Key Drivers of the Implementation of Smart Technology in the Food Value Chain: Innovation for a sustainable Food Production

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Abstract*: The food industry faces big challenges. In the future, more and more people around the world will have to be fed. Research has shown that the world's population will double by 2050. Accordingly, the productivity of the food industry must be doubled as well. In addition, agriculture must adapt to climate change and adapt food production to global warming. At the same time, the food industry must also use natural resources more sustainably and produce more environmentally friendly products in order to curb climate change. Increasing productivity while increasing sustainability at the same time has been a challenge so far. But new "smart" technology can change this situation. Innovative agricultural machines can communicate generated Date through the Internet of Things (IoT) with each other and to respond autonomously to the sent information. Through precision and resource-saving operation, this technology has the potential to increase the productivity of agriculture and sustainability at the same time. The benefits of implementing this technology are very extensive. There are also different key drivers along the food value chain, which promote the implementation of smart technologies in agriculture. Those will be shown in this review.

***Index Terms*: Smart Technology, food industry, internet of things, food value chain**

I. INTRODUCTION

The food industry is becoming more and more important. As the world's population grows, so too does the responsibility of all those involved in the food industry, especially among producers. The United Nations released data that by 2050 9.8 billion people will need to be fed. By comparison, in 2017 it was around 7.6. Billions [1]. In order to feed the growing world population, however, a large number of problems have to be solved. These problems include e.g. irrigation and land management, climate change management, lack of investment in research and development, and infrastructure inefficiency in the distribution of food [2]. The simultaneous occurrence of climate change, globalization and urbanization have serious implications for the international provision of food [3]. It is the greatest challenge of humankind kind to meet the demand of food and to realize a sustainable use of natural resources [4]. A challenging task, especially in relation to scientific forecasts of global food needs. As a result, food production will have to be doubled over the next 25 years [5]. There are no quick and short-term solutions to realize these goals of an increasing food production while reducing the ecological footprint and food security globally [2]. The only long-term solution is to focus on the agricultural sector. Because this is the key to reducing food insecurity [6]. Investing in research into technical innovation can prevent e.g. food waste [7]. Farm machinery manufacturers such as John Deere are focusing their product development on combining sustainability with maximizing productivity [8]. Thus, many of their machines are sold with Smart Farming technologies that enable farmers, e.g. sow the seeds autonomically to the nearest centimeter [9]. Smart technologies are taking on more and more "human capabilities”. They are able to recognize objects, they possess skill and have a memory. Thus, these technologies are used in areas where before people were employed, such as packaging, testing of products and mounts of the smallest electronics. [10] Porter and Heppelmann split smart technology and machines into four categories: Monitoring, control, optimization and autonomy [11]. Thus, the effectiveness of agriculture reaches a new technological level. Agricultural processes can be optimized by robots, mapping, geomatic technologies and statistical analysis even more than by precision farming. This allows technologies to react to specific conditions, depending on the situation [12]. This allows technologies to react to specific conditions, depending on the situation.
The implementation of smart technologies in the food industry involves many advantages along the food chain.

II. FOOD CHAIN

Thus, the definition of the food chain does not differ significantly from definitions of the value chain. Only branches, actors and activities are integrated into processes of the theoretical value chain. Looking at the food industry's sales system from a traditional perspective, farmers increase seed and the product is "pushed" into the market. They are isolated from the consumer and have little control over input costs [13]. With the aim of maximizing agricultural production, the processes of food chain operators are increasingly interlinked [14]. These links can be horizontal and vertical. Horizontal links connect players from the same markets or sectors. Vertical links, on the other hand, connect suppliers, buyers and consumers. Thus, in the vertical integration, all the necessary processes and actors that are relevant for the creation of an agricultural product are linked together in the food chain [15]. The input is given to the farmer as seed, which then multiplies and produces it. The harvested product is then delivered to the aggregators, which aggregate the product. The cereal can then be sold as seed for other farmers or to the processors. These then process the cereal into a consumable product, e.g. bread. The now marketed product passes through the

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wholesaler to the retailer and from there to the consumer [16]. Depending on the food, the activity of the aggregator can be skipped. E.g. this activity is not integrated with potatoes. In value chain theory, farmers are therefore also connected to consumers, which may have an impact on satisfying the needs and preferences of consumers. Farmers are also working more closely with suppliers and processors [13].

The dynamics of the food chain has changed in the past. These changes are due to factors such as climate change [17]. Farmers in particular are strongly affected by this factor. Thus, their production can be particularly negatively influenced by drought, overhydration or even fire [18].

Another influence on the food chain is an increased complexity in consumer demand for food. Characteristics of foods such as quality, safety and origin play an important role in the decision-making of consumers [17].

The food industry must adapt to changes in consumer behavior. This change is marked by a growing number of allergic, vegetarian and vegan people who are calling for more information about food [19].

By creating transparency of production activities, needs of consumers can be met. At the same time, the competitiveness of the respective companies is increased [18].

III. SUSTAINABILITY

The idea of sustainability was first formulated in 1713 in „sylvicultura oeconomica“ by the authors of Carlowitz and by Rohr using the example of forestry. So one must also pay attention to the clearing of forests, that following generations also have wood available [20]. The formulation of sustainability using the example of forestry is one of the first definitions of sustainability. The World Commission on Environment on Development (WCED) is also based on this definition in the report "Our Common Future", which is also referred to as the "Brundtland Report" by its chairman Gro Harlem Brundtland. Thus sustainability is to be defined as a lasting development in which the needs of the present are satisfied, without endangering the satisfaction of the needs of the next generation [21]. Both definitions refer to the receipt of resources. These resources can be described as a means that companies need to achieve their goals. Thus, companies are dependent on these funds [22]. Definitions of sustainability by Carlowitz and von Rohr as well as the WCED mainly refer to the components of ecology and social issues. The preservation of resources for non-existent generations also has an impact on the dimension of the economy. The current concept of sustainability can be characterized by the dimensions of ecology, social and economic [23].

Regarding the definition of sustainability, the dimension of ecology can be described from a biological perspective as prevention of extinction and the pursuit of propagation.

In the economic dimension of sustainability, it is important to avoid economic disruptions and discontinuities and to hedge against instability and instability [24].

The social dimension can be deduced from the definitions of the authors of Carlowitz and von Rohr as well as the WCED. Thus, the social dimension refers inter alia on the protection of the following generations. By minimizing and eliminating the degradation of resources, the satisfaction of the needs of future societies should be guaranteed.

In economic theory the idea of saving resources is described as rationality of action. This rationality of action is plausible until the substance or the resource is visible and the degradation leads to consequences, such as hunger. However, fossil fuels are not visible underground and the rationality of action has become less important due to the immense raw material and energy resources [22]. In the past, the loss of the meaning of rationality of action has endangered the ecological, economic and social dimensions of sustainability and thus also the satisfaction of the needs of the following generations. Many companies now integrate sustainable management into their infrastructures. Through sustainable management, economic decisions are influenced by the aforementioned dimensions in order to ensure a sustainable development of the company and at the same time to have a positive influence on the ecology and society [25]. Sustainability initiatives by companies have many positive effects. This will open up new market opportunities, improve product quality, minimize damage to the environment, and improve social and work standards [26].

IV. FOOD SECURITY

The simultaneous occurrence of climate change, globalization and urbanization are having serious consequences for the international provision of food [3]. It is the greatest challenge of humankind to meet the demand for nutrients and at the same time to realize a sustainable use of natural resources [4]. A challenging task, especially in relation to scientific forecasts of global food needs. Thus, the production of food must be doubled in the next 25 years [5]. For the world's population, it is of paramount importance to cope with the problem of food insecurity and enforce global food security [6]. In today's scientific literature, food security no longer only refers to the global provision of food. Food security is no longer defined only by the quantity but also by the quality of the food. Diseases such as cancer, heart disease or even diabetes are often due to poor diet. So it is important, especially people of young age, to consume food that is rich in micronutrients that can be purchased cheaply [2]. The steadily growing protein demand of the world's population must also be capped by food securtiy measures [28].

Actors who are seeking the realization of global food security, are facing ever-new challenges. Only one of them, but one of the biggest challenges, is the rise in food prices since the end of 2006. The price hike worsened the global hunger situation. In 2007, the number of starving people rose to 923 million people. For comparison, in 2003 there were 75 million less. The price increase of food for regions in Asia and sub-Saharan Africa has had a particularly negative impact. Nearly 90 percent of the world's starving people come from these regions [6].

There are no quick and short-term solutions to realizing food security globally [2]. The only long-term solution is to focus on the agricultural sector. Because this is the key to reducing food insecurity [6]. Investments in research into technical innovation, in particular, can prevent food waste [7]. The waste of water could also be reduced by technologies in the future [4]. In addition, modern technology improves crop yields, improves livestock farming and food quality [2]. Accordingly, agriculture can meet the requirements of food security through modern technology.

V. SMART TECHNOLOGY

Before the topic of smart farming is described in this chapter, the term "smart" should be defined. Smart technologies and machines are already firmly integrated into professional and private everyday life.

In social research, smart technologies are described as a kind of mirror of society. Smart technologies record users' intuitive decisions, allowing them to image their moral and their personalities [29]. In addition, smart technologies are taking on more and more "human capabilities. They are able to recognize objects, they possess skill and have a memory. Thus, these technologies are used in areas where before people were employed, such as packaging, testing of products and mounts of the smallest electronics [10].

Porter and Heppelmann split smart technology and machines into four categories: Monitoring, control, optimization and autonomy [11]. For a farmer, the protection of the environment can be the motivating factor for implementing smart farming technologies in the business. For other farmers, more accurate feeding of animals through smart technologies may be the motivating factor for implementing smart farming [30]. Real-time capable sensor technology currently available on the market can measure the so-called leaf area index, biomass and chlorophyll concentration through spectral analyzes by light reflection. The results of the measurement can be used as needed for the application of fertilizer [31] [32]. But even in the context of surface irrigation, sensor technology can sustainably protect the environment and minimize expenses for the user. Thus, experiments have shown that the irrigation efficiency of e.g. fruit trees could be increased by 40 percent compared to conventional irrigation [33].

Another example showing the potential of state-of-the-art sensor technology relates to real-time ground sensors. These were previously used only offline. The real-time capable soil sensors can measure the electrical conductivity of the soil down to a depth of 1.1 m on the field surfaces. So the characteristics of the soil can be determined. This results in compression zones and water saturation in the soil. Farmers can benefit from the soil sensors, especially in tillage. This allows devices to adjust to the values communicated by soil sensors to optimize the soil [31].

VI. RESULTS

So there are different key drivers with an interest in implementing smart farming in the food industry. These key drivers are to be divided into two interest groups. Thus, there are interest groups with ecological intentions and interest groups with economic intentions. Environments with an ecological intention in sustainability can be defined as one of the key drivers. According to von Carlowitz and von Rohr, the following generations are also to be assigned to the interest group with ecological intentions, as the current ecological footprint will not allow conventional agriculture to last for generations [20]. Accordingly, the expectation of smart farming technologies is to produce food more resource-efficient and effective. And this is possible, especially in to crop production [33] [31]. The key drivers for implementing smart farming in the value chain with economic intentions are companies that expect competitive advantages [34]. Smart Farming generates a large amount of data. Integrating them into the value chain can optimize processes. For example, harvest quantities can be predicted. Value creating activities along the value chain are increasingly interlinked [14]. Smart farming strengthens this link and creates a vertically integrated value chain [15]. There is also another benefit through smart farming. By increasing sustainability, smart farming also has a positive impact on the marketing of companies, such as Edeka or ALDI. So those companies communicate their sustainable to the target group [35]. By conserving resources and increasing sustainability, the implementation of smart farming can be communicated by the food industry as Corporate Social Responsibility (CSR) activities. CSR communication has a positive impact on sales of products. There is a positive correlation between the integration of CSR and consumer buying behavior [36].

VII. DISCUSSION

Nevertheless, there are also obstacles in the way of implementing smart technology. For example, the technologies must be affordable for farmers or subsidized. In addition, the technology must constantly evolve. It has to be mobile, usable long term through efficient power consumption, it has to be easy to understand, always controllable and scalable [37]. A very relevant obstacle remains the topic of data protection. Thus, the internet of thing is high risk. There where data is collected and communicated, there is also the risk that data may reach third parties, who then use it for their own purposes. Many farmers fear the implementation of IoT technologies because data could be otherwise used, e.g. for market speculation [38] [39]. In the future, policy makers will have to decide on regulations for the use of data along the food chain, which will help to advance the implementation of smart technology in the food industry.

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