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Using Internet of Things for Sustainability in Agriculture in The Pandemic

Pandemide Tarımda Sürdürülebilirlik için Nesnelerin İnterneti Kullanımı

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ABSTRACT

The aim is to determine the usage of the Internet of Things (IoT) in agriculture in order to prevent contagion with applications and use cases in the field with its facilitating role in the pandemic. For this purpose, content analysis of articles from MDPI, PubMed, and Google Scholar was conducted, the governments' good practices were examined, and implementation projects were combined to obtain the Internet of Things to deal with COVID-19. The IoT architecture in agriculture, examples of IoT use in agriculture, monitoring of livestock, monitoring of climate conditions, greenhouse control, and drone use are important IoT use cases. Productivity, expansion, resource use, and clean processes are among the benefits of IoT in COVID-19. In COVID-19, comprehensive government initiatives, food demand growth, precision agriculture and increasing government initiatives are important IoT initiatives. The Internet of Things proposed to mitigate the impact of the pandemic could become a relatively major part of the solution and farming future with the development.

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ÖZET

Bu çalışmada amaç, salgında kolaylaştırıcı rolü ile sahadaki uygulama ve kullanım örneklerinin bulaşmasını önlemek amacıyla nesnelerin internetinin (IoT) tarımda kullanımını belirlemektir. Bu amaçla MDPI, PubMed ve Google akademik makalelerin içerik analizi yapılmış, hükümetlerin iyi uygulamaları incelenmiş ve COVID-19 ile mücadelede Nesnelerin İnterneti'ni elde etmek için uygulama projeleri birleştirilmiştir. Tarımda Nesnelerin İnterneti mimarisi, kullanım örnekleri, hayvancılığın izlenmesi, iklim koşullarının izlenmesi, sera kontrolü, drone kullanımı önemli IoT kullanım örnekleridir. Verimlilik, genişleme, kaynak kullanımı, temiz süreçler, IoT'nin COVID-19'daki faydaları arasında yer almaktadır. COVİD-19'da kapsamlı hükümet girişimleri, gıda talebindeki artış, hassas tarım ve artan hükümet girişimleri önemli IoT girişimlerindendir. Pandeminin etkisini hafifletmek için önerilen "Nesnelerin İnterneti" gelişimle birlikte çözümün ve tarım geleceğinin için nispeten önemli bir parçası haline gelebilir.

1. INTRODUCTION

Since COVID-19 has taken the whole world under its influence, governments have imposed measures for the safety of farmers and workers in agriculture by taking protective measures, conducting COVID-19 tests and providing the necessary isolation, ensuring a safe working environment, safe food production. Such efforts are crucial for both the nutrition and economy of the country's population. Continuing agricultural production is also affected by the pandemic, the freedom of production is restricted, and people cannot sow, reap, and do the necessary agricultural processes at the desired level (Woodhill et al., 2022).

Agriculture 4.0, also called Smart Agriculture or digital agriculture, is important to offer agricultural solutions during the pandemic by enabling management applications beyond the concept of agriculture thanks to the Internet of Things, developed with the awareness of the contact, away from the place of operation, and with real-time events (Khan et al., 2021).

Smart Agriculture, mentioned within the IoT, often includes smart services to implement and manage digitalization in farming and allow production processes, food safety, and traceability. Therefore, the IoT could be a key technology for agriculture during the pandemic as it enables the flow of data between sensors and devices to add value through automated processing, analysis, and access to the data obtained (Haque et al., 2021). Simultaneously, the IoT provides real-time responses to trigger events such as weed, pest, or disease detection, air or soil monitoring alerts, contamination reduction and control, and contact reduction. IoT facilitates the documentation and auditing of activities, tracking of products, remote investigation, and compliance with contact tracing and quarantine requirements (Zhuang et al., 2021).

The concept of IoT has introduced by Kevin Ashton in 1999 by creating a network of "things" on the Internet without direct human intervention with Radio Frequency Identification (RFID) connectivity for supply chains. Objects can be any device with sensors and/or actuators that uniquely addressable, interconnected, and accessible over the Internet (Krishnamoorthy et al., 2021). The application of IoT in agriculture can monitor and control many different parameters in an interoperable, scalable, and open context with the increasing use of heterogeneous automated components. As a result of IoT, making informed real-time decisions to manage agriculture based on data can reduce the spread of the pandemic by reducing uncertainties and contact (Gaspar et al., 2021).

IoT solutions, which are considered useful for growers who want to stay at home during the ongoing epidemic, are aimed at helping you monitor your farm without going to the field. This is done by deploying the device containing multiple sensor nodes in the fields. However, studies on the use of IoT and digital technologies in the pandemic have not been found in the literature. The pandemic poses the following challenges to agriculture (Akhtar et al., 2021):

- Design of sensor networks,
- Installation and cost of IoT systems,
- The use and maintenance of IoT systems.

IoT in agriculture is an evolving field that is rapidly replacing outdated methods. This allows us to overcome the limitations and challenges of the pandemic by focusing critically on general principles, and key application areas. This study aims to reveal the use cases of IoT in agriculture and its facilitating role in the pandemic with current and new research. In line with this main purpose, the following sub-objectives will be predicted:

- To examine the current status of IoT technologies and architecture,
- Outline the capabilities and use cases of IoT in agriculture,
- To indicate the impact of the pandemic on agriculture,
- Identifying IoT solutions in agriculture for the practical challenges of the pandemic.

2. IOT IN AGRICULTURE

The IoT ecosystem is a connection of various types of devices that sense and analyze data and communicate with each other over networks. In the IoT ecosystem, user uses smartphones, tablets, sensors, etc. to send commands or requests to devices to receive information over networks using smart devices. The device responds and after analysis performs the command to send information back to the user over the networks (Nilakantha et al., 2021).

There is no unique or standardized consensus about the IoT architecture. IoT architecture is different from its functional areas and solutions (Mrabet et al., 2020). The layers of the IoT, which provide solutions for the IoT architecture can be specified as four main components (Sethi and Sarangi, 2017):

- Sensors / Actuators,
- Gateways and Networks,
- Data Center,
- Application / Edges.

Sensors / Actuators: These devices can connect to the network wired or wirelessly, transmit, accept, and process data over a Local Area Network or Personal Area Network.

Gateways and Networks: Because sensors and actuators generate a lot of data, they require high-speed Gateways and Networks to interconnect networks and systems for data transmission.

Data Center: Data Centers or Cloud are parts of Management Services that process information through analytics, device management, and security controls. In addition, the cloud transmits data to end-user applications such as retail operations, health, emergency, environment, and energy.

Application / Edges: Edges and applications are hardware and software gateways that analyze and preprocess data before transferring it to the cloud. If the data received from the sensors and gateways is not changed from the previous reading value, it will not be transmitted over the cloud, but these data will be recorded. This component consists of a combination of IoT and Agricultural Market Intelligence (Li and Niu, 2020).

The above IoT architecture consists of wireless connectivity and embedded systems that interact with devices, sensors, and actuators. The system provides different data from the temperature, humidity, and soil moisture sensors. Sensors are used to detect different agricultural data and factors affecting production. Sensors are classified as position, optical, mechanical, electrochemical, and airflow sensors (Hu et al., 2021). These sensors collect information such as weather, soil, precipitation, wetness, chlorophyll, wind, dew, humidity, sun, and pressure. Data is transferred to different modules and central servers by communication methods such as ZigBee (Shafi et al., 2019).

2.1. Use Cases of IoT

In addition to monitoring weather, crops, and soil, IoT devices have benefited from increased crops and profitability by managing livestock, dairy production, and innovative applications. Additionally, IoT, big data, and cloud applications adopt technologies in periodic storage so that the market can grow and the produced crops can be consumed throughout the year (Akhigbe et al., 2021). Therefore, incorporating IoT devices in agriculture for various purposes meets increasing demands for high-quality food products as well as driving growth in the market. Let's take a look at the use cases of how the Internet of Things can bring its applications in agriculture to real life (Ayaz et al., 2019).

2.1.1. Monitoring livestock activities

IoT applications help farmers collect data about the location, condition, and health of animals. Thus, the status of the animals is determined. For example, locating sick animals so they can leave the herd can prevent the spread of the disease to all cattle. Forecasting farm owners' cattle with IoT-based sensors helps reduce labor costs. A company called Cows can run algorithms that combine milk information and machine learning to manage dairy farm operations with IoT, a non-invasive monitoring system with smart lanyards, taking information about the environment of the cows from sensors (Akbar et al., 2020).

2.1.2. Monitoring of climatic conditions

Thanks to smart sensors, weather data can be collected and necessary information can be given to the farmers. The data is analyzed and the farmer makes inferences to avoid crop loss. For example, allMETEO serves as an IoT-based agriculture project that provides farmers with early warning in case of extreme temperatures, frost, and wet weather on their farms (Haque et al., 2021).

2.1.3. Greenhouse control

In addition to the environmental data, weather stations can automatically adjust the greenhouse conditions to provide the appropriate conditions in line with the given parameters. GreenIQ is a smart system controller that allows remote management of irrigation and lighting systems using smart agricultural sensors (Colonel and Doğan, 2020).

2.1.4. Use of drones

Drones have a wide range of uses, from soil and crop area analysis to planting and pesticide spraying in agriculture. Drones provide time-dependent and region-specific information to farmers through various imaging technologies (Gupta et al., 2020). In this way, dry places in the fields can be farmed and irrigated. EBee SQ, an agricultural drone, operates over a huge area with its flight for crop monitoring and analysis (Naji, 2019).

2.2. Advantages of IoT

Technology advancements have increased the use of the internet of things to promote agricultural production systems' productivity, cost-effectiveness, and resource use efficiency, particularly in light of the current climate change situation. The world's expanding population, fluctuating climatic circumstances, and rising food consumption are some of today's urgent issues. To increase output and eliminate obstacles, the farming sector needed the Internet of Things and innovative techniques. The Internet of Things (IoT), which is currently focusing on the agriculture economy, will help farmers overcome the immense obstacles they face. Thanks to the Internet of Things, farmers may have access to a wealth of data and knowledge about emerging trends and innovation (Ali et al., 2023).

IoT explains the technologies involved with yield estimates and improvements as well as smart management tactics. Studies have shown that using IoT and smart technologies will increase the productivity of crop production systems. With an average simulation accuracy of up to 92%, it was discovered that different neural networks and simulation models might help with yield prediction for better decision support. Many methods have been developed for yield prediction, pest control, intelligent irrigation, disease classification, and detection for effective crop health and water status monitoring. Compared to a soil moisture-based irrigation system, advanced irrigation lowered costs by 25.34%. Different irrigation models and smart irrigation technologies can cut energy use by up to 8% (Ali et al., 2023).

A successful strategy for disease prevention and yield maintenance requires smart and precise disease management. By using image processing techniques, such as by utilizing a genetic algorithm with 90% precise accuracy, a variety of leaf diseases on a variety of crops can be controlled. The research obtained precision up to 98% in detecting and classifying diseases in various crops. Diseases can be detected and classified with the use of image processing techniques by neural networks. In order to comprehend its impact on world food production, particularly as a means of eradicating or greatly reducing the negative effects of urbanization on food yield, vertical farming and its many indoor production techniques have been examined (Ali et al., 2023).

For improved growth and development of various horticultural products, the use of artificial illumination with the intention of delivering an effective photosynthetic photon flux density has been explored. The current evaluation also covered many useful strategies, crucial methods, IoT-based smart technologies, the use of sensors, as well as the global limitations that prevent the use of these smart technologies in agriculture (Rangasamy et al., 2022).

With the use of the Internet of Things in agriculture, productivity increases, cost decreases with less resource use, and automation and data-driven applications provide advantages and solutions to agricultural problems. These advantages can be stated as follows (Singh et al., 2021):

Productivity: Today's farmers strive to grow more crops on degraded soil, dwindling land, and bad weather conditions. Using IoT in agriculture allows real-time monitoring of crops and production conditions. With IoT, you can predict problems before they happen and make informed decisions to avoid problems. In addition, the IoT can automate irrigation, fertilization, and robot-assisted harvesting.

Expansion: Systematic greenhouses and hydroponics with IoT enable the creation of short food supply chains and can provide the opportunity to feed the growing population. With smart closed-loop farming systems, it is possible to grow crops in the appropriate place.

Reduced resource usage: Basically, IoT can optimize resource usage such as water, energy, and land. Precision farming using IoT helps farmers use data collected from sensors in an optimized way for scarce adequate resources.

Clean process: IoT-based systems are going to replace traditional agriculture by reducing the use of pesticides and fertilizers, while saving water and energy to producers, making agriculture more environmentally friendly.

3. IOT IN AGRICULTURE DURING THE PANDEMIC

IoT in agriculture adopts advanced technologies for sustainable agriculture and its practices for increased productivity. IoT includes IoT sensors that can collect real-time data in smart agriculture, and analyze and update itself in working situations. Because of its benefits, in Agriculture, the growth of the IoT market and the use of precision farming techniques are being directed towards IoT and cloud-based solutions. However, data security risks and the lack of skilled farmers to implement IoT effectively are limiting factors (Ray, 2017).

The ongoing COVID-19 pandemic has affected major manufacturing and operating areas by shutting them down. Before the pandemic, industries were actively competitive and innovative (UNICEF, 2020). The agriculture sector was also thriving by adopting IoT and big data analytics. However, with the sudden emergence of the pandemic, many industries have stopped or postponed their production and projects. The financial impact on farmers due to the pandemic has resulted in a large reduction in non-emergency spending and investment as shown in Figure1 (Meticulous Research, 2021).

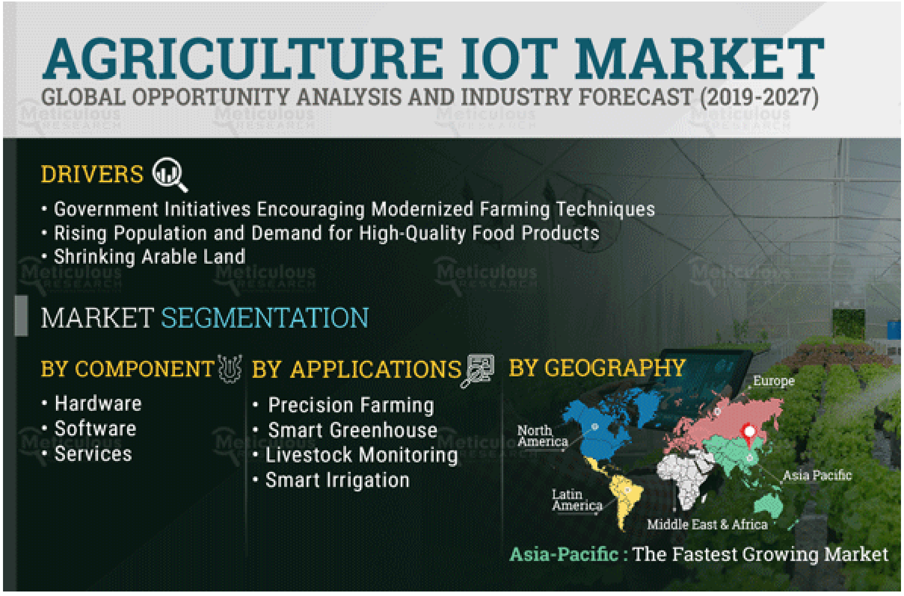

Figure1. Agriculture IoT market (Meticulous Research, 2021)

The decrease in raw materials and the rapid decline in demand, the difficulty of finding labor and assets cause production plans to change very often. This will slow the adoption of agricultural IoT solutions. However, it is waiting to be implemented as a proactive automation technology to reduce the worker density of agricultural IoT solutions in the regions most affected by the pandemic (Gaspar et al., 2021).

IoT solutions have boosted agricultural productivity in these pandemic times. IoT-based solutions are mostly run directly on their smartphones. For this reason, IoT has been a leading sector in agricultural technology in recent years. Every year, several agriculture-focused companies produce high-tech products to help farmers increase productivity, cope with nature's uncertainties, find the right farm machinery, and smarten their cold storage and supply chains – in short, they offer growers smart technology (Khan et al., 2021).

In India, smartphone-powered Kraashak provides customized recommendations for the grower with an IoT sensory system capable of measuring and monitoring all ground conditions suitable for a crop's growth. It measures temperature, humidity, conductivity, pH, and moisture absorption to detect soil conditions. The collected data is sent to a private cloud platform, AgriVital; where an AI-powered expert system reads them and performs predictive analytics for specific plants or crops. There has been an increase in demand for the IoT sensory system as it reduces the need for labor in the epidemic era (Almalki et al., 2021).

Currently, it is the growers keen to try contactless farming that are driving sales, given the pandemic. The government is working with farmers with small farms as well as large landowners to help them achieve higher yields and higher profits. The initiative also offers services to urban growers exploring the joys of hydroponics, vertical farming, roof gardens, and organic and greenhouse farming (Agarwal, 2020).

3.1. Impact of COVID-19 on IoT Market

The COVID-19 pandemic has adversely affected agriculture, causing a slowdown in production due to shutdowns and suspensions. In particular, the negative financial impact on farmers led to a decrease in non-essential expenditures and investments (Stephens et al., 2020). In this context, farmers and ranchers are watching the digitalization of agriculture, and this scenario is not expected to turn positive in the short term but is expected to change to positive in the next few years (Yoshida et al., 2019). The need for high production, limited resources, and skilled labor will drive agriculture to use IoT. In addition, government subsidies, declining IoT hardware prices, and advances in IoT technology will spur agricultural IoT mitigating COVID-19.

3.1.1. Comprehensive government initiatives

Many governments and organizations are focusing on applying precision farming techniques with easy access to data and analytical capabilities by launching awareness programs, reforms, and partnerships with the private sector to facilitate smart agriculture. It analyzes the potential of IoT applications in the food and agriculture sectors within the framework of the European Commission's 'Internet of Food and Farm 2020' project. In this context, the development of smart agriculture that reduces the negative effects of the pandemic and the granting of government support to farmers encourage the growth of this market.

3.1.2. Food demand increase

It is expected that the world's population will reach 9.8 billion by 2050, and it is going to increase by about 83 million each year. Agricultural land per capita is decreasing. This will cause food demand and it is expected to rise from 59% in 2019 to 98% by 2050.Thus prompting precision farming, and the adoption of new digital are requirements.

3.1.3. Precision agriculture

Precision farming is a farming management technique based on observing and measuring the in-field production variability of the crops grown while feeding the animals in the pastures and making the necessary interventions. Precision agriculture helps farmers with improvement measures related to yield, profitability, suitable working conditions, animal welfare, and natural environment management.

In addition, farmers describe the use of fertilizers, chemicals, water, and other inputs to be applied proportionally in the field without manual intervention using variable rate application methods to apply fertilizer spatially in precision agriculture. Easy accessibility and smart system integration are demanded in two stages the sensor-driven approach and the map-loaded controller approach. The adoption of smart agriculture with IoT in the COVID-19 era enables farmers to work in safe conditions (Igor, 2018).

3.2. Troubleshooting with IoT in Agriculture

The COVID-19 pandemic has distanced itself from mundane business and forced closures, with minimal activities and containment other than just food supply operations. During the pandemic, the outlook for 2020 was positive for wheat and other core commodities, with global grain supply at manageable levels, but remains unclear due to lock-ins and disruptions in the value chain of these high-value products. With the global situation of the pandemic, the probability of transition to innovation for safe operations in the agricultural sector seems high (Laborde and Parent, 2020). IoT-based smart applications in agriculture are a clean and sustainable high-tech system that will enable manufacturers to increase farm productivity through the use of fertilizers (Akhtar et al., 2021).

Today, various irrigation techniques work with electricity and reduce dependence on air. The water level indicator mounted on the water tank manages the soil sensitivity detection information in the root zone of the plant with soil moisture sensors and transmits the data to the processor (Chaowanan et al., 2020). In addition, value-added products should be given importance with the use of IoT in agriculture. Cold storage should be installed near the farm/production as they will minimize product and food loss. In the pandemic, this allows farmers to monitor the value of their wares and mitigate damage (Adejumo and Adebiyi, 2020).

The scope of the IoT market in agriculture differs from country to country. This is due to the speed of technological development. In North America, companies are gaining advantages by using IoT agricultural applications of 5G and cloud computing technologies to increase agricultural production (OECD, 2020). Embedded agricultural IoT applications have accelerated the growth of the agricultural IoT market in North America.

Increasing government initiatives towards digitization in the Asia Pacific, the strong trend of businesses and governments to store and process data locally, and the growing adoption of agricultural IoT by farmers in the region are helping the global agricultural IoT market record the fastest growth (Otero, 2020).

As a result, the IoT-supported agriculture system is implemented in the pandemic, that is, technological innovations are brought to the agricultural sector that support the farmer and increase the product quality, production volume, and profitability of an enterprise (Köksal and Tekinerdoğan, 2019).

4. CONCLUSION

IoT can boost the effectiveness of agricultural and rural sector activities by automating more human tasks. IoT, a basic subset of things to come online, combines information in general and devices connected to the internet. IoT aims to automate processes by minimizing human interaction. During the robotization phase, IoT uses actuators to finish the mechanization operations by transferring information from sensors through regulators.

To attain maximum productivity, modern agriculture requires regular monitoring of the seeds, animals, and equipment. There is a lot of opportunity for IoT integration in agriculture. It transforms the way we manage our farms, raise cattle, and cultivate crops. Additionally, today's farmers are attempting to reconcile the dwindling amount of arable land with the depletion of limited natural resources. By utilizing the power of connected devices, sensors, and data analytics, farmers can maximize resource consumption, increase production, and make data-driven decisions to ensure sustainable and effective agricultural operations.

Smart farming achieves extraordinary outcomes by going much beyond the usual method. It increases crop yields, lowers operating costs, and maximizes resource use. protection. The technology that can enable all of these systems is built on the foundation of IoT solutions. Given the quarantine and limitations in place all across the world, the pandemic has resulted in a slight drop in the growth of agriculture. Farmers should resume production after this quarter and utilize agricultural IoT solutions for varied crops to their fullest potential. Farms should aim to reduce the number of simultaneous workers because doing so will promote the use of agricultural IoT technologies. The service market for IoT solutions for agriculture is anticipated to benefit from this. Additionally, as farmers start to make data-driven decisions to expand their enterprises more quickly, the utilization of agricultural IoT software solutions, principally classified as data analytics and management, is anticipated to rise even higher in the pandemic.

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