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STATE OF THE ART REVIEW OF SMART FARMING

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Abstract
Smart farming is becoming the future of agriculture by implementing new smart technologies such as robotics, artificial intelligence (AI) and autonomous systems. This integration tries to tackle some of the most prominent challenges like environmental sustainability and resource management. With modern technologies resources can me optimized, crops can be monitored to ensure quality and prevent failures while still minimizing the impact on the environment. The main technologies used in smart farming include autonomous ground and aerial vehicles, IoT sensors and support systems for decision making. The integration of such sophisticated technologies is however challenging, as it includes high costs with many maintenance issues. Overall, smart farming is rising, and the global market values is rising at a significant rate and are paving the way for a sustainable and efficient future for agriculture.
Keywords: Smart farming; Internet of Things; Robotics; Sustainable Agriculture; Precision farming

1. Introduction

Smart farming is an emerging field that uses advanced technologies to be used in agriculture and help improving efficiency, productivity and sustainability. It allows the use of new and improved tools for a responsible and sustainable use of resources such as water or fertilizer. Farmers can optimize every aspect of their production to ensure a good harvest every time. [1]

The new technologies that are being developed are diverse and rapidly changing. Due to this, there are some different terms to describe specific aspects of this field. Smart farming or agritech for example is widely representative of the whole field of technologies and innovations in agriculture.

Precision Farming represents a key component of smart farming. It focuses on the individual and localized management of recourses such as water, fertilizer or pesticides. It allows farmers to individually treat specific parts of a field or animals with all their needs. So, it is possible for example to water one part of a field more then the others, because the crop and the land in the area is drier than in other parts. Similarly, food for stock animals can be adjusted to their specific needs and current health state.

Digital farming describes the aspect of gathering and analysing data for decision-making. This involves all kind of sensors and IoT devices to gather data all around the farm and monitor any changes to act accordingly. This can minimize the risk of bad crops or spreading infections.

Smart farming in general is gathering more traction in recent years due to the global challenges, such as climate change, scarcity of resources and a fast-growing population. This can be seen in the economic sector. Between 2020 and 2025 the market value for IoT technologies in agriculture in north America is expected to double, reaching 4 billion US-Dollars [2]. Similarly, the global market value of smart farming is projected to reach 33 billion dollars by 2027, a threefold increase since 2021 [3]. This reflects the needs and fast-growing nature of smart farming in recent years and can be observed in figure 1.

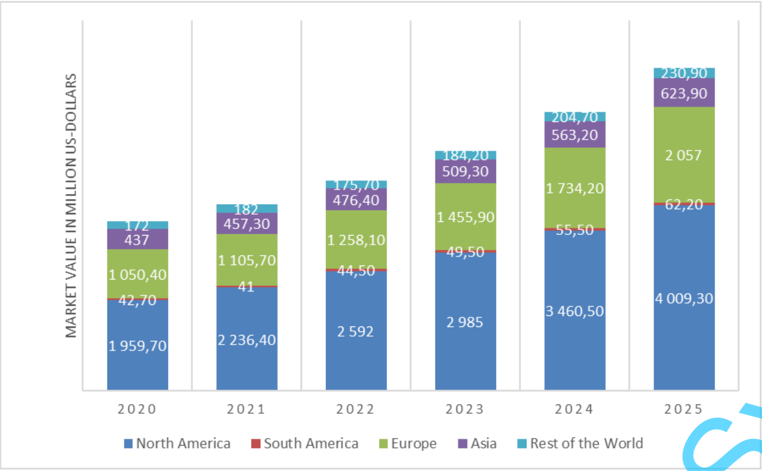

Figure 1: Market value of IoT technologies integrated in agriculture worldwide by region from 2020 to 2025
Source: [2]

2. Technologies in Smart Farming

The technologies that are being implemented are widely spread. They are significantly dependent on different factors, one of them being the climate and geographic characteristics of different regions. As countries focus on different crops or different stock animals, the employed technologies and research tend to diverge and focus on different priorities. For instance, Spain has emerged as the leading country in the EU in research and development of robots for wine production. These robots can perform various tasks, such as collecting grapes from grapevines or monitoring the condition of the plants [4]. In contrast, Germany has its priority in harvesting other crops. It has more significant research in autonomous driving, especially with autonomous tractors [5].

Despite all the differences, the used technologies in smart farming can be categorized in two major groups: Unmanned ground and aerial vehicles and IoT sensor networks for data collection.

Unmanned vehicles play a crucial role in modern farming. Ground vehicles, such as tractors or harvesters, are being used to maximize efficiency and minimize the use of resources [6]. Equipped with modern GPS technology and sensors, they can navigate entire fields accurately. Also, mobile robots are being deployed more often, as research is getting more traction and more fundings [4].

Similar, aerial vehicles or drones can observe fields and crops when equipped with cameras. They can cover large field quickly and precisely, showing data that allows farmers to have a better overview of the fields and identify any issues. However, aerial vehicles are used much less than ground vehicles, as the development didn’t start getting traction until 2015, when the word “drone” was created [7]. For comparison, the first research for automatic tractors with GPS tracking was published in 1996 by Stanford university in USA [8].

Sensor networks are the second big cornerstone of smart farming. As they can provide real time data about a crop field or various environmental factors, farmers are able to monitor data and act accordingly when needed. Depending on the network, specific crop parts or stock animals can be treated individually to ensure better quality with precision farming [9]. Collected data often gets transmitted through IoT-devices, which enables a remote access to all data. This approach leads to a better management of resources, allows a greater yield and reduces the environmental impact.

The synergy of this technologies can create an ecosystem for precision farming. With aerial images of the crops and exact real-time data from ground sensors, farmers can evaluate the field conditions and act accordingly. They are also able to react faster to changing conditions or diseases.

3. Examples for application of technologies

One of the earliest examples of smart farming technology is the automated milking machine, first patent and research done in 1987 [10]. Today this machines not only can milk cows in a steady and unharmful way, they can also collect data about each cows, for instance there vital values to determine the health state, the yield and the frequency of each milking procedure. With this data farmers can adjust feeding practices and react to health issues, which improves productivity and animal welfare [11].

In addition to milking, smart livestock monitoring systems are set to be a critical component in modern animal husbandry. Sensors and IoT-devices can track many different vital values and track the behaviour of each individual animal. If unusual data is identified, farmers can react to potential health issues faster than without technology. [12]

Agricultural robots have also been pushed by several funded projects in the EU. The European Clearing House for Open Robotics Development (ECHORD++) is an initiative to get researcher and manufacturers together to cooperate [13]. Many projects were funded by this initiative. For instance, the Mobile Agricultural Robot Swarms (MARS) project was creating mobile robots for seeding crops that could work in swarms [14]. Unlike traditional tractors, these robots can minimize soil compaction, which benefits the soil health. Another project was the Ground Robot for vineyard monitoring and protection project (GRAPE) which aimed to create mobile robots that can autonomously monitor grapevines and harvest them if needed [15].

WaterBee was another EU funded project that aimed to introduce more technologies for water management. The conservation of water is a critical concern in modern agriculture, especially in very dry climates and regions. WaterBee introduces a network of IoT sensors placed in the soil of a field. They monitor the moisture level in real time and can adjust watering of the crop depending on the parameters. With this method specific parts of a field can get watered if needed and the whole schedule can be adjusted to the real-time needs. This ensures an optimal use of water as a resource. [16]

Artificial Intelligence is getting more significant with recent breakthroughs. They are mostly integrated in decision-making components to analyse data and act accordingly. These systems can analyse data from sensors, weather, drones and all kind of IoT devices. This ensures an optimal and sustainable use of resources and can even help farmers to decide on daily operations and prioritization [17]. As an example, AIs gets used as an effective animal repellent combined with ultrasound to protect crops [18].

4. Advantages and challenges

As it offers significant advantages to farmers, the implementation of smart technologies can be challenging and overwhelming.

There are high initial costs that need to be carried. Machinery and IoT sensors require a high capital. Small or medium-sized farmers are usually not able to make such an investment. Additionally, after the initial expenses, costs can still be high with regular maintenance, updates or repairing costs [4]. However, there exist many funding programs that can support farmers. In the EU there exist many different programmes and research projects that were discussed in the previous chapter like ECHORD Plus Plus or waterBee. Other than that, the EU also has funding projects like the common Agricultural Policy (CAP), which aims to provide direct development funds for farmers [19]. This funds often require the implementation of smart technologies and digital practices. There is also the Partnership for Agricultural Productivity and Sustainability (EIP-AGRI) which helps to connect farmers with researchers and businesses and provides grants when adopting new smart technologies [20]. Additionally, the European Agricultural Fund for Rural Development (EAFRD) also finances rural projects and farmers and helps to develop new technologies which align with the EUs Farm to Fork Strategy and the green deal [21].

While the initial costs can very high, the long-time savings are considerably higher. The need for manual labour is minimized and an optimal use of resources is guaranteed. More critical is the ability to create a sustainable agricultural standard. By optimizing the use of all recourses, the environmental impact gets minimized and the carbon footprint gets reduced. It also increases the yield of the crops and increases the revenue of the farmers. [22]

Farmers often don’t have the necessary skills to employ and use smart farming technologies. A fundamental knowledge about data analytics, machinery and modern technologies is needed to ensure an efficient use of smart devices [23]. Furthermore, there is currently a lack of standardization across all smart farming technologies. Manufacturers use systems, that often don’t interact with each other and create an inefficiency, as farmers need to work on multiple systems and platforms. This increases the needed knowledge level even more [24].

With the new systems collecting and transmitting large amount of data, cyber security and data privacy get more important. The fear of a data breach and the misuse of information can hinder many farmers on adopting new technologies. In some regions there also may be policy constrains that don’t allow the implementation of such networks. This includes unclear regulations about the ownership of data. [25]

5. Conclusion

Smart farming shows a shift in agricultural techniques from a traditional way, that is highly depended on manual labor, to a modern way with the introduction of sophisticated technologies and innovative solutions. With the gcurrent global challenges of resource shortages, labor shortages and a unsustainable environmental impact the integration of smart technologies is getting more crucial. The technologies allow a precise and optimized use of recourses, promote more sustainable practices and reduce the overall costs of farmers.

As demonstrated, the use of smart farming technologies can be very diverted and implemented in different ways. Robotic systems are changing tasks like milking, harvesting or planting to be executed easier and without manpower. Precision farming enables a more specific observation of the farm and introduces a more precise way of managing crops and stock animals.

However, these technologies are met with notable challenges. The costs of such systems can be very high, especially for small or medium-scale farmers. Pairing this with a high degree of complexity and a notable risk of a data breach makes it a very daunting task to implement such systems into a farm. Additionally, the social impact of automation must be considered as a risk of displacement of labor is ensured.

Despite all the challenges, it is prognosed that the global market will rise and so reflects the interest in modern technologies in agriculture.

In conclusion, smart farming shows to be a promising future for agriculture. As research and development tend to push the boundaries and create new technologies, smart farming will address some of the most crucial global challenges like global warming. Smart farming will eventually start a new era in agriculture, one with a sustainable progress for the future.

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