultural products that a supermarket sells, should be bio. That would have a huge impact. But the problem is that we are only 10% of the farmers who are doing bio, which is only a small part of it, so politics tend to forget us and not allow enough budget in this sector. That is a vicious cercle, because that does not incentivize farmers to turn out and could even have the opposite effect. Politics should find ways to encourage people to consume bio, whether it is financial or other means. But the problem is that if they are too much in favor of the bio, they will end up having against them all the companies that sell chemical fertilizers. Our small 10% of farmers or the big companies, do not hesitate long to choose a party, especially with the elections coming soon.

Personally, I'm not in favor of the Ecolo party but if it is the only one to have reached our goal, we will all vote for them.

For sure the transition to a more sustainable world will cost, but doing nothing will cost even more.

Appendix 7: Interview Farmer, Jana Du Bois

1. Can you briefly introduce the farm and how you differ from others?

We have a small (+/- 100 cattle) family business that is fairly well known in Asse and the surrounding area. Our location is one of our strongest assets, as it is located at a roundabout + ring road and very close to the Brussels periphery.

2. What are the current sustainability measures in the food sector that you stand for?

- The PAS (Programmatic Approach to Nitrogen), reducing nitrogen emissions in

Flanders.

- MAP 7 (Manure Action Plan) which requires farmers to actively contribute to improving

water quality (applying sustainable cultivation and fertilization practices).

3. How does your farm currently address sustainability issues in its operations?

- Energy consumption is reduced by energy-saving lamps in the stables

- Creation of erosion strips in the fields

- Use of rainwater for sprayer and drinking water for cattle

- Solar panels

4. Farmers would like to change, but often cannot. Agree or disagree?

Here I agree. We are very much tied to regulations and applying for/obtaining permits and people are getting stricter on this every year. This restricts us from doing business.

5. How do you think technology can help improve the sustainability of the food industry?

By developing certain technological systems, people can produce food in a more sustainable way, such as systems where they can generate their own electricity, purify water... After all, farms consume a lot of electricity and water.

6. Which specific digital innovations do you think hold the most promise for improving sustainability in the food industry?

I believe in solar panels, which are already used in many farms now, possibly also wind turbines (to the extent possible).

There is also the possibility of installing a biogas plant for the fermentation of dairy cattle manure which would enable people to provide themselves with electricity and heat.

A water treatment system could also be an asset.

7. What challenges do you face in putting technology into practice? Too expensive, lack of knowledge?

We no longer have opportunities to expand the business any further (lack of space). In addition, there is certainly a serious cost involved in implementing new technological methods. The lack of knowledge does also play a role here.

8. What partnerships or collaborations with other organizations could help your organization implement more technologies to improve sustainability?

Possibly a joint purchase of these technologies with other farms to reduce the cost a bit. This would also encourage faster implementation of these technologies on different farms.

9. What data and metrics do you use to measure and track the sustainability impacts of your operations and supply chain?

Tracking electricity consumption

Calculation of the amount of nitrogen using formulas that can be used in the field may be used

-Perform soil analyses

- Monitoring rainwater consumption

10. What role do you think policies and regulations could play in supporting the adoption of digital technologies for greater sustainability in the food industry? What government measures could be taken?

The government could offer more guidance (at a reasonable cost) to farmers so that knowledge about these increases. Possibly in doing so, also provide advice on which specific digital technologies are best implemented at a specific farm

Appendix 8: Interview with Veerle Poppe - Sustainability strategist at Colruyt Group

1. Can you quickly present yourself and your role within the company?

My name is Veerle Poppe, and I have been a sustainability strategist at Colruyt for 9 years. As a strategist I focus on sustainability and health consumption, especially from the consumer perspective. I have a background in marketing, which makes me the only one with a less scientific background. I am mainly focusing on health, ecology, social and welfare which are the 4 teams of sustainability at Colruyt. I have a passion for informing, nudging and empowering consumers towards a healthier and more sustainable lifestyle based on robust scientific evidence.

The past year I have been leading the introduction of the Eco-Score at Colruyt Group. I combine this with the role as lead for European innovation projects around food, health and urban mobility.

2. What are the current challenges regarding sustainability in the food sector or that Colruyt is facing

Data overload and a lack of a standardized way to measure some concepts like the Life Cycle Assessment, there are 38 different ways to assess it. We need quality, security and standardizing in this industry to provide the consumers relevant and easy information. I worked and still work for the eco-score right now that is put on our private label food such as Boni, Boni Bio, Spar, Graindor and Colruyt Lowest Prices on the price label. The big challenge is to gather all the needed information upstream in the supply chain to guarantee the consumer transparent information about the product's ecological impact throughout the life cycle. As this score is based on 13 different indicators, you can already imagine the mess that it is to oblige the actors upstream to put on a certain platform all the data required of one single product. How can we be sure that this data is even true?

Besides the problem of the data itself, the access to platforms differs also from firm to firm. Nowadays, we are using the GS1 that makes the barcodes. It links organizations such as supermarkets, drugstores, construction markets, and their suppliers and provides global standards for identification, data capture and sharing. But not everyone has access to it.

The solution would be to have an all-in-one standardized platform accessible to everyone throughout the supply chain and user-friendly. The European Commission has a huge role to play in this process

Finally, once the data is gathered, one must draw conclusions from it to transform it to useful information. There is a pain point as well. Not everybody has the required software and knowledge to do so.

Another challenge for Colruyt is the fact that the social part of the ESG is very hard to measure. As mentioned, the European Commission plays a big role because of the green deal. However, reducing co2 emissions and being able to measure them is difficult.

3. How does your organization currently address sustainability concerns in your operations, supply chain, and products?

We are using the scope 1 scope 2 scope 3 emissions to see how we are actually doing regarding the emissions. This is really important because it is one of the only ways to measure it. We also find it very important to implement the eco score, nutri score, BEF... there are over 16 impact categories that Colruyt takes into account.

4. How are you currently using digital technologies to improve the sustainability of your operations and supply chain?

At Colruyt we use something called GDS1 which is a platform where data gets exchanged automatically between suppliers and retailers.

5. How can digital technologies help your organization to achieve specific sustainability goals related to the SDGs?

We are looking for a software to turn all the data into valuable information for all the players within Colruyt. A lot more standardization is needed to achieve this.

6. What role do you think policy and regulatory frameworks can play in supporting the use of digital technologies for sustainability improvements in the food industry?

It is a way to make every business compliant.

Appendix 9: Interview with Geoffrey de Hennin and his wife - Owners at Intermarché

1. Can you quickly present yourself and your role within the company?

I am responsible for the Intermarché in Ramillies, which is an independent cooperative structure. This means that each manager has his own shop, the independents each have their own role in a group of independents. So, you can say that there is an interdependency with all the shop managers. This is a different model than our competitors. It is a food distribution shop, local products or products that we import

2. What are the current challenges regarding sustainability in the food sector or that Intermarché is facing?

Our biggest challenge is energy, especially at the moment with everything that is going on. We have to be careful with our energy consumption, especially in the big shops. The fridges and shelves in our stores consume a lot of energy. Another concern is cardboard and plastic, we get a lot of that too and we have to find an efficient way to get rid of it or recycle it. Another challenge in a shop like ours is expired products. Fresh produce is very hard to manage. However, the biggest problem is not with us but with the larger shops like Danone where they can send us products that are more than enough days before they are no longer edible according to the expiration date. Now we can send them back, there is a law or if for example Danone sends us products that expire within 10 days, we can send them back. Otherwise, we end up with these products and we have to throw them away or find a way to sell them at a reduced price which is not interesting for us.

To reduce our energy consumption, we installed panels. This was installed 5 years ago, and we even installed a TV screen that shows how much energy and electricity was returned to the shop thanks to the solar panels. The purpose of this screen is to show the consumers that we are careful

with our electricity consumption, but we won't lie to ourselves that it is also good publicity. Intermarché also has a wind turbine in their warehouse. It is important to know that the energy from the fridges that we recover helps to recover the heat from the fridge and it puts this heat back into the shop.

3. What challenges do you face in implementing digital technologies to improve sustainability in the food industry?

The legislation with the AFSCA, they are very strict, or the shops can be penalized.

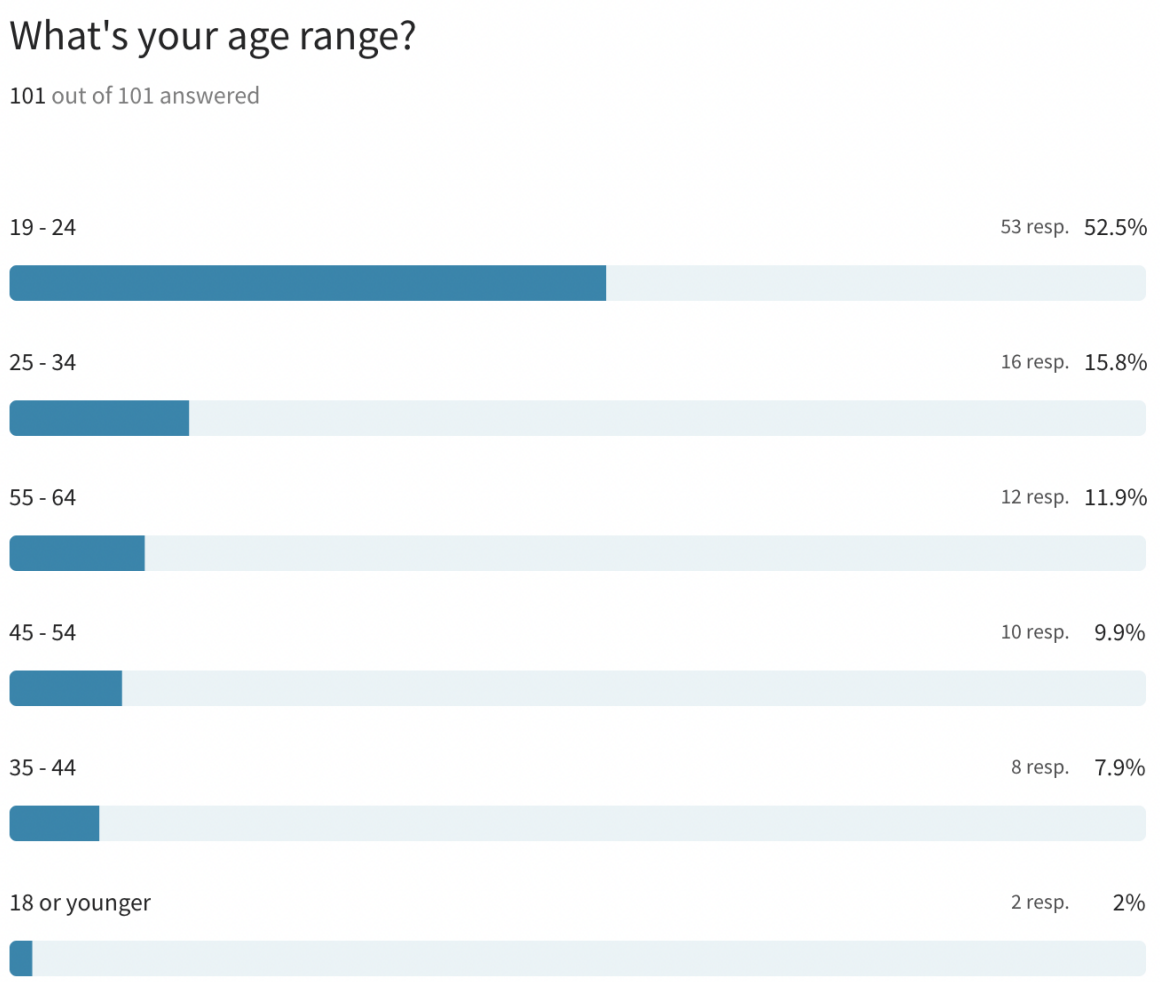
4. In what ways do you think digital technologies can help improve the sustainability of the food industry?

We also address the issue of food waste by using toogoodtogo. So, to reduce waste, especially in the creamery and bakery. But we know that there is more we can do to reduce waste in our shop. Then we also have a software to manage expiry, we encode dates to know when the product is expired. This makes our life much easier because before we had to encode everything by ourselves. There are a lot of certifications that are displayed on products, and this is becoming more and more important for consumers. Another one we discovered recently is Ethiquable. We also try to arrange with associations to donate food to avoid waste but if the food is out of date, then it should be thrown away.

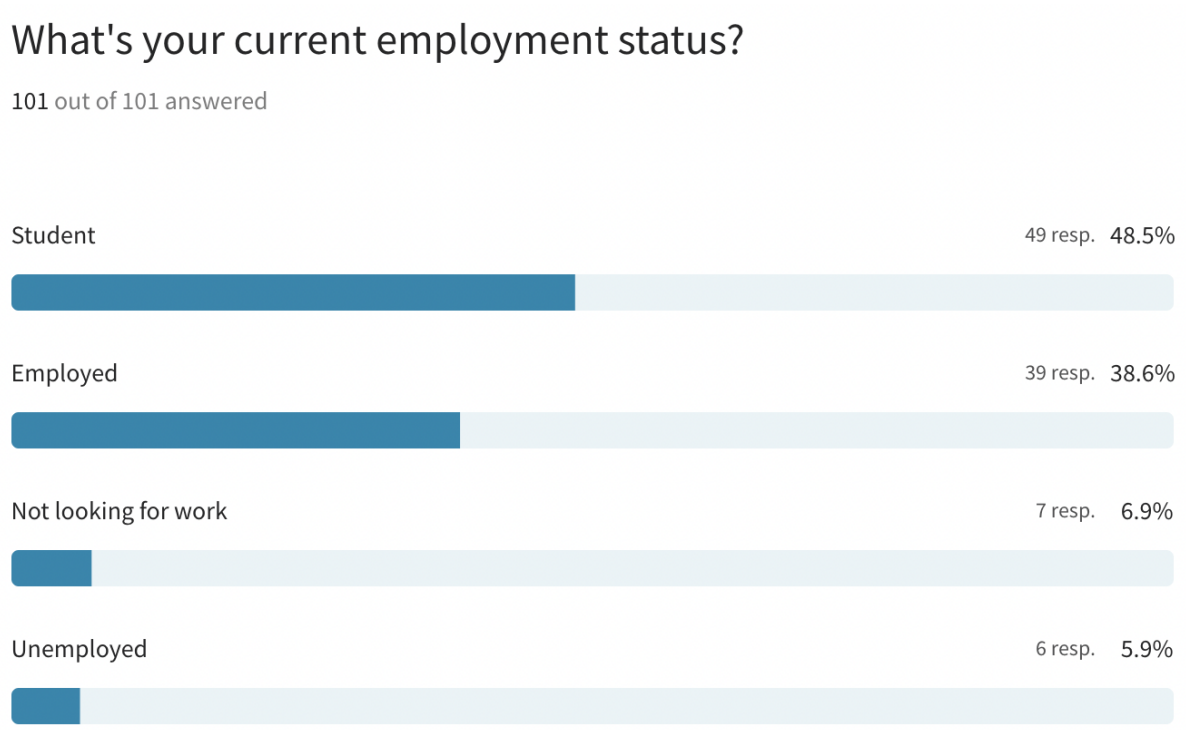
However, we think it is necessary to have a standardized platform to communicate through each supplier, employee, etc. → some kind of Odoo (supplier, point of sale, support to buy material like clothes or printers etc.)

Appendix 10: Results of the consumers' survey

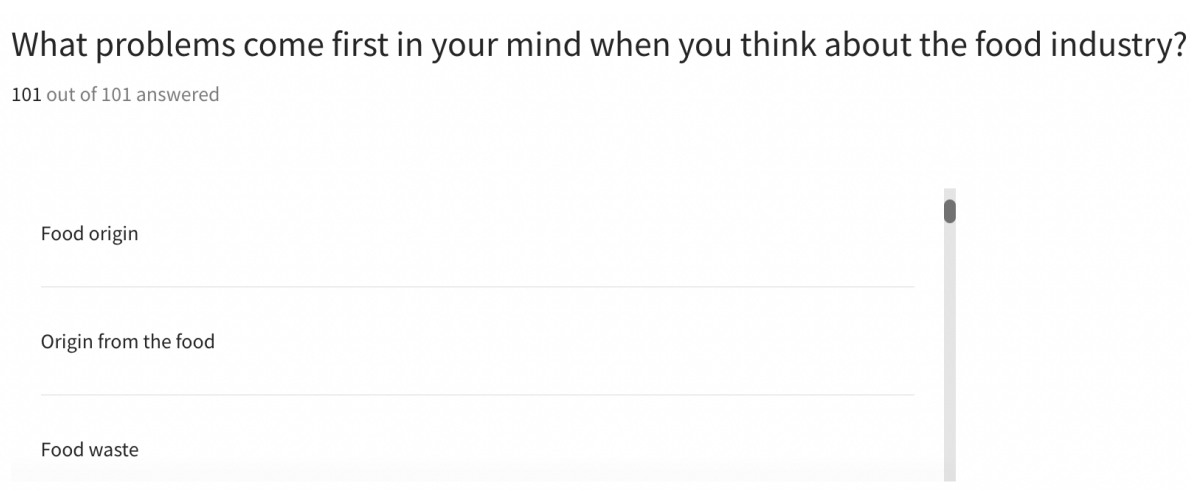
Question 1



Question 2



Question 3

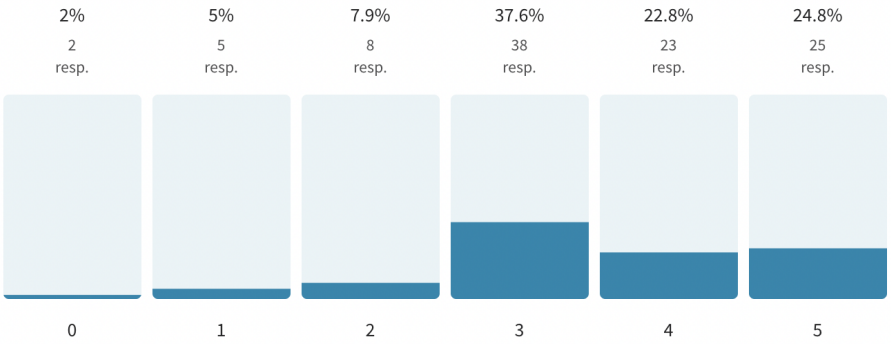


Question 4

Would you be willing to pay more for food products that are produced sustainably and in a transparent way ?

101 out of 101 answered

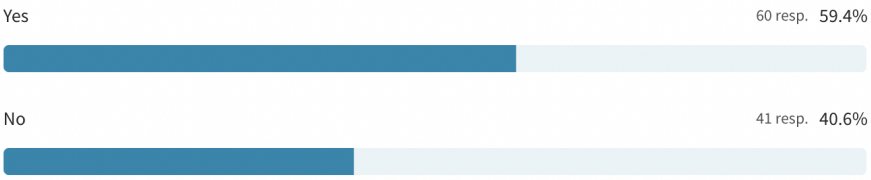
3.5 Average rating



Question 5

Before doing this survey, had you ever heard about the 17 SDGs?

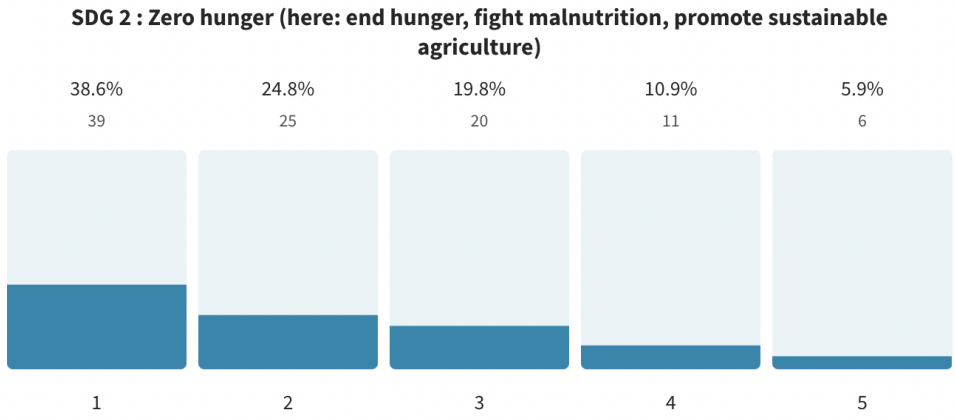
101 out of 101 answered

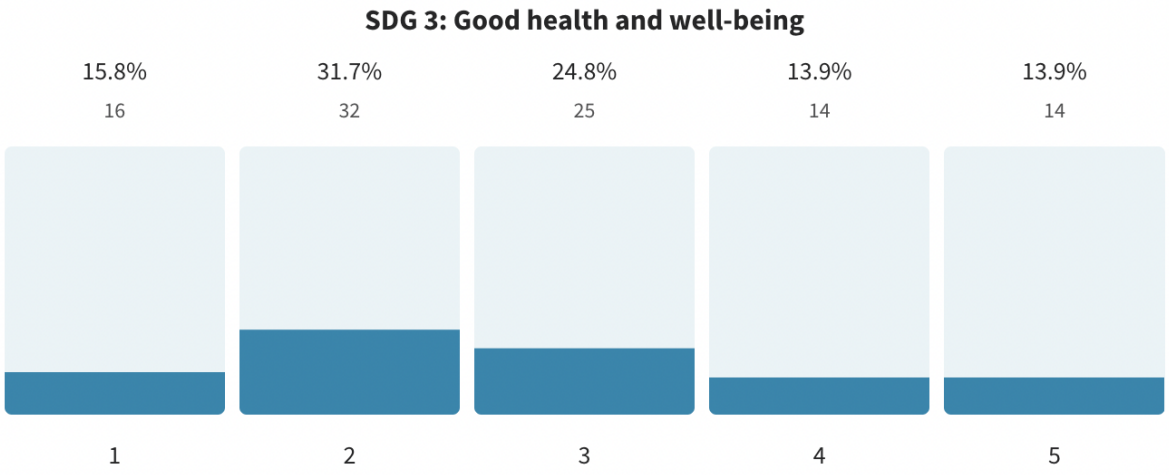


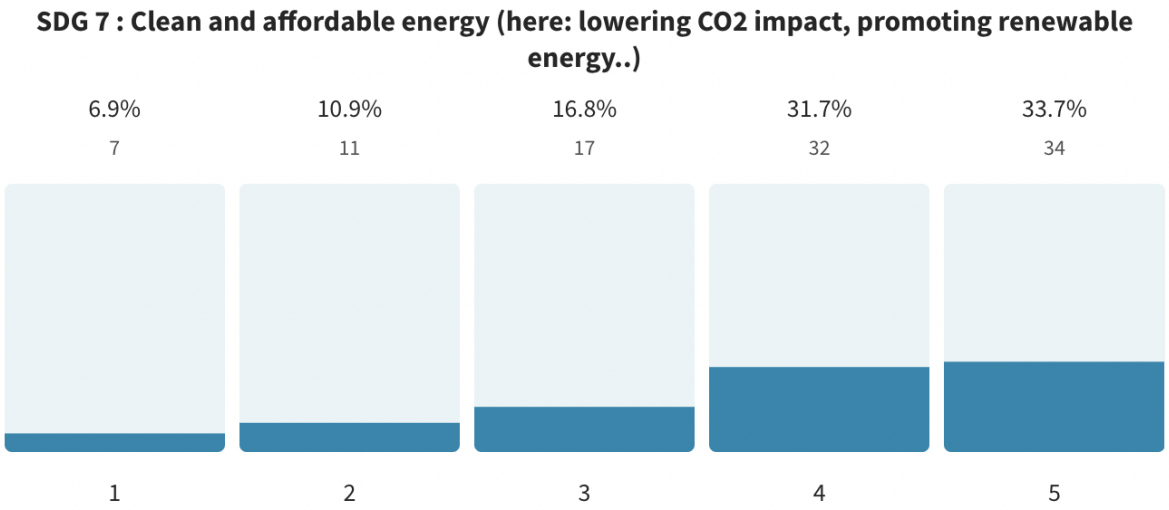
Question 6

In your opinion, which of the following SDGs are the most important for the food industry to address?

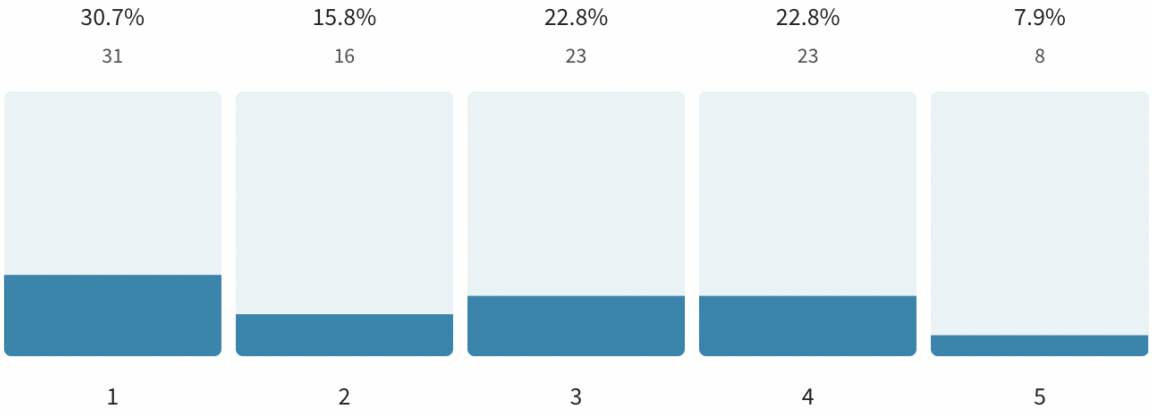
101 out of 101 answered



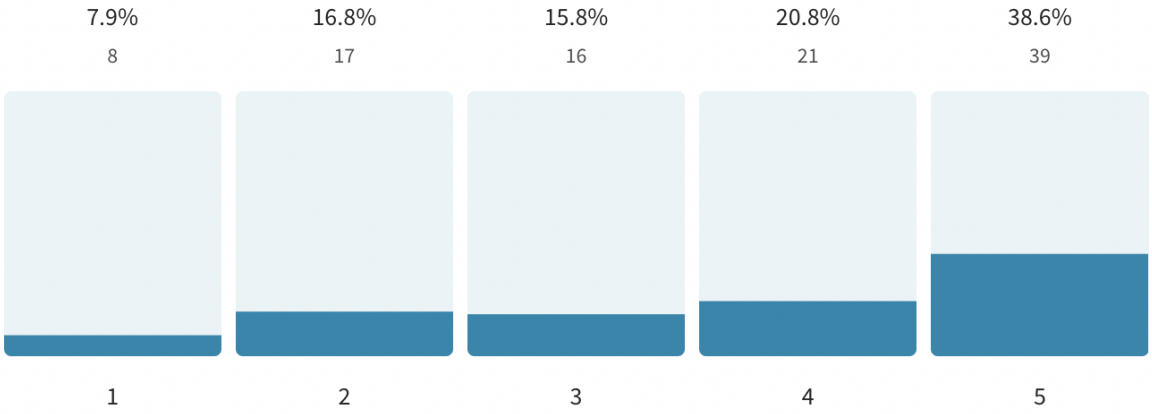




SDG 12 : Responsible consumption and production (here: food waste, preserving natural resources, less packaging...)



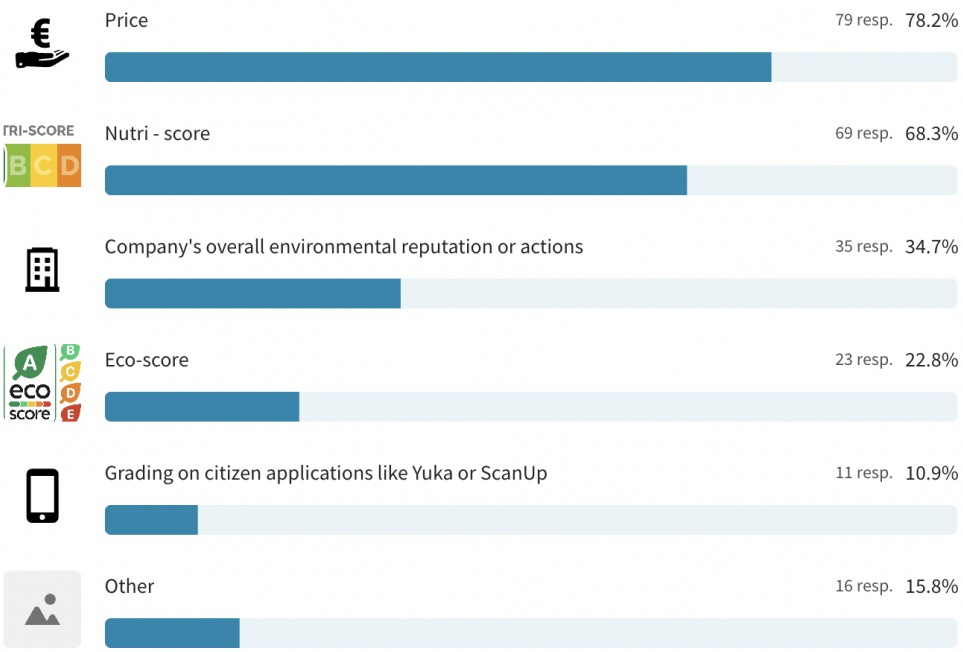
SDG 13 : Climate action (here: taking concrete initiatives to fight climate change)



Question 7

Which of the following options influence your decision when buying products ?

101 out of 101 answered



Question 8

What digital innovation(s) that is/are already implemented do you consider as useful?

101 out of 101 answered

Online ordering that reduces intermediaries throughout the supply chain, app for food sharing (too good to go)

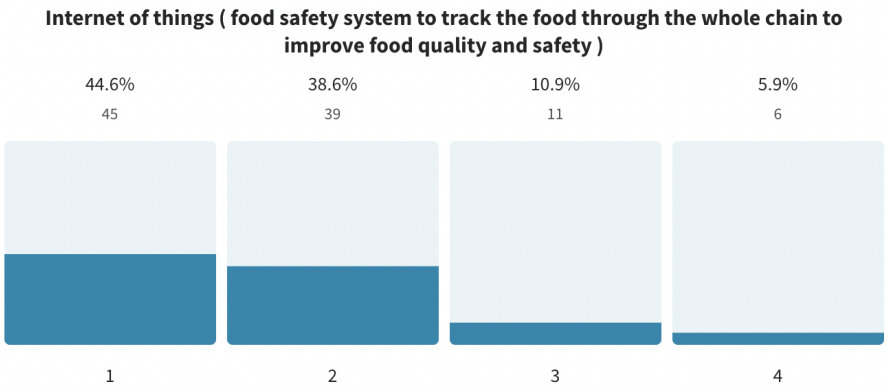
Food tracter and sustainability to know more about food we buy

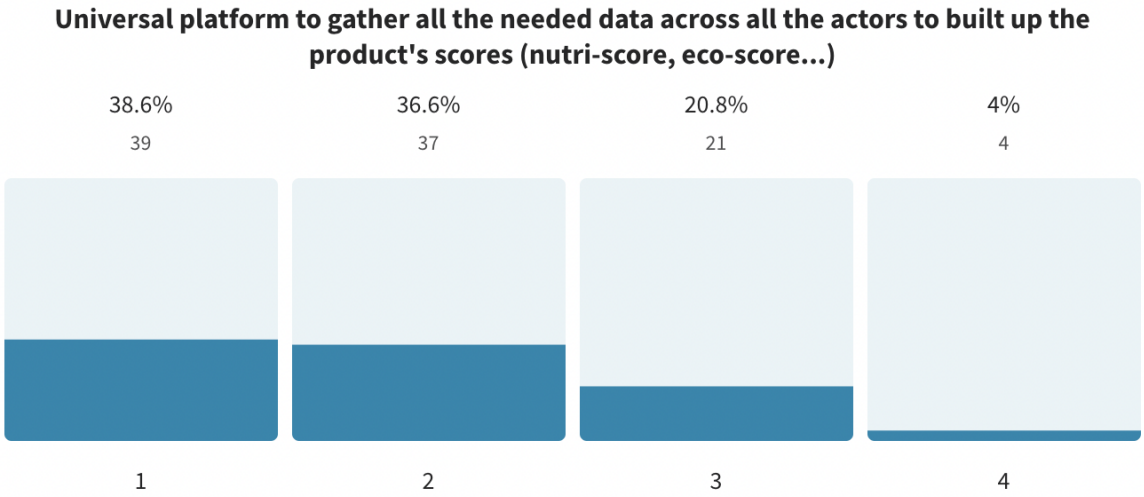
Yuka, Click&Collect

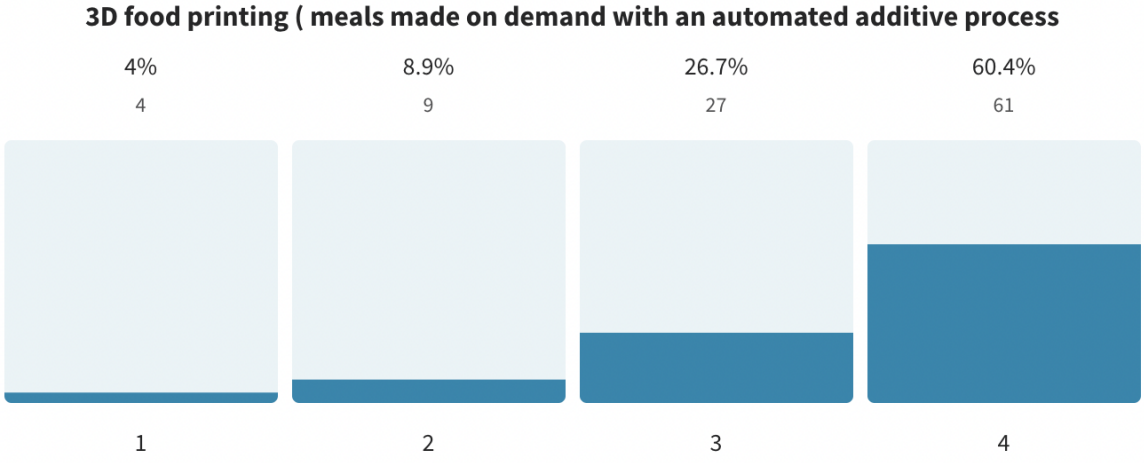
Question 9

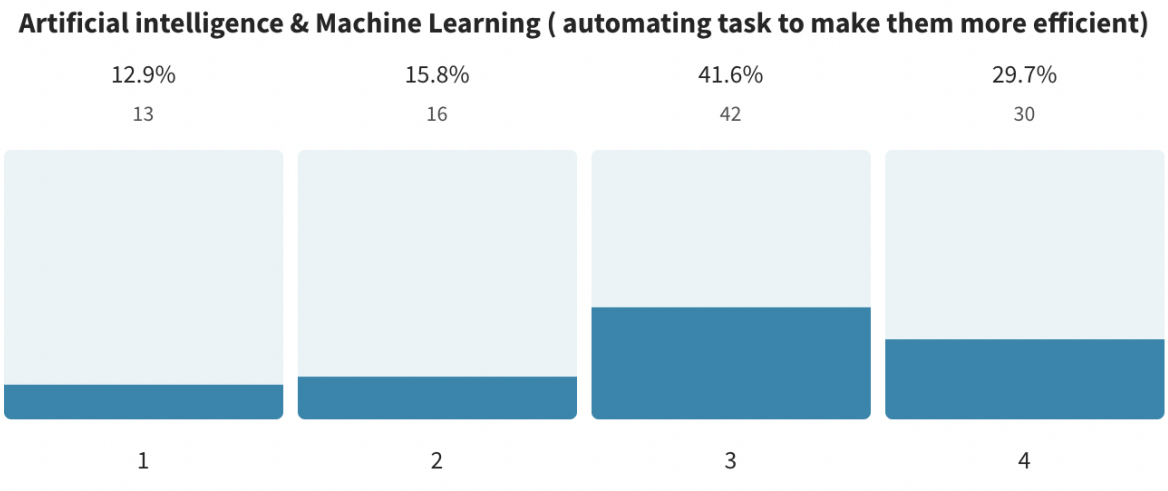
In your opinion, which of these digital innovations will have the greatest impact on the sector?

101 out of 101 answered









Question 10

Based on your previous answer, what is the reason of your first choice ? Can you also perhaps give other examples of promising innovations?

101 out of 101 answered

Good to be able to seewhere things come from

Track food safety quality

Standardisation and transparency are key