GU J Sci, Part C, 10(2): 360-367 (2022)

Gazi University

Journal of Science

PART C: DESIGN AND TECHNOLOGY

http://dergipark.gov.tr/gujsc

Irrigatıon in Agriculture and Automation Based Irrigation Systems (Mini-Review)

Mustafa ARIK[1,*] İhsan KORKUT[1]

[1]Gazi University, Faculty of Technology, Department of Manufacturing Engineering, ANKARA/ TURKEY

Article Info

Review article
Received:25/04/2022
Revision:14/05/2022
Accepted:26/06/2022

Keywords

Irrıgatıon,
Agrıculture,
Smart system,
Automatıon,
Modern applications

Abstract

With the technological developments, modern agricultural applications and the effects of these applications in daily life are increasing day by day. Automation-based smart systems, which have replaced old-style fixed irrigation systems created for only a specific purpose, have brought along remote-controllable agricultural productions in line with agricultural product needs. Automation-based smart irrigation systems have brought significant gains to the agricultural sector. The most important of these gains are time, cost, and labor savings. This study tried to summarize the research on smart (automatic) irrigation systems in the last seven years and emphasize the necessity and advantages of automatic irrigation systems.

1. INTRODUCTION

It is predicted that the world population will increase rapidly, reaching 8 billion in 2025 and 9.15 billion in 2050. Parallel to this increase, it is estimated that the current population's food requirement will increase by 60% by 2025. To maintain vitality, agricultural production should be increased to meet the food demand that will increase in parallel with the population increase [1]. Researches and predictions show that in addition to the increasing food requirement, the population increase will increase the water requirement in the world and the clean water resources will gradually decrease. It is predicted that after 2030, there will be water scarcity across the world and this situation will cause significant water crises [2]. Existing clean water resources and arable land are of great importance in the production of agricultural products that are needed/will be needed. For this reason, it was understood that agricultural lands and water should be used efficiently to slow down the speed of the crisis scenario foreseen in the coming years.

Agricultural irrigation is the sector where freshwater resources are used the most, not only in Turkey but also in the world. Agricultural irrigation is carried out on 280 million hectares of land, which corresponds to 19% of the world's agricultural lands [1] Approximately 70% of freshwater resources are used for agricultural irrigation [3,4]. However, it is reported that the share of clean water resources allocated for agricultural production is gradually decreasing with the increasing need for drinking water worldwide [5]. Considering the increasing population, increasing food needs, and climate change, it is seen that the most important natural resource necessary for human life is water [6]. As a result, more effective and efficient use of water allocated for agriculture is becoming increasingly important [7].

The socio-economic development of Turkey and the decrease in migration from rural areas to cities significantly depend on the increase in productivity in agricultural production. The increase in productivity in agricultural production is directly related to developments in the agricultural sector and agricultural irrigation efficiency. Turkey has in total $28x10^6$ hectares of agricultural land. $25.8x10^6$ hectares of this land is an irrigable specialty. It is known that Turkey has a water potential of $112x10^9$ m^3/year. These potential existing water resources are used to meet drinking, irrigation, and industrial needs [8]. Unless the current

*Corresponding author, e-mail: arikmustafa372@gmail.com
DOI:10.29109/gujsc.1108504

irrigation technologies are improved, it is predicted that only $8.6x10^6$ ha area of water resources that can be used for irrigation in agriculture can be irrigated [9]. Therefore, in our country, it is necessary to develop new strategies for the management of usable water in the agricultural sector, the design of new irrigation systems, and irrigation planning [10,11].

The irrigation system refers to how water is delivered to the soil i.e. the plant's root zone. There are two types of irrigation systems: surface irrigation (wild) and pressure irrigation. Drip irrigation and sprinkler irrigation systems are examples of pressure irrigation systems. It is well understood that pressure irrigation techniques allow for more efficient water use in agricultural irrigation. Approximately 85% of the irrigated agricultural areas in the world are irrigated by wild irrigation and 15% (44 million ha) are irrigated using pressurized irrigation methods [12,13]. In addition, sprinkler irrigation is used in 35 million hectares of irrigated agricultural areas worldwide, while drip irrigation is used in 9 million hectares [13].

Sprinkler irrigation system, in its most basic form, is an irrigation technique in which water from any water source, such as a river, canal, or well, is conveyed to sprinkler heads under pressure via closed pipes and then sprayed to the plants as uniformly [14]. The following are the primary reasons for the widespread use of sprinkler irrigation systems in agricultural irrigation:

(i). Since irrigation water is transmitted through closed pipes, water transmission losses are eliminated.
(ii). System performance is high in all soils except heavy soils with excessive clay content.
(iii). The water application efficiency is high with good management.
(iv). It provides an increase in plant product efficiency as water can be applied homogeneously to the plants.
(v). Even if there are suspension particles in the irrigation water, the probability of clogging in the irrigation system's nozzles is low.

However, it is also known that the performance of the sprinkler irrigation system depends on the selection of the right pump and power source, pipelines, and sprinkler heads [14]. Studies on the examination/development of the system parameters expressed to increase the sprinkler irrigation performance are continuing [4,15].

2. AUTOMATION BASED IRRIGATION SYSTEMS

Advances in technology have led to rapid progress in the agricultural sector, as in many areas today. Studies have started to be carried out to meet the increasing food needs in parallel with the increasing population and to ensure the efficient use of natural freshwater resources. In this context, the development and use of automation-based irrigation systems in agricultural production have gained importance.

Arif and Abbas (2015)[16] developed an Arduino-based greenhouse control system. It was reported that soil moisture, relative humidity, temperature, CO_2, and light measurements can be made successfully. By using a wireless sensor network, they automatically controlled the irrigation system required for the greenhouse. They reported that with the developed system, the workforce was reduced and remote control and monitoring were provided. In another study, the researchers who took temperature and humidity measurements from every point of the garden and evaluated the measurement data with the fuzzy logic method designed a Zigbee-based garden irrigation system [17]. An irrigation system was developed as a solar-powered plant [18]. System control was done with Arduino Uno. It was aimed to determine the optimum amount of water needed by the plant and to meet the water need of the plant efficiently. Thanks to the buttons on the LCD Shield, the plant type was reported to Arduino and the humidity rate was determined. Humidity was checked with Arduino Uno, when the humidity decreased, the photo was taken with Rapery-pi before watering the plant and sent to the e-mail of the grower. The plant was irrigated until the humidity reached the determined level. In case of the end of irrigation, the watered photo of the plant was taken with Rapery-pi again and sent to the e-mail of the grower. In the cited study, it was reported that the energy used was entirely provided by the solar panel.

Kopdra and Martin (2016)[19] carried out the design and application of a smart irrigation system with the help of an Arduino microcontroller. In the design, Arduino Yun, real-time clock DS1302, two humidity sensors, relay, and solenoid valve were used. A mobile application interface was developed for the control of the irrigation system. Java programming language was used for mobile application technology for remote control of irrigation. In this way, it was able to control from both phones and tablets. Mritunjay et al. (2016) [20], the main purpose of their work was to prevent negative situations that may arise from forgetfulness and to contribute to the pleasure of growing plants. In this study, it was conducted studies on the irrigation of potted plants. Desing the sprinkler irrigation system was used Arduino board. The Arduino board was programmed to sense the humidity level of the plants and supply water when needed. The system was coded to irrigate twice a day. The software, which reminds the user to refill in case the water tank was empty, was designed to help the user. Kavianand et al (2016)[21] designed a fully automatic irrigation system. The designed system consisted of GSM, ARM processors, soil moisture sensor, soil pH sensor, and drip irrigation system. A solenoid valve was used for irrigation system control. When soil fertilizer was added to the irrigation system, not only soil moisture but also soil pH were taken into account in controlling the irrigation system. In addition, a comparison of the sprinkler irrigation system and the system in terms of water consumption was made in the study. It was emphasized that the designed system consumes less water. It was reported that there was no need for manpower in the designed system. Patil et al. (2016)[22] designed an irrigation system using Arduino Uno. In this designed system, Arduino, Arduino compatible Ethernet shield, and Arduino compatible motor shield were used. In general, soil moisture in the system was measured with a soil moisture sensor. The measured humidity value was evaluated by Arduino. If it was below a predetermined threshold value, the servo motor was started and irrigation was started. When the moisture value of the soil was exceeded the threshold value, the servo motor was turned off and irrigation was finished. All these operations and instant humidity value information were present to the user via the Ethernet shield.

Karaca et al. (2017)[23] investigated moisture sensors, which were widely used in agricultural irrigation and were used to determine the amount of moisture in the soil. The importance of these sensors in terms of sustainable agriculture was determined. As a result of their research and examination, the researhers were seen that FDR-type soil moisture sensors were more widely used because of their low cost, but they have some disadvantages. They emphasized that farmers should be informed about the disadvantages of these sensors. Suman et al. (2017)[24] stated that the soil moisture level was critical for crop growth. For this purpose, the researchers conducted the necessary research to keep the soil moisture level under control. The researchers, created a development-ready automatic irrigation system, supported the system with rainwater collection technology, and smart wireless humidity sensors. Solar panels were used to improve the system's efficiency. In this paper, it was also mentioned that a smoke sensor can be added to prevent fires. Rehman et al. (2017)[25] stated that the deficiencies that occur with the manual irrigation method can be eliminated with the automatic irrigation method. In this study, it was stated that humidity sensors, temperature sensors, and soil moisture sensors were the most important elements for automatic irrigation systems. In the examined design, the GSM feature was used. The needed power was provided with solar panels. The motors were designed to start and stop automatically when the soil moisture was reached the lower or upper limit values determined by the user. When the motor started or stopped, the information was sent to the user via SMS. Thus, it was determined that the wasted water had decreased. Less margin of error was provided due to less labor. Due to solar energy, and uninterrupted electricity supply was provided. In another study, Kumar et al. (2017)[26] designed an automatic irrigation system using a microcontroller, temperature, and humidity sensor. A system was created that allows the temperature and humidity changes of the environment to be detected with the help of sensors and the pump to operate by sending a signal by the microcontroller. It was stated that the designed system was less costly than other systems. By using the developed system, it was stated that the farmers could irrigate overnight and there was no need for them to be physically present while irrigating. To more efficiently use water, Taneja and Bhatia (2017) [27] developed a new automatic irrigation system, using sensor technology together with Arduino. There were two humidity sensors in the designed system. These were the soil moisture sensor placed in the soil and the water level sensor placed in the water tank where water was pumped in irrigation. As a result, it was emphasized that automatic irrigation systems should be used to optimize the use of water resources.

Kizil et al. (2018) [28] experimentally investigated the calibration and data generation capabilities of resistive soil moisture sensors, which were easy to find and have low cost. While doing this study, they measured the decrease in the moisture content in the sand with the help of a sensor and compared these data with the weight reduction with the help of a specially designed device. As a result of these controlled experiments, the average regression coefficient was determined as 0.91, and it was emphasized that this value was statistically significant. García et al. (2018)[29] developed a model called the Intelligent Photovoltaic Irrigation Manager (SPIM), which powers irrigation systems with photovoltaics. SPIM was used to simulate the management of photovoltaic irrigation of an olive grove in southern Spain during the irrigation season of 2013. To operate the irrigation system efficiently; was used common climate, crop, hydraulic, and soil data. This irrigation system met the water needs of the crop during the irrigation season. When the irrigation was not sufficient, the system detected it and increased the irrigation time for the next days. In addition, it was reported that it prevents 1.2 tons of CO_2 emissions since only solar-generated electricity from the panels was used. Wazed et al. (2018) [30] conducted research on PV and solar thermal technologies to pump water for irrigation of remote rural farms. Studies were shown that the best way to optimize the cost and design of the PV-powered system was to conduct extensive field research to understand the crop requirements and analyze the operating conditions of the system. It was determined that the cost of the PV system was lower than other motorized systems, it was effective on environmental problems and reduced its carbon footprint. This study was shown that solar technology has great potential to meet the requirements of the small-scale rural farm. It was presented that the research on these systems was minimal and there was little data on feasibility. Yang et al. (2018) [31] proposed an IoT-based greenhouse system that uses cloud services for data storage and Hadoop for data analysis. In this greenhouse system, environmental data were collected from sensors such as humidity, temperature, amount of light, CO_2, O_2, O_3, NO_2. ESP8266 Wifi module, which uses TCP protocol, was used for sending data. Data stored in MySQL periodically were transferred to the cloud platform and analyzed with Hadoop HDFS. The analyzed data was presented to the end-user via the web and android interface. Aliev et al. (2018) [32] proposed an IoT-based system that detects temperature, humidity, and soil moisture as environmental parameters and also predicts the weather with neural network technique. STM32L476RG microcontroller was used to control the sensors and ESP-12 Wifi module was used for communication. The collected data was stored on the ThingSpeak cloud platform. The user accessed the sensor values using the Androidmobile application. In this study, high accuracy was obtained with the help of the neural network. Subashini et al. (2018) [33] developed an IoT-based smart agriculture system that monitors light intensity, air humidity, soil moisture, and temperature and provides automatic irrigation to the plant. The data received from the field was transmitted to the ThingSpeak web server by HTTP GET request by the ESP8266 Wifi module. The irrigation pump was connected to the microcontroller and operated automatically according to the sensor values. Goap et al. (2018a) [34] designed an open-source, technology-based smart system to predict the irrigation requirements of a field by sensing weather forecast data from the internet, as well as soil parameters such as soil moisture, soil temperature, and environmental conditions. The intelligence of the proposed system was based on an algorithm that considers the detected data along with forecast parameters such as precipitation, air temperature, humidity, and UV in the near future. A pilot-scale system was developed in which sensor node data was collected wirelessly over the cloud using web services. The system was a web-based information visualization and decision support system that provides analytics-based real-time information insights. In another study, a Raspberry Pi and Arduino-based system was developed to collect environmental data such as soil moisture, air temperature, humidity, ultraviolet (UV) in a rose garden. For the estimation of soil moisture value, MLR, ridge regression, weighted linear regression, and SVR models were created and evaluated with the data taken from the sensor. SVR was found to be the best model with an R^2 value of 0.9383 [35].

Sudharshan et al. (2019) [36] worked on automatic irrigation systems. They have used three important sensors in the system. These sensors; soil moisture sensor, humidity sensor, and temperature sensor. In the system was met the power needed from solar panels. Thanks to the fuzzy logic-based automatic smart irrigation system, was determined how often the land would be irrigated with the data, was received from various sensors such as humidity and DHT sensors. With the new irrigation system, significant resource savings were achieved and the need for manpower was reduced. Kang et al. (2019) [37] investigated the relationship between root growth and correct volumetric water content. Lettuce seedlings were used in the study. The seedlings were placed in 10 cm round pots filled with soilless substrate. Four EC-5 soil moisture sensors were used to determine the effect on root size over eight weeks. According to the results, it was found that there was an 8.7% difference between the actual volumetric water content and the measured volumetric water content. As a result of research on growing plants, it was reported that there were difficulties in providing the correct volumetric water content with FDR-type soil moisture sensors. Yılmaz (2019) [38] developed a 5 kWh photovoltaic drip irrigation system in a hazelnut orchard. In the study, the installation and effectiveness of the system were evaluated. The hazelnut orchard was irrigated according to the soil moisture sensor data for July and August. The study showed that there was an 89% yield increase in hazelnut. It was reported that leaf water potential, fruit weight, and fruit core weight, which affect hazelnut yield, develop positively. Mekala and Viswanathan (2019) [39] measured the crop temperature and humidity and then transferred these data to the cloud. With these data, the cloud-enabled clay-mist measurement index was proposed to assess the comfort levels of a crop. In this study, Arduino Uno was used as a gateway and CloudMQTT protocol was used for inter-device communication. The observed data was stored in ThingSpeak. Keswani et al. (2019) [40] designed an IoT-based irrigation system using soil moisture and temperature sensors, ambient temperature sensor, humidity sensor, CO_2 sensors, and sunlight sensors. The data collected from the sensors powered by solar energy was sent to the Raspberry Pi board with the ZigBee communication system. The stored data were evaluated using MATLAB and the fuzzy logic system was applied for weather forecasting. Using the structural similarity technique, the place where the water was missing was determined and the irrigation unit was triggered only in dry areas.

Domnguez-Nio et al. (2020)[41] investigated how to incorporate sensors into the programming approach using the drip irrigation system as an example. They studied the system for two years with the help of a web application called IRRIX. Precision irrigation doses was determined throughout the season by adjusting the algorithm based on sensor feedback. The investigations was demonstrated the viability of sensor-based irrigation planning. Demirbaş (2021) [42] has designed an irrigation system that will use water in a controlled manner in agricultural irrigation and, at the same time, determine the amount of water needed by the plant and perform automation-based irrigation. The electricity needed by the system was met by solar energy, which is one of the renewable energy sources. The test of the designed system was carried out in the agricultural land where tomato and pepper plants were cultivated. Automated and non-automated irrigation systems were compared. According to the findings, it was determined that there was a decrease in the amount of water consumption in the automated irrigated system and it contributed positively to the plant productivity. It was reported that the system was both environmentally friendly and also offers the possibility of use in areas where there was no electricity since the energy it needs was met with solar panels.

3.CONCLUSIONS

In the light of the research papers examined in the study, the following conclusions were reached.

- The design of pressurized irrigation systems with high initial investment costs is also a very complex and time-consuming process. It was determined that computer-aided software models should be used to minimize the errors that may occur during the design and operation of these systems.
- It was concluded that automation-based and remote control of irrigation systems was able to prevent human errors and save labor/time. Studies have also proven that automation-based irrigation systems increase product yield and quality.
- Soil moisture is a critical parameter used to develop smart irrigation systems, measure soil fertility, monitor droughts, increase crop yields, improve weather forecasts, and predict floods. For this reason, it was determined that the most used and developed sensors in the development of automation-based irrigation systems are sensors that measure soil moisture.
- In addition to the data obtained from soil moisture sensors in the stage of real-time data supply to irrigation systems, temperature, pressure, rain, etc. It was understood that the data obtained from the sensors can be added. It was concluded that irrigation efficiency and plant productivity increased depending on each added sensor data.
- It was determined that the energy needed in the irrigation process can be met from solar energy. It was observed that successful results were obtained in the solar energy-based irrigation systems. It was concluded that the use of solar energy, which is a clean and renewable energy source, in the agricultural sector, especially in irrigation, contributes to the economy of the producers. It was understood that it should be promoted due to its positive environmental effects.

REFERENCES

[1]. Aküzüm, T., Çakmak, B. ve Benli, B. (1999). Yirmibirinci Yüzyılda Dünyada Su Sorunu. 7. Kültürteknik Kongresi, s.8-16, Nevşehir.

[2]. Özgürel M., (2019). Adıyaman Bölgesi Modern Seracılık İşletmelerinin Isı Tüketimlerinin Hesaplanması Ve Isı Koruma Önlemlerinin Isı Tüketimine Etilerinin Araştırılması, Kahramanmaraş Sütçü İmam Üniversitesi, Fen Bilimleri Enstitüsü, Yüksek Lisans Tezi.

[3]. De Pascale, S., Costa, L., Vallone, S., Barbieri, G. ve Maggio, A., (2011). Increasing water use efficiency in vegetable crop production: From plant to irrigation systems efficiency, Hortechnology, 21(3): 301-308.

[4]. Yavuz, D., Topak, R. ve Yavuz, N., (2014). Determining energy consumption of sprinkler irrigation for different crops in Konya Plain, Türk Tarım ve Doğa Bilimleri Dergisi 1(3): 312-321.

[5]. Cai, X. and Rosegrant, M. W. (2003). World Water Productivity: Current Situation and Future Options. Water productivity in agriculture: limits and opportunities for improvement, 1: 163.

[6]. Kim, D. and Kaluarachchi, J. (2015). Validating FAO AquaCrop using Landsat images and regional crop information. Agricultural Water Management, 149: 143-155.

[7]. Debaeke, P. and Aboudrare, A. (2004). Adaptation of crop management to water-limited environments. European Journal of Agronomy, 21(4): 433-446.

[8]. Anonymous,2015. http://www.dsi.gov.tr/toprak-ve-su-kaynaklari

[9]. Sönmez, N., Benli, E. (1976). Lineer programming as a means in project Evalation and Aplplication to the Alpu irragation project. A.Ü. Ziraat Fakültesi yıllığı Cilt:25, Fasikül 4'ten ayrı basım. S. 942-950.

[10]. Smith, M. (2000). The application of climatic data for planning and management of sustainable rainfed and irrigated crop production. Agricultural and Forest Meteorology, 103(1-2): 99-108.

[11]. Malik, A. Shakir, A. S. Ajmal, M. Khan, M.J. and Khan, T. A. (2017). Assessment of AquaCrop Model in Simulating Sugar Beet Canopy Cover, Biomass and Root Yield under Different Irrigation and Field Management Practices in Semi-Arid Regions of Pakistan Water Resources Management, 31(13): 4275-4292.

[12]. Emeksiz, F., Albayrak, M., Günes, E., Özçelik, A., Özer, O.O., Tasdan, K., (2005). Türkiye'de Tarımsal Üretimin Pazarlama Kanalları ve Araçlarının Degerlendirilmesi, Türkiye Ziraat Mühendisligi VI. Teknik Kongresi, 3-7 Ocak 2005, Ankara, 2.Cilt, 1155-1171.

[13]. Kulkarni, S., (2011). Innovative technologies for water saving in irrigated agriculture, International Journal of Water Resources and Arid Environments, 1 (3): 226-231.

[14]. Kay, M., (1988). Sprinkler Irrigation Equipment and Practice.

[15]. Yavuz, D., (2006). Yağmurlama Sulamanın Enerji Gereksinimi. Master Tezi. Selçuk Üniversitesi, Fen Bilimleri Enstitüsü, Tarımsal Yapılar ve Sulama Anabilim Dalı, 49 s.

[16]. Arif I. ve Abbas, H. F., (2015). Design and Implementation a Smart Greenhouse, ISSN: 2320– 088X, https://ijcsmc.com/docs/papers/August2015/V4I8201560.pdf

[17]. Al-Ali, A.R., Qasaimeh, M., AI-Mardinia, M., Radder, S., Zualkernan, IA. (2015). ZigBee-Based Irrigation System for Home Gardens, Communications, Signal Processing, and their Applications (ICCSPA), 2015 International Conference on, American University of Sharjah, 1-5.

[18]. Ersin, C., (2016) Arduino mikrodenetleyici ve güneş enerjisiyle çalışan otomatik bitki sulama sistemi, http://tez.sdu.edu.tr/Tezler/TF02790.pdf

[19]. Kopdra, S. ve Martin, M., (2016). Implementation of Microcontroller Arduino in Irrigation System, ICIC 2016: Intelligent Computing Theories and Application pp 133–144DOI: http://dx.doi.org/10.1007/978-3-319-42291-6_13.

[20]. Mritunjay, O., Sheetal, M., Shraddha, K. ve Diksha, T., (2016). Microcontroller Based Automatic Plant Watering System, ISSN: 12278-9960, Vol. 5, Issue 3, Apr - May 2016; 25-36. https://www.semanticscholar.org/paper/MICROCONTROLLER-BASED-AUTOMATIC-PLANT-WATERING-Ojha-Mohite/ac12bb74aad84864c31522be894d84a19e2e31f8

[21]. Kavianand G., Nivas V. M., Kiruthika R.,. Lalitha S. (2016). Smart drip irrigation system for sustainable agriculture. In 2016 IEEE Technological Innovations in ICT for Agriculture and Rural Development (TIAR), 19–22.

[22]. Patil A., Beldar M., Naik A., Deshpande S. (2016). Smart farming using arduino and data mining. In 2016 3rd International Conference on Computing for Sustainable Global Development (INDIACom), 1913–1917

[23]. Karaca, C., Tekelioğlu, B., Büyüktaş, D., (2017). Sürdürülebilir Tarımsal Üretim için Toprak Nem Sensörlerinin Etkin Kullanımı, Acedemia Journal of Engineering and Applied Science, 2 (3), 33-41.

[24]. Suman, S., Kumar, S., Sarkar, R., Ghosh, G., (2017). Solar Powered Automatic Irrigation System on Sensing Moisture Content Using Arduino and GSM, International Journal of Advanced Research in Electronics and Communication Engineering (IJARECE), 6, 549-555.

[25]. Rehman, A.U., Asif, R. M., Tariq, R., Javed, A., (2017). Gsm Based Solar Automatıc Irrıgatıon System Usıng Moısture, Temperature And Humıdıty Sensors, International Conference on Engineering Technology and Technopreneurship (ICE2T), Pakistan, 1-4.

[26]. Kumar, B. D., Srivastava, P., Agrawal, R., Tiwari, V., (2017). Microcontroller based automatic plant irrigation system, International Research Journal of Engineering and Technology (IRJET), 4 (5), 1436-1439.

[27]. Taneja, K., Bhatia, S., (2017). Automatic Irrigation System using Arduino UNO" International Conference on Intelligent Computing and Control Systems ICICCS 2017, Madurai-India.

[28]. Kızıl, Ü., Aksu, S., Çamoğlu, G., (2018). Kontrollü Ortamda Bitkisel Yetiştiricilik için Arduino Uyumlu Bir Toprak Nemi İzleme Sistemi Tasarımı, ÇOMÜ Zir. Fak. Derg., 6 (2), 131-139.

[29]. García, A. M., García, I. F., Poyato, E. C., Barrios, P. M., Díaz, J. A. R., (2018). Coupling irrigation scheduling with solar energy production in a smart irrigation management system, Cleaner Production, 175, 670-682.

[30]. Wazed, S. M., Hughes, B.R., O'Connor, D., Calautit, J.K., (2018). A review of sustainable solar irrigation systems for Sub-Saharan Africa", Renewable and Sustainable Energy Reviews, 81, 1206-1225.

[31]. Yang, J., Liu, M., Lu, J., Miao, Y., Hossain, M. A., Alhamid, M. F., (2018). Botanical internet of things: toward smart indoor farming by connecting people, plant, data and clouds, Mobile Networks and Applications, 23(2), 188–202.

[32]. Aliev, K., Jawaid, M. M., Narejo, S., Pasero, E., Pulatov, A., (2018). Internet of plants application for smart agriculture. International Journal of Advanced Computer Science and Applications, 9(4), 421–429.

[33]. Subashini, M. M., Das, S., Heble, S., Raj, U., Karthik, R., (2018). Internet of things based wireless plant sensor for smart farming. Indonesian Journal of Electrical Engineering and Computer Science, 10(2), 456–468.

[34]. Goap, A., Sharma, D., Shukla, A. K., Rama Krishna, C., (2018). An IoT based smart irrigation management system using machine learning and open source technologies. Computers and Electronics in Agriculture, 155(October), 41–49.

[35]. Goap, A., Sharma, D., Shukla, A. K., Rama Krishna, C., (2018). Comparative study of regression models towards performance estimation in soil moisture prediction, 309-316, International Conference on Advances in Computing and Data Sciences, 20-21 April, Dehradun, India.

[36]. Sudharshan N., AVS Kasturi Karthik., JS Sandeep Kiran., S. Geetha., (2019). Renewable Energy Based Smart Irrigation System, Procedia Computer Science, 165, 615–623.

[37]. Kang, S., Van Iersel, M. W., Kim, J., (2019). Plant root growth affects FDR soil moisture sensor calibration", Scientia Horticulturae, 252, 208-211.

[38]. Yılmaz, A., (2019). Fotovoltaik Sistem ve Damla Sulama Yöntemiyle Sulanan Fındıkta Sulama Uygulamalarının Verim ve Verim Bileşenlerine Etkisi, Yüksek Lisans Tezi, Ordu Üniversitesi Fen Bilimleri Enstitüsü, Yenilenebilir Enerji Anabilim Dalı, Ordu.

[39]. Mekala, M. S., Viswanathan, P., (2019). CLAY-MIST: IoT-cloud enabled CMM index for smart agriculture monitoring system. Measurement: Journal of the International Measurement Confederation, 134, 236–244.

[40]. Keswani, B., Mohapatra, A. G., Mohanty, A., Khanna, A., Rodrigues, J. J. P. C., Gupta, D., de Albuquerque, V. H. C., (2019). Adapting weather conditions based on IoT enabled smart irrigation techniques in precision agriculture mechanisms. Neural Computing and Applications, 31, 277–292.

[41]. Domínguez-Niño, J. M., Oliver-Manera, J., Girona, J., Casadesús, J., (2020). Differential irrigation scheduling by an automated algorithm of water balance tuned by capacitance-type soil moisture sensors", Agricultural Water Management, 228, 59-66.

[42]. H. Demirbaş, (2021). Güneş Enerjili Otomatik Bitki Sulama Sistemi, Yüksek Lisans Tezi, Pamukkale Üniversitesi Fen Bilimleri Enstitüsü Makina Mühendisligi˘ Anabilim Dalı, Mugla.