The Digital Transformation of Agriculture

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Abstract — Many industries have undergone a digital transformation in recent decades. The levels of digital transformation vary widely from one industry to another. In particular, agriculture has gone through various levels of digitization in context of technological innovation. These each had a major impact on the effectiveness of food production. Like no other industry, the digitization process is as relevant as it is in agriculture. Many experts in industry and politics expect the digital transformation in agriculture to increase sustainability while increasing productivity. The expectation attitude relates to the curb of global warming while simultaneously safeguarding food security.

Keywords — Digital Transformation, Agriculture, Internet of Things, Precision Farming, Smart Farming

I. INTRODUCTION

In the context of social and economic development, the issue of digitization is repeatedly the focus of political debates [1]. In science too, digitization is the origin of many studies of modern technologies and services. Digitization is a conversion of analog data into a discrete system with few value states, such as a binary code (0 and 1). Digitized data can then be used and mapped using technical systems. If digitization is so defined, it can be traced back to 1833, where it was possible to communicate through signal transmission using the morse alphabet. Within the third industrial revolution (since 1950), also called the digital revolution, digital techniques were increasingly used. Digitization developed slowly. From 1990, however, the use of computers to improve processes in the economy prevailed. In the fourth industrial revolution (from about 2000), the internet is used for networking. Companies can communicate with it without interruption. The use of the internet has also become established in private households. Current developments in digitization are referred to as “4.0 technologies” as they are created within the development process of the 4th industrial revolution [2]. Even 185 years after being able to communicate with the Morse Code, digitization is in a process of development. There are different dimensions from an entrepreneurial perspective. So there are companies that call themselves after setting up a homepage as digitized. Others are implementing digitization by identifying and analyzing data or even using robotic technology [3]. The digitization development process is driven by innovations such as state-of-the-art technology and software. For example, digital innovations can be defined as new products, platforms and services. As long as the product or the result has been produced through the use of digital technology or digital processes, it is also considered digitally innovative, even though it is not of a digital nature itself. An example of this is 3D printing. The produced object itself is analogue in nature, while the printer is digital technology. The printed object and the printer are regarded as digitally innovative [4]. Particular innovative strength can be seen in the areas of big data, cloud computing, social media, mobile technologies and Industry 4.0 technologies [5].

Especially since 1990 companies began to digitize themselves to invest in Information and Communication Technologies (ICT). Based on this modern technology, digital innovations have been created. Some of these innovations have a permanent function in everyday life today, others of them have long since disappeared [6]. Since 1990, innovation has been the predominant factor in the economy, where production is not based on physical transactions, such as financial services [1]. Especially the food industry is undergoing a digital transformation. In relation to the trend of smart technology this critical review is intended to illustrate this digital transformation.

II. INTERNET OF THINGS

Since the Internet of Things (IoT) is the basis of digitizing food production due to the technical possibilities, the following definitions of the properties of the IoT are of highest relevance for this investigation. Due to the fact that IoT is a relevant topic of current scientific literature, there are many definitions of IoT.
This will be differentiated between “consumer internet of things” and “industrial internet of things”. The consumer internet of things relates for example on home entertainment devices that generate data and communicate with each other [7]. Especially in the last decade and the rapid progress of information technology, the IoT becomes more and more noticeable in everyday life [8]. In general, IoT refers to the connection of physical objects to the internet and the connection of these objects with each other [9]. More specifically, the IoT can be described as a network in which devices are interconnected within an existing internet infrastructure. These devices can then communicate with each other within the network. This integrates between a physical layer and a computer-based layer [10]. Data must first be generated before they can be communicated with each other. Therefore, sensors are an integral part of the IoT. For example, sensors combined with radio frequency identification technology (RFID) can determine the status, residence, movement and temperature of a machine [11]. The preparation and communication of this technology is as follows:

1. Sensing Layer: Here the objects (“Things”) such as e.g. Sensors or RFID tags integrated.
2. Sensing Layer: This supports the transfer of information over a wired or wireless network.
3. Service Layer: Here data is “translated” by middleware technology and can thus be integrated into applications.
4. Interface Layer: Here, users have access to the data (for example, via displays), allowing interaction with the system [12].

The data generated by the IoT technology are then stored in a so-called “cloud”. Cloud computing then calculates this collected data according to the requirements [13]. In scientific literature, the connection between IoT and cloud computing is referred to as ”cloud-based IoT Systems” [13]. The ongoing innovations in the software segment mean that the potential of the IoT is far from exhausted. These innovations ensure that the IoT is constantly being used in new areas and facing new challenges [14].

III. TECHNOLOGICAL DEVELOPMENT IN AGRICULTURE

In human history, agriculture has always been one of the most relevant industries. Agriculture is responsible for the production of unimaginable resources such as food, food, medicine or even energy [15]. Agriculture has always played the most important role in the development of human civilization. Thus, the technology of agriculture developed further. Technological development has always focused on maximizing and optimizing food production. The mechanization of agriculture dates back to the beginning of the last century. For example, draft animals were replaced by the use of tractors. At present, agriculture is faced with the task of satisfying the needs of food, due to the permanent increase in the world's population [16]. To meet these demands, agriculture is increasingly turning to digital technology. While the topic of industry 4.0 has been the subject of much discussion in other industries, digitization in agriculture has already become integrated and is practiced on many farms and other segments of the food industry's value chain. Technological advances have also allowed the use of fertilizers and, for example, seed varieties to be optimized [17].

IV. PRECISION AGRICULTURE

Precision farming was already mentioned in scientific literature in 1996. Of course, the more than 20-year-old definitions do not mention modern technologies such as smartphones and cloud computing. Data from the time of e.g. tractors could be collected, such as distance or temperature, were defined in 1996 as a decision-making aid for farmers [18]. In scientific literature of 2001 to the subject of precision farming, the attention was already paid to the environmental friendliness created by precision farming [19]. At this time precision farming was associated with very accurate fertilization. Farmers who invested in precision farming technology in 2001 had two expectations. On the one hand, they were hoping for a reduction in fertilizers while maintaining a constant yield and, on the other, an increase in yields due to the same amount of fertilizer [19].

Example without precision farming technology: A farmer uses a machine to spread fertilizer. The farmer only has the possibility of orienting himself on the given spreading width of the machine and on the conditions of the field (for example by driving lanes). It can happen that fertilizer is doubled in some places and not applied in other places.

Example with precision farming technology: A farmer uses a machine to spread fertilizer. Precision farming gives farmers several options. A simple form of precision farming is a tracking arm system that allows the farmer to make almost identical tracks, each offset by the spread. Thus, in some places, neither double nor even scattered. Fertilizers can be reduced and used more accurately, even more efficiently. Which parts of the field have been sprinkled with fertilizer and which are not, is marked on a screen.
These examples are based on literature on precision Farming from the year 2001. Computer technology has already been increasingly used here. The University of Nebraska interviewed farmers who have invested in precision farming technology, which economic differences could be identified compared to use without precision farming technology. A clear majority of 70% said that the profit of agricultural products could be increased [20].

V. TRANSFORMATION FROM PRECISION FARMING TO SMART FARMING

Articles in professional journals are increasingly reporting that the terminology "precision farming" as it was defined no longer exists. Instead, the connotation of "smart farming" has been superseded. Today, more and more systems are being developed that are based on precision farming properties but have become even more digitized. Farmers can monitor or plan their machines using typical devices such as tablets or phones [21]. In scientific literature, which addresses the technological changes in agriculture, there are several definitions of smart farming. Nevertheless, all are based on Porter's "smart criteria" that define smart as technology with capabilities of Monitoring, controlling, optimization and autonomy [22]. So smart farming is based on information that is shared among the technologies. This allows autonomous actions of smart farming technologies to be implemented [23]. Using the example of agriculture, Porter & Heppelmann describe how complex smart farming can be integrated into a business. A tractor extension such as internet-enabled tablets and other mobile devices can turn a tractor into a “smart, connected product”. Adding further machines to smart, connected products, such as a planting machine, creates a complex interconnected product system. If this product system then receives data relating to the respective application from external sources of information, this can be referred to as a "system of a system" [22]. Thus, in contrast to precision farming, smart farming is no longer just about location data, but more about a mass of data communicated in real time among the technologies. In this way, technologies can actively react to specific conditions. These Reactions can be based on changes in weather or the recognition of a leaf disease [24].

VI. CONCLUSION AND DISCUSSION

The effectiveness of agriculture reaches a new technological level. Smart agricultural processes can be optimized by robots, mapping, geomatic technologies and statistical analyzes even more than by precision farming [23]. However, experts also have requirements that smart farming processes must meet. These criteria are relevant for the implementation of smart farming processes in agriculture. So smart farming technologies must be affordable and globally available. Moreover, as part of a performance assessment, the system needs standardized. Furthermore, the systems must be mobile and portable as part of deployments. The technologies must be also able to be used over the long term. So, battery powered technologies need to have efficient power consumption. Of course, the system must be easy to understand in operation. Simple schooling should assist users in the operation. Smart farming technologies must always be controlled and monitored. In addition, the system must be scalable in its network sizes [16]. The addressees of these criteria are above all the manufacturers of smart farming technology. In addition, the criteria are also geared to the respective agricultural and educational policy. A limiting factor is the training of young and already working farmers, as this affects their later skills, especially in relation to smart farming technologies. In emerging economies such as Brazil, low education in rural areas hinders knowledge transfer on agriculture and new technologies. This knowledge gap can only be filled if macroeconomic measures improve access to education or corporate courses (Pivoto et al., 2018, S. 31). The change from a traditional farm to a connected farm by implementing smart farming technology in an existing farm structure can be done in different ways. Thus, there are various effects that change the respective smart farming model of a company. At the same time, these effects can also be regarded as intentions of the farmer. An integration of digital innovation like smart technology can have different intentions. As a result, there are different models of the smart farm. These can vary from operation to operation. For a farmer, the protection of the environment can be the motivating factor for implementing smart farming technologies in his business. For other farmers, the more accurate feeding of animals through smart technologies can be the motivating factor for implementing smart farming. Likewise the production efficiency or a support in the decision-making of production processes [25].
REFERENCES


