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**Öğr. Gör. Dr. Nebi SEREN**

**Prof. Dr. Ahmet TURHAN**

Sefa Salih BİLİRİCİ
Yayın Grup Başkanı

05/11/2024

**Konu:** Kabul Mektubu

***Say****ın Nebi SEREN ve Ahmet TURHAN*

Yayınevimize göndermiş olduğunuz **UTILIZATION OF DIGITAL AGRICULTURAL TECHNOLOGIES IN GREENHOUSE CULTIVATION**başlıklı bölüm, Aralık 2024 yayın döneminde yayınlanacak olan CONTEMPORARY RESEARCH IN ENGINEERING AND APPLIED SCIENCES adlı kitapta yayınlanmak üzere kabul edilmiştir.

Katkılarınıza teşekkür eder, çalışmalarınızda başarılar dileriz.

Seda Salih BİLDİRİCİ
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**30 Ekim 2023**

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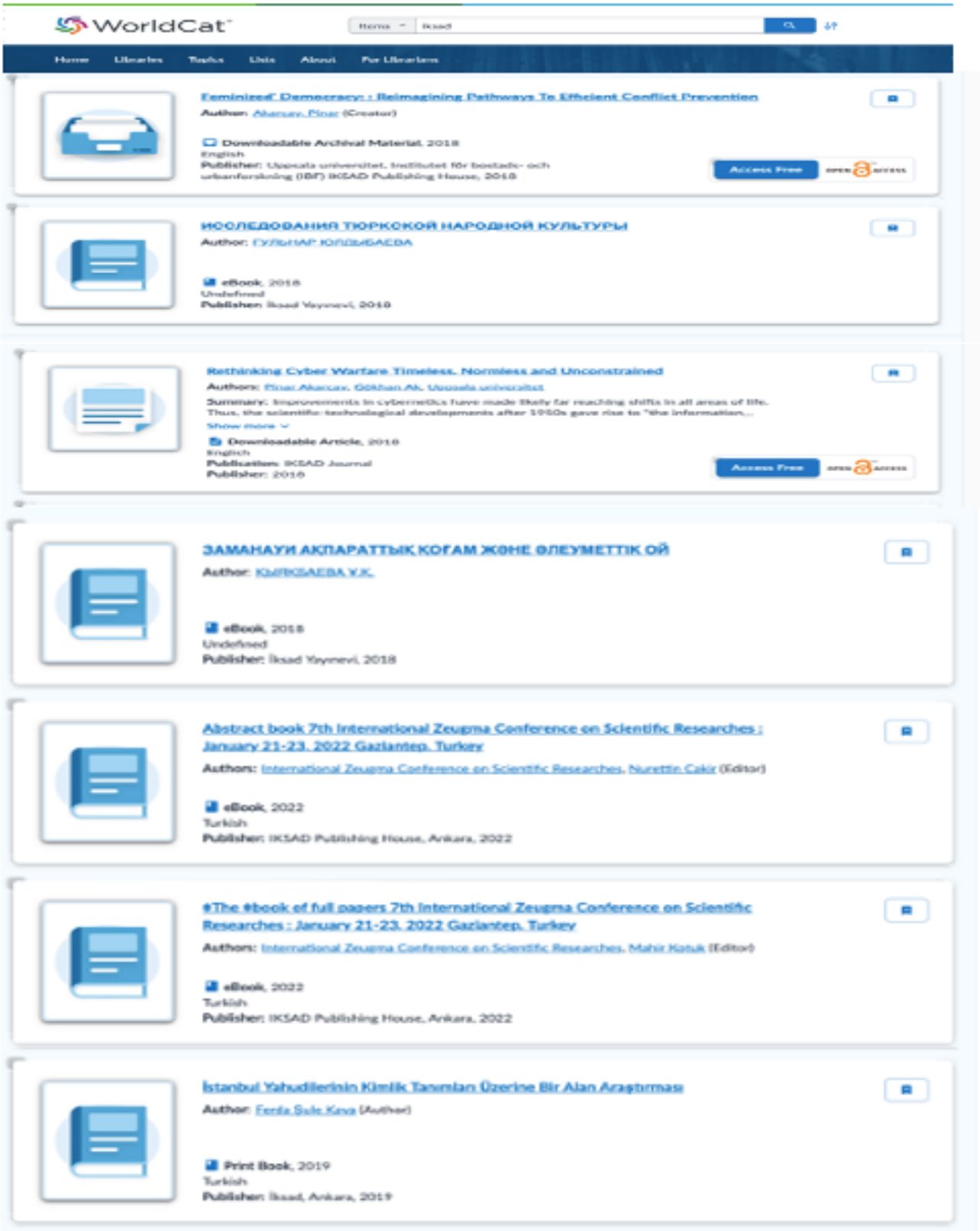
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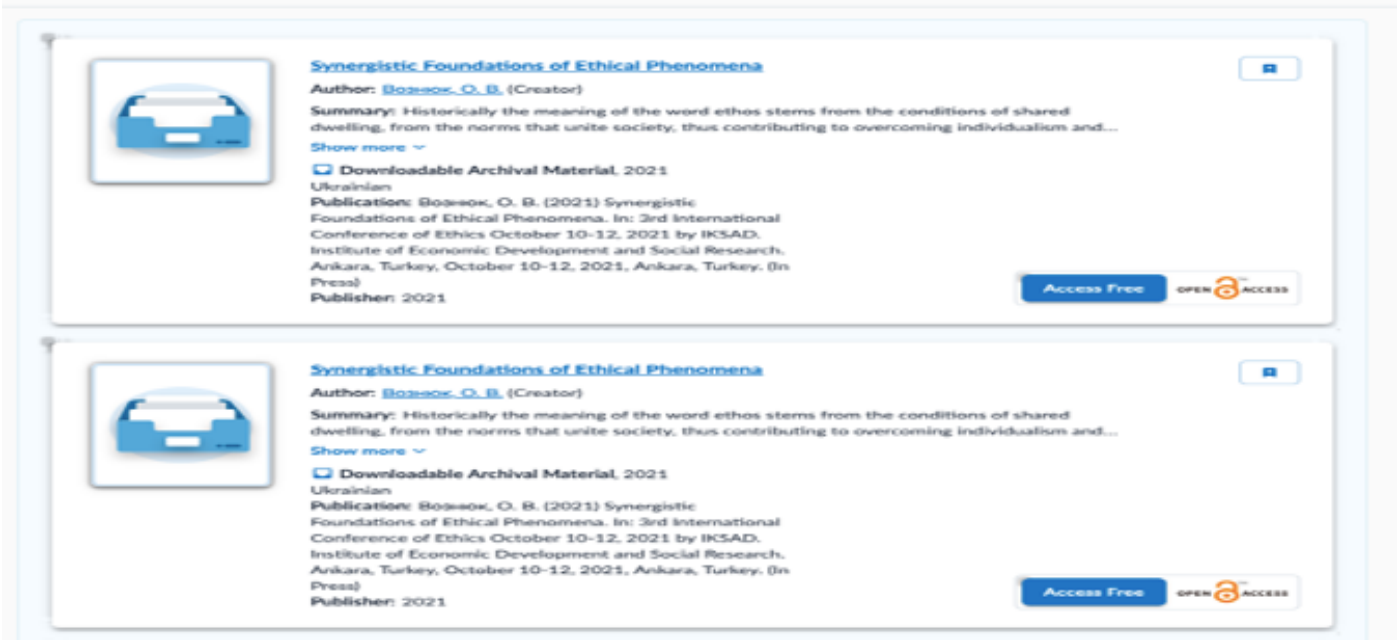
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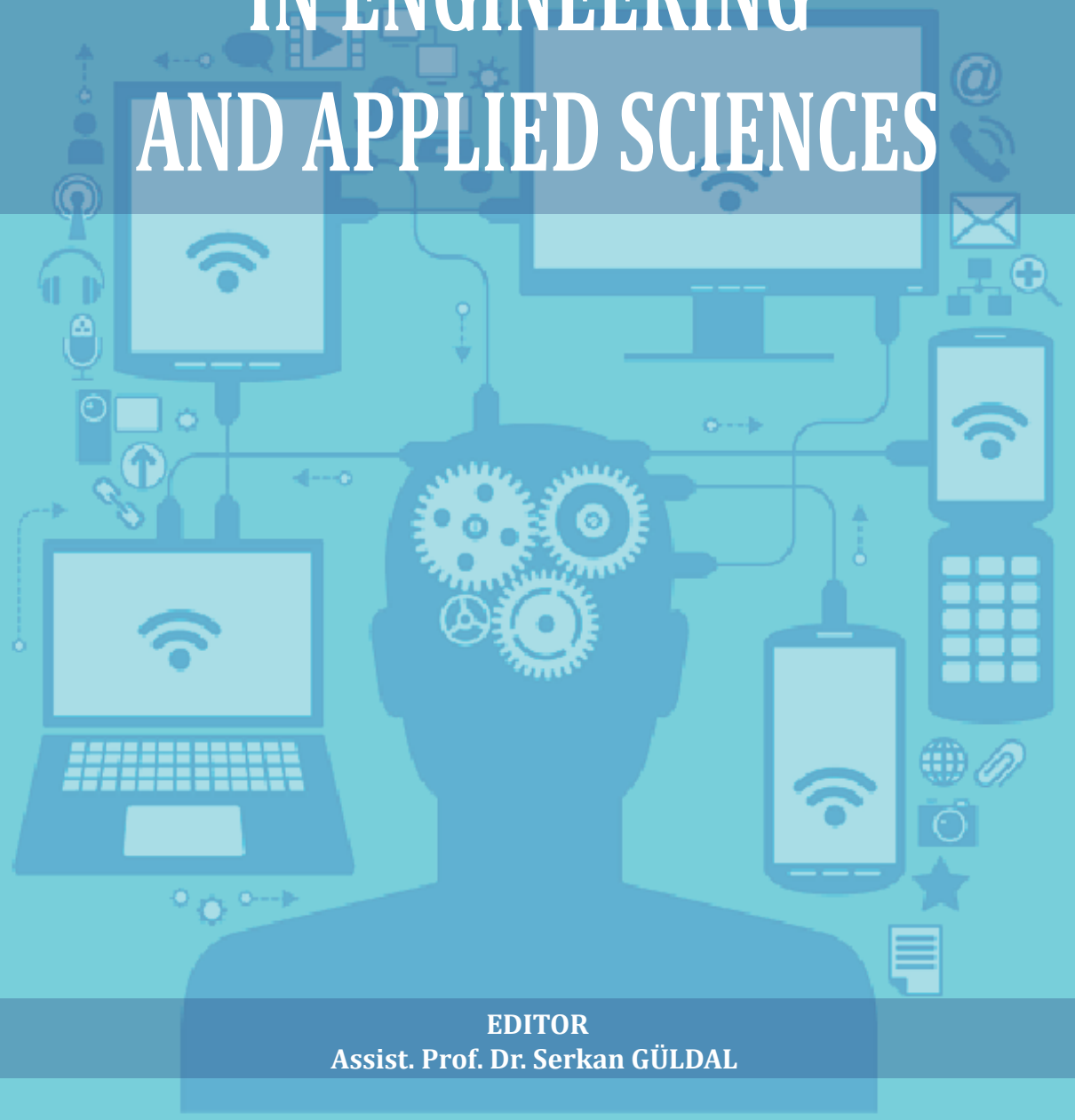
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# CONTEMPORARY RESEARCH IN ENGINEERING AND APPLIED SCIENCES



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# CONTEMPORARY RESEARCH IN ENGINEERING AND APPLIED SCIENCES


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## PREFACE

Dear Readers,

It is with great pleasure that I present to you this compilation of insightful chapters that delve into the pressing issues of our time, encompassing advancements in technology, environmental sustainability, and innovative methodologies in various fields. This book is a testament to the collaborative efforts of esteemed authors and researchers who have dedicated their expertise to contribute to the ongoing discourse in their respective domains.

In the first chapter, **"Utilization of Digital Agricultural Technologies in Greenhouse Cultivation: A Necessity in Modern Times,"** the authors explore the transformative impact of digital technologies on agricultural practices, particularly in greenhouse cultivation. Their findings underscore the importance of integrating smart technologies to enhance productivity and sustainability in agriculture, addressing the challenges posed by a growing global population.

The second chapter, **"Investigation of High Pass Filter Circuit Using Only MOS Transistor,"** presents a novel approach to circuit design, showcasing the potential of MOS transistors in creating efficient high-pass filter circuits. This work not only contributes to the field of electronics but also opens avenues for further research and development in integrated circuit design.

In the third chapter, **"Multi-Objective Optimization: Non-Dominated Sorting Genetic Algorithm II (NSGA II),"** the author provides a comprehensive overview of multi-objective optimization techniques, particularly the NSGA-II algorithm. This chapter is essential for researchers and practitioners seeking to navigate the complexities of optimizing multiple conflicting objectives in various applications.

Lastly, the chapter titled **"Determination of Suleyman Demirel University Students' Level of Social Acceptance of Renewable Energy Resources Use and Investment"** sheds light on the critical role of social acceptance in the transition to renewable energy. The insights gained from this research are invaluable for policymakers and educators aiming to foster a more sustainable future.

It is important to note that the ideas and materials presented in each chapter are the sole responsibility of the respective authors. Furthermore, the publisher does not assume any responsibility for the content or accuracy of the information provided. The contributions reflect the individual research and perspectives of the authors, and readers are encouraged to critically evaluate the information presented.

I would like to extend my heartfelt gratitude to all the contributors for their hard work and dedication in bringing this book to fruition. Your commitment to advancing knowledge and understanding in your fields is truly commendable. I also wish to thank ISPEC PUBLICATION for their support in publishing this work. Additionally, I would like to thank our readers for your interest and engagement with this important work. It is my hope that the insights shared within these pages will inspire further research, discussion, and action towards a more sustainable and technologically advanced future.

Thank you for joining us on this journey of exploration and discovery.

Respectfully,

Serkan Güldal

Lead Editor

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# CHAPTER 1

## UTILIZATION OF DIGITAL AGRICULTURAL TECHNOLOGIES IN GREENHOUSE CULTIVATION

Dr. Nebi SEREN[1]

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## INTRODUCTION

Technological advances have significantly facilitated various agricultural processes by providing alternative solutions to existing problems and ensuring precise and timely execution of production and applications. It has also contributed considerably to efficient, productive, high-quality agricultural production. The rising global population and decreasing agricultural land have made technology essential to meet the increasing food demand. With technological development, producers have started obtaining higher yields and better-quality products from the same unit area (Kılavuz and Erdem, 2019; Özgüven, 2023).

Smart greenhouses are an agricultural innovation that merges technology with farming (Soheli et al., 2022). Smart agricultural technologies aim to apply the right amount of input to the right place at the right time using appropriate methods, thereby increasing plant production. The smart farming revolution can address the challenges faced in traditional agriculture (Abdel-Fattah et al., 2021). Different crops have unique requirements for their growing environment, including temperature, humidity, light, and other factors. With smart agricultural greenhouse control systems, we can optimize the growing environment according to the needs of various crops, thereby enhancing growth efficiency. Consequently, the advent of smart agriculture has increasingly become a necessity in modern times (Sundmaeker et al., 2016; Wang, 2024).

Digital agriculture applications involve the real-time collection of information and data from agricultural fields using various sensors, cameras, or systems. These data are transmitted to develop software to analyze, store, and manage data-driven processes (Özgüven, 2023). The concept of digital agriculture is often confused with precision agriculture technology. Precision agriculture applications generally suggest field farming because the sensors, devices, equipment, and

systems developed for precision agriculture are more suitable for field farming, where precision agriculture is most intensively used (Özgüven, 2023).

Technological advancements have also manifested in greenhouse farming, leading to the increased use of greenhouse automation systems. Producers must adjust environmental factors inside the greenhouse according to the needs of their crops. Providing the greenhouse climate more accurately and efficiently with artificial setups is possible (Öz et al., 2008). Greenhouse automation refers to the system architecture that uses sensors and electronic units placed at various points within the greenhouse to monitor and control factors like temperature, light, soil moisture percentage, internal humidity, and fertilizer levels via a computer program (Ciğer, 2010; Latha, 2016; Arıcı, 1999). Additionally, smart systems, machines, and objects that communicate with each other and have internet access can increase efficiency and enable more effective use of energy, water, fertilizer, and resources (Dayıoğlu et al., 2016). Ciğer (2010) defined automation as a method where the production process, controlled by electronic equipment from the processing of input material to the output product, is integrated among industrial equipment.

## 1. SMART GREENHOUSE AUTOMATION AND MONITORING OF GROWING CONDITIONS

The primary goal of greenhouse cultivation is to create the most favorable environmental conditions for the plants produced in the greenhouse, ensuring their growth is highly controlled and free from adverse conditions. Since it is impossible to control natural ecological conditions, it is easier to control the climate conditions inside the greenhouse. When managing the climate inside a greenhouse, the greenhouse volume should be large enough to give the impression that the plants are in a natural environment. This leads to increased growth

and productivity. Ventilation, heating, cooling, and lighting are the most critical greenhouse design factors. (Öneş, 1990; Arıcı, 1999).

Smart greenhouses are an advanced farming method that plays a crucial role in the future of modern agriculture. These greenhouses use a range of automation, control systems, and sensors to optimize plant cultivation, save energy and water, monitor and enhance plant health, and simplify operational processes (Kesercioğlu et al., 2023). Öz et al. (2008) reported that smart greenhouses (heating, cooling, irrigation, fertilization, lighting, and ventilation) automatically control systems. In this way, it can achieve the optimum conditions desired by the plants.

### 1.1. Heating and Cooling Systems

Temperature plays a significant role in the growth and development of plants inside the greenhouse. Both very low and high temperatures harm plants; low temperatures limit plant growth, while high temperatures cause wilting. Therefore, temperature is a leading parameter in greenhouse control (Siddiqui et al., 2017). Plants commonly grown in greenhouses are typically adapted to average temperatures between 17-27°C. Hence, the optimal internal greenhouse temperatures should be between 15-20°C at night and 22-28°C during the day (Büyüktaş, 2023). Generally, greenhouses need heating when the average outside temperature is below 15°C. When the average outside temperature is below 27°C, natural ventilation will prevent extreme internal temperatures; artificial cooling methods (fog, fan-pad, shading) become essential when temperatures exceed this value to maintain product quality. The internal temperature should not reach 30-35°C for extended periods. The control of ventilation windows should not be abrupt, as sudden climate changes inside the greenhouse can stress plants. Greenhouse heating is achieved using various systems based on the cultivation method, crop pattern, and climate conditions. When the internal temperature drops to 17°C, the heating system automatically starts operating and stops when the desired temperature is

reached, thus providing a continuous cycle between the set temperatures (Öz et al., 2008). It is economically advisable to keep nighttime temperatures at a minimum of 15°C and daytime temperatures between 22-26°C (Kürklü and Çağlayan, 2005).

Modern greenhouses control temperature variations using well-planned heating systems. The energy required for greenhouse heating is determined by the heat which greenhouse needs per unit of time. Factors like greenhouse volume, the requirements of the plants to be grown, cultivation times, ventilation rates, surface area, covering material, local weather conditions, and potential heat leaks are considered in heating. The success of heating automation depends on the system's response when the greenhouse needs rapid heating (Titiz, 2004).

### 1.2. Irrigation Systems

Smart agricultural applications provide significant convenience and advantages in efficient water use and management in agricultural irrigation. Studies have utilized soil moisture sensors, IoT-based dynamic irrigation planning systems, machine learning models, and artificial intelligence techniques to determine irrigation needs and improve irrigation processes. These applications have not only saved water but also increased crop productivity. These advancements in water management are crucial for addressing the challenges related to water resources in the agriculture sector. Greenhouse plants are sensitive to irrigation water's pH and EC balance, affecting plant response. Therefore, it is critical to check the pH and EC balance of the water before irrigation and fertilization to ensure plant health and productivity. Accurate and precise measurements are essential. Knowing the pH, EC, weight, and total drainage values before each irrigation ensures correct and appropriate feeding each time. All sectors need automatic measuring devices for this purpose.

In automatic irrigation systems, irrigation programs can determine the amount and duration of irrigation and irrigation timing. Different programs are created according to the plant type or water requirement and stored in the computer memory for later use. Thus, controlled and economical water use is provided (Oz et al., 2008). (Öz et al., 2008). Information obtained through Wi-Fi-connected moisture sensors placed in cultivation areas enables better water management, resulting in water conservation. Users can also monitor the processes remotely from their homes or other locations (Ray, 2017).

Furthermore, water quality can be measured using sensor nodes with wireless network communication (Paventhan et al., 2012). IoT allows real-time water quality monitoring, including conductivity, water temperature, pH, turbidity, and dissolved oxygen (Ray, 2017). Recent technological advancements in agricultural activities have introduced new irrigation methods for reduced water usage and real-time weather forecasts (Ray, 2017).

### 1.3. Ventilation Systems

In the greenhouse, after absorbing the non-reflected solar radiation, some of this absorbed energy is used as latent heat for evaporation. At the same time, the rest increases the temperature of the environment. The hot air inside needs to be replaced with cooler outside air at specific rates and periods before reaching dangerous levels for plants. The internal temperature should not exceed 30°C even on the hottest days. Good ventilation can lower the internal temperature. Proper ventilation also helps maintain the desired humidity levels and ensures adequate $CO_2$ levels by preventing depletion (Kürklü et al., 2005). Long-term relative humidity above 80%, especially at night, accelerates the spread of fungal diseases. Adjusting the vapor pressure balance inside the greenhouse regulates transpiration and reduces disease problems. If greenhouses are not heated at night, the inside and outside temperatures become almost

equal, and if the outside humidity is high, it becomes difficult to reduce the inside moisture. (Yılmaz, 2013). When the temperature exceeds the desired level, windows automatically open for natural ventilation. A mechanical ventilation system activates to expel hot and humid air if natural ventilation is insufficient. This cycle continues constantly within the desired temperature range (Öz et al., 2008).

### 1.4. Fertilization Management

Fertilization in greenhouses is a fundamental aspect of successful plant cultivation. The quantity and form of fertilizer used, as well as the method of application, are crucial. When selecting the fertilization method, soil fertility, plant production system, and irrigation must be considered. Smart fertilization is a root zone management tool that directly provides suitable water and nutrient composition to the roots according to the crop development cycles. These systems, integrated with soil moisture sensors and weather data, deliver the required amount of water precisely when needed, ensuring water conservation. Designed by soilless and traditional farming methods, these systems prevent plant nutrient deficiencies by maintaining optimum nutrient solution levels (Anonymous, 2024).

Greenhouse areas are mostly far from residential areas due to their geographical location. Because of this distance, irrigation and fertilization can become quite challenging. Thus, automation systems are essential in cultivation areas. In agricultural fields equipped with automation systems, various sensors can measure and monitor all values related to plants. Additionally, data from the agricultural area can be recorded for retrospective analysis and reporting. One of the system's key features is the fertilization unit, which allows fertilization with desired values similar to the irrigation method on the applied field. This ensures that plants receive their necessary minerals and water regularly. The amount of fertilizer needed for each plant is determined using weight sensors integrated into the system, allowing plant-specific

fertilization amounts. The agricultural automation system also aims to inform the user. Notifications are generated within the system and emailed to inform users about system activation, real-time changes, and unexpected errors.

Furthermore, instant information can be accessed using the designed mobile application. The system can operate manually and automatically, and remote control options are provided. The manual mode system can operate at any time and day for application, irrigation, and fertilization. In automatic mode, irrigation decisions are made based on data from the sensors, eliminating the need to visit the greenhouse for irrigation and fertilization, thereby reducing the human workload in agriculture. Time-focused irrigation ensures regular watering, increasing efficiency and preventing water waste. The fertilization system prevents over-fertilization, posing significant problems for plants and soil (Kurt et al., 2022).

### 1.5. Disease, Pest, and Weed Control

Greenhouse-grown plants grow faster and healthier. During this period, the primary factor affecting plant productivity is the inability to diagnose diseases quickly. When diagnosis is delayed, the disease spreads over a wide area. If these factors are detected quickly and necessary precautions are taken, plant productivity and quality will increase. Currently, the leaves of diseased plants are collected and identified in laboratory conditions, which prolongs the process and delays treatment. Instead of evaluating a single sample, continuous observation of the entire plant development process and prompt intervention is a more accurate option. This requires using real-time deep learning-based methods with the highest accuracy (Karakan, 2022).

A pheromone trap system attracts pests and insects in the greenhouse and processes photos taken at specific times with artificial intelligence to detect, count, and report pests automatically. The types and numbers of pests can be tracked metrically via the web panel, and necessary warnings can be made automatically. Balanced use of pesticides and fertilizers helps improve quality and minimize input costs. Controlled use can predict potential plant damage by collecting data via IoT-based sensor nodes (Ray, 2017). IoT and smart systems can evaluate plant diseases, pests, and weeds at early stages and inform farmers using smart tools to eliminate pests and pathogens with precision targeting. Autonomous weeding, precise weed management, weed detection, weed control, robotic arms, smart spraying, and inter-row weed cleaning can be done using computer vision and artificial intelligence (Natu and Kulkarni, 2016; Sujaritha et al., 2017; Partel et al., 2019).

## 2. SENSORS AND MONITORING SYSTEMS

Greenhouses have sensors that constantly monitor data such as air temperature, humidity, soil moisture, and sunlight. This data facilitates monitoring plant health and growth conditions (Öz et al., 2008). Precise monitoring of the interior environment of a greenhouse is only possible by intelligently selecting and strategically deploying sensors. Only in this way can comprehensive and accurate detection of environmental parameters in various regions of the greenhouse be achieved (Wang, 2024). Sensors in smart remote sensing systems are responsible for measuring and monitoring all desired factors (Karaman, 2022). Different sensors can monitor soil moisture levels, pH values, irrigation system control, plant growth, disease and pest detection, and weather conditions. The collected data is analyzed to provide meaningful information about plant health, environmental conditions, and other factors, enabling rapid intervention and continuous optimization (Kumar et al., 2021; Öz et al., 2008).

To obtain comprehensive environmental data, temperature, light, and humidity sensors are evenly distributed throughout the greenhouse. Light sensors are strategically positioned to detect changes in light and allow real-time monitoring of light conditions. Temperature-humidity sensors are used to measure air temperature and humidity at two-hour intervals during the day and four-hour intervals at night. When levels exceed/fall below desired levels, the microcontroller sends corresponding signals to the interface device. The microcontroller is programmed to activate the heating system when the temperature drops below the desired level. The cooling system will activate if the temperature is detected above the desired level. In other words, if the temperature falls below the desired level, the heater will activate to increase the temperature and automatically stop working when the temperature reaches the desired range. It also uses various sensors to collect environmental information, such as temperature, humidity, pressure, wind speed, precipitation, and location. (Li-Ying, 2016; Hua, 2014; Harshit et al., 2019; Özgüven, 2023).

Optical, mechanical, electrochemical, airflow, and position sensors are becoming more widespread. Image recognition is one of the most critical areas. Sensors can provide images that allow farmers to make appropriate and more informed decisions at the right time and to be warned early about diseases and pests. At the same time, smart monitoring offers the possibility of optimizing harvest, monitoring plant quality characteristics, and increasing income (Goedde et al., 2020).

Automatic monitoring systems are essential in smart digital farming, allowing farmers to make and implement quick and accurate decisions at the right time. In precision and digital agriculture, the real-time monitoring and measurement of parameters such as air and greenhouse gas monitoring, plant monitoring, soil monitoring, water quality, and irrigation parameters, as well as soil parameters like

temperature, humidity, conductivity, pH value, and nutrient content, are crucial for sustainable agricultural management. To measure these parameters in real-time, IoT sensors, data analysis, decision support systems, and artificial intelligence must be used in a coordinated manner (Çakmakçı and Çakmakçı, 2023).

The soil moisture sensor periodically measures the volumetric water potential in the soil and reports it to the control system. It monitors soil moisture content, controls irrigation in greenhouses, and measures moisture loss over time due to evaporation for various plant species. The soil moisture sensor reminds the user to irrigate greenhouse plants and monitor soil moisture content. The microcontroller sends a signal to the relevant devices to turn the pump on/off to meet the requirements based on the soil condition signal. When soil wetness reaches a threshold level, the microcontroller sends a signal to turn off the pump via reliable interface devices. There is a fixed moisture sensor to measure the moisture in the soil. If there is not enough water in the soil (<70%), the pump automatically starts supplying water until it reaches the threshold value. On the other hand, when the moisture level reaches the desired level, the pump will automatically stop working (Soheli et al., 2022).

The sensor camera and data analytics provided continuous feedback on plant health and growth status, aiding harvest timing and crop quality. This allows farmers to make better decisions and use resources more effectively. (Kesercioğlu et al., 2023). Sensors can also automatically collect data for pest control, such as detecting the presence of pests or determining when a trap is activated by catching a pest (Friha et al., 2021). According to Yue et al. (2018), advanced high-resolution sensors significantly improve smart pest detection.

Smart sensors, robotics, region-based convolutional neural networks (R-ESA), UAVs, IoT devices, artificial intelligence, and machine learning-based computer vision techniques can help achieve

sustainable production with lower-cost production, less labor, reduced harvest costs, yield optimization, and increased productivity (Horng et al., 2020; Zhang et al., 2020; Sharma et al., 2022).

## 3. SMART GREENHOUSE BASED ON IOT TECHNOLOGY

One of the ways to make a greenhouse (smart) is to integrate IoT (Internet of Things) technology (Dagar et al., 2018). Smart farming uses IoT technology to maximize agricultural productivity and ensure the most efficient use of resources by reducing operational costs. Special equipment, wireless connectivity, software, and computer technologies are part of the IoT (Samaila et al., 2018). IoT technology offers unconventional and practical solutions in many areas, including smart agriculture, and has promising potential. In agriculture, IoT technology has made significant advances in agricultural management. This technology ensures that all agricultural devices and equipment work together in an integrated manner in irrigation and fertilization processes (Kumar and Periasamy, 2022). Wireless sensor networks (WSNs) collect data from different sensing devices. In addition, it is emphasized that cloud services should be integrated with IoT to analyze and process the data collected by the remote sensing system (Farooq et al., 2020; Alaboz et al., 2022). To dominate the cultivated area with IoT technology, ICT (Information Communication Technology), ground sensors, and remote sensing systems should be integrated with robots, autonomous vehicles, and other automatic devices (Belal et al., 2020).

According to Akkas and Sokullu (2017), interconnected computing devices, sensors, objects, microcontrollers, and cloud servers that can transfer and control data over a network can be remotely controlled without human intervention to other devices. Sensors capture data inside and outside the greenhouse and automatically transmit it to a central cloud server for storage. End-user devices can access this data, and the information generated about their

crops, appropriate harvest time, energy consumption, etc., can be used (Gomes et al., 2015). In addition, cloud endpoints can be used to store data for faster processing. IoT sensors and infrastructures can monitor and control the conditions of the environment. The integrated IoT cloud server allows it to process data remotely and control IoT infrastructures such as irrigation valves and window openers. The IoT cloud server will enable farmers to monitor and control via mobile devices instead of manual monitoring. As a result, IoT-enabled greenhouse farming allows farmers to plant multiple crops in favorable seasons with minimal human effort, increasing productivity and reducing labor costs (Jumaah et al., 2021; Hosny et al., 2024).

An IoT-based automated smart greenhouse is a system designed to automate the management of greenhouse cultivation. The system integrates IoT-based remote sensing technologies, AI-based decision support systems, and advanced data analytics tools to manage climate control, irrigation, fertilization, and pest control processes. By leveraging real-time data from a network of sensors, the smart greenhouse system adjusts environmental parameters such as temperature, humidity, light, and soil moisture to create optimal plant growth conditions. The system can also predict potential issues, provide early warnings, and suggest preventive measures based on historical data and predictive modeling. This approach ensures efficient resource utilization, minimizes human intervention, and enhances crop yield and quality. Implementing IoT-based automated smart greenhouses represents a significant advancement in precision agriculture, contributing to sustainable farming practices and food security (Meng et al., 2021).

When discussing the use of IoT in greenhouse automation, it is necessary to first touch on how the need arose. Danita et al. (2018) defined greenhouses as climate-controlled structures with walls and roofs specially designed for the off-season cultivation of plants.

Researchers have stated that most greenhouse systems use manual systems to monitor temperature and humidity, which can be uncomfortable for workers. Greenhouse workers visit the greenhouse daily and manually monitor the environment (such as temperature and humidity) to ensure the productivity of the plants. At this point, it has been reported that using IoT and, therefore, the automation of greenhouse systems can solve some problems without any human intervention (Subahi and Bouazza, 2020).

Although IoT has been a technological phenomenon studied recently, it is not a standard application. The difficulties encountered in obtaining IoT structure are also included in the literature. Lucero (2016) describes these difficulties in his study: managing complexity, creating and maintaining reliable connections, ensuring data security and privacy, making the best use of data, and enabling an open IoT ecosystem.

## 4. CONCLUSION

Greenhouse farming in Turkey has not yet gained its thoroughly modern identity. In Turkey, greenhouses equipped with modern systems and found in developed countries are few. In particular, failure to regularly control the temperature and humidity of the greenhouse indoor air causes negative results. The most crucial criterion for increasing plant productivity is to achieve optimum growing conditions. Using digital agricultural applications in greenhouse plant cultivation has improved agricultural processes and maximized operational efficiency. There is a greater need for scientific and technological developments to cope with the challenges encountered in greenhouse cultivation, which will increase in the future, and to increase efficiency. New technologies developed in recent years make processes more efficient. These technologies improve yield and quality, reduce costs, and increase irrigation and plant nutrient use efficiency. It can also reduce pollution caused by efficient, rational fertilization and

pesticide use. Remote control of critical climate variables in the greenhouse optimizes crop growth and contributes significantly to sustainable agricultural practices. Integrating remote sensing technologies into agriculture by solving cost issues can facilitate the sustainability of the greenhouse sector. Agricultural technology should be based on sustainability, reduce input requirements, facilitate applications, make high use of agricultural biology, and be respectful and reliable to nature, humans, and resources such as soil, the environment, and water. Future work should optimize greenhouse management, continuously monitor technological developments, and, as a result, bring more advanced data analysis and machine learning algorithms to the sector.

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