IRAQI Academic Scientific Journals
العراقية المجلات الأكاديمية العلمية
University of Kut Journal
ISSN (E): 2616 - 7808 II ISSN (P): 2414 - 7419
www.kutcollegejournal.alkutcollege.edu.iq
k.u.c.j.sci@alkutcollege.edu.iq
Special Issue for the Researches of the 6th Int. Sci. Conf. for Creativity for 16 -17 April 2025

SMART IRRIGATION: ITS IMPORTANCE AND APPLICATIONS (ARTICLE REVIEW)

Prof. Alaa Salih Ati [1] , Agri. Eng. Sanarya Sabah Mohammed [2] , Assis. Lec. Taha Talal Ali alwazzan [3] , Lec. Marwan Musa Nasr [4] , Shatha Salim Majeed [5]

Abstract

Many scientific studies stress the incredibly important role of water resource management, especially in countries with acute water shortage problems. The issue, which grows in importance every day, is compounded by climate change impacts to which global warming primarily leads. As the average temperature increases, there is a simultaneous sharp rise in the need for agricultural water, thus adding more stress to relatively scarce water resources. The raised problem expresses an urgent need for more developed systems that are mostly aimed at maximizing water usage, especially in agriculture, where inappropriate irrigation adds to the aggravation of water scarcity. The best remedy that has surfaced so far to deal with this condition has been the adoption of smart irrigation technologies that incorporate advanced sensors and instant data analysis as well as control automation to optimize water distribution for the crops to get exactly the amount of water they need for maximum growth. Smart irrigation reduces waste by improving the efficiency of irrigation systems; therefore, it saves water resources and helps support agricultural productivity. In this regard, technology greatly contributes to the enhancement of food security, reduction of associated risks due to water scarcity, and adoption of sustainable farming practices amid a changing climate.

Keywords: Smart Irrigation, Global Warming, Machine Learning, IoT

Affiliation of Authors

[1, 2, 4] College of Agricultural Engineering Sciences, University of Baghdad, Iraq, Baghdad, 10001

[3] College of Energy and Environmental Science, Al-karkh University of Science, Iraq, Baghdad, 10001

[5] Ministry of Water Resources, Iraq, Baghdad, 10001

[1]alaa.salih@coagri.uobaghdad.edu.iq
[2]sanarya.sabbah1707b@coagri.uobaghdas.edu.iq
[3]Tahaalwzzan@kus.edu.iq
[4]marwan.m@coagri.uobaghdad.edu.iq
[5]shathasalim@yahoo.com

[1] **Corresponding Author**

Paper Info.
Published: Oct. 2025

الري الذكي، اهميته وتطبيقاته

أ. الاء صالح عاتي [1] ، م. سناريا صباح محمد [2] ، م. م. طه طلال علي [3] ، م. مروان موسى نصر [4] ، شذى سالم مجيد [5]

المستخلص

تؤكد العديد من الدراسات العلمية على الدور البالغ الأهمية لإدارة الموارد المائية، خاصة في البلدان التي تعاني من مشكلات حادة في نقص المياه. وتزداد أهمية هذه القضية يومًا بعد يوم، حيث تتفاقم بسبب تأثيرات التغير المناخي، التي يعد الاحترار العالمي السبب الرئيسي لها. ومع ارتفاع متوسط درجات الحرارة، يزداد الطلب على المياه الزراعية بشكل حاد، مما يزيد من الضغوط على الموارد المائية المحدودة نسبيًا. تُبرز هذه المشكلة الحاجة الملحة إلى تطوير أنظمة متقدمة تهدف بشكل أساسي إلى تعظيم كفاءة استخدام المياه، لا سيما في القطاع الزراعي، حيث يؤدي سوء إدارة الري إلى تفاقم أزمة ندرة المياه. ويُعد الحل الأمثل الذي ظهر حتى الآن لمعالجة هذه المشكلة هو تبني تقنيات الري الذكي، التي تعتمد على أجهزة استشعار متطورة، وتحليل البيانات الفوري، بالإضافة إلى الأتمتة الذكية للتحكم في توزيع المياه، مما يضمن حصول المحاصيل على الكمية الدقيقة من المياه اللازمة لنموها الأمثل. يساهم الري الذكي في تقليل الهدر من خلال تحسين كفاءة أنظمة الري، وبالتالي فإنه يعمل على توفير الموارد المائية وتعزيز الإنتاجية الزراعية. ومن هذا المنطلق، تلعب هذه التقنية دورًا كبيرًا في تعزيز الأمن الغذائي، وتقليل المخاطر المرتبطة بنقص

انتساب الباحثين

[1، 2، 4] كلية علوم الهندسة الزراعية، جامعة بغداد، العراق، بغداد، 10001

[3] كلية علوم الطاقة والبيئة/ جامعة الكرخ للعلوم، العراق، بغداد، 10001

[5] وزارة الموارد المائية، العراق، بغداد، 10001

[1]alaa.salih@coagri.uobaghdad.edu.iq
[2]sanarya.sabbah1707b@coagri.uobaghdas.edu.iq
[3]Tahaalwzzan@kus.edu.iq
[4]marwan.m@coagri.uobaghdad.edu.iq
[5]shathasalim@yahoo.com

[1] **المؤلف المراسل**

معلومات البحث
تأريخ النشر: تشرين الاول 2025

المياه، وتبني ممارسات زراعية مستدامة في ظل مناخ متغير.

الكلمات المفتاحية: الري الذكي، الاحتباس الحراري، التعلم الآلي، IoT

Introduction

Climate change remains the most imperative challenge facing the present world throughout the 21st century; recent studies prove its acceleration, which is due explicitly to global warming and is taking place at a much faster rate than was first determined. Human activities are the primary drivers behind the rise of global temperatures; these activities are causing further depletion of freshwater resources due to increased evaporation and changes in patterns of precipitation. Such changes represent a rationale that has increasingly emphasized the significant need for adaptive measures that would reduce the supply of freshwater resources in saline-prone areas around the world. These environmental stresses often go hand in hand with land degradation, loss of diversity, high intensification in irrigation support, and major economic investments related to land reclamation works [1]. Since agriculture is one of the most important economic sectors worldwide, ostensible water management is essential to maintain productivity and resilience. Therefore, considering the increasing demand for dynamic irrigation practices, smart irrigation systems were introduced in the market that provides the opportunity for farmers to monitor the water consumption based on the accurate needs of the crop. Among these innovations, smart irrigation technology has received greater attention for water conservation, increased agricultural productivity, and sustainability over the long term. Smart systems control water delivery systems using advanced sensors and up-to-the-minute monitoring in a very precise manner. These smart irrigation systems read soil moisture and send the data to a central control unit to ensure that the crops get exactly the amount of water they need for optimal growth. Such systems can save up to 80% of what is used, providing targeted irrigation without any wastage [2,3,4]. Other benefits associated with smart irrigation systems include the more precise and efficient scheduling of irrigation, reduced labor, and early detection of crop water stress. The systems, with both automated controls and sensor networks, have improved the accuracy of water application. It helps optimize crop yields with minimization of environmental degradation. Furthermore, it helps greatly in mitigation measures against adverse impacts of prolonged droughts and unpredictable climate conditions. Because of the above benefits, the promotion of smart irrigation technologies is gaining more prominence as a potential solution in battling water scarcity problems and ensuring sustainable crop production under continuously changing climatic conditions [5, 6, 7, 8,9 , 10].

Smart Irrigation System

Smart irrigation systems are major components of modern agricultural technology, which allow for the automatic scheduling of irrigation without any human intervention. It reads information from multiple sensors continuously monitoring soil moisture and climatic data then uses that data to determine precise irrigation needs. Real-time data can be used in ensuring the plants get the necessary amount of water to support healthy growth and realization of their full yield potential. One of the immense values of this smart system is

its huge capability to check and control irrigation systems even in huge farm fields. It works as a highly effective water-saving irrigation system; irrigation is optimized according to the amount of water in the soil, climate conditions, and water needs of plants at their varied growth stages [11, 2, 12, 13,14].

The smart irrigation system uses specialized sensors for estimating soil moisture, though supported by smart temperature sensors to enhance water management efficiency in agricultural production. Eliminating uneven water distribution, the systems make plants absorb maximally and use water optimally with minimum wastage of excess water. High-precision control on water application reduces manual labor significantly because the system can be adjusted through advanced software to calculate the specific demands of different crops [15, 16]. Automatic irrigation scheduling uses up-to-the-minute real soil moisture data primarily to allow the farmer to fine-tune irrigation practices according to crop type, seasonal variations, and environmental conditions. Wireless sensors not only monitor soil moisture, but they also account for relevant external conditions, such as climate, soil type, and the general condition of the field. This will enable them to monitor soil moisture levels, decide on the best time that irrigation should be done, and set appropriately timed watering cycles, thereby enhancing both water efficiency and crop yield.

Since more and more people are practicing water-saving irrigation methods, experts have placed greater focus on improving smart irrigation technologies. This rise in population as well as agricultural practices has called for better ways to manage water resources. As a result of this, easy access to the Internet paved the way for web control systems as well as storage systems for managing irrigation data up in the cloud [17, 18, 19, 20, 21]. In the 21st century, wireless sensor networks attained great interest as an enabling technology for environmental monitoring, soon after finding large application areas in agriculture. These networks give real-time information for crop water needs; hence farmers can now monitor and control irrigation activities with much-improved accuracy and efficiency [22].

In addition, up-to-date research in agriculture appropriately merges the high-octane technologies of Machine Learning and Artificial Intelligence with Unmanned Aerial Vehicles and the Internet of Things for smart irrigation, pest control, disease prediction, and soil fertility assessment. This would initiate a rather predictive, automated decision-making with better resource allocation in agriculture [23, 24, 25, 26, 27, 28]. A layered structure of smart irrigation systems, as shown in Figure (1), can be used to indicate the components and functioning of such systems when tightly integrated with high agricultural technologies.

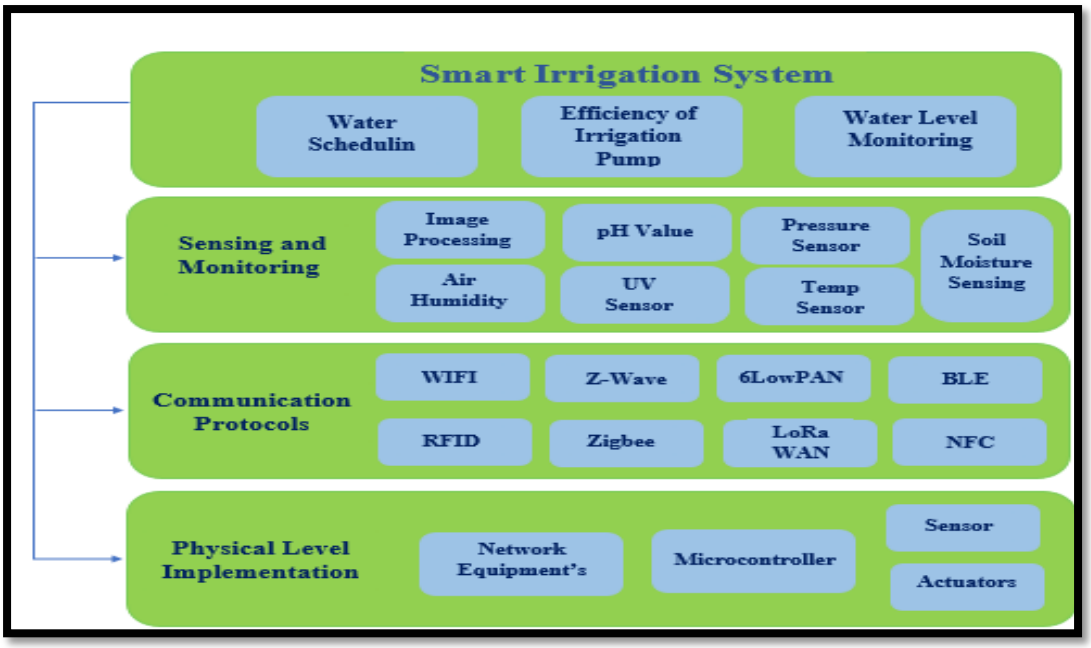

Figure (1): Description of the Layered Architecture of Smart Irrigation Systems.

Importance of the Smart Irrigation System

The smart irrigation system is designed for precision in supplying water needs for agronomic crops, which basically means optimizing hydration in cases where rainfall does not meet crop demand. [17] described that such systems are designed and executed based on several parameters, e.g., the shape and size of the agricultural field, soil characteristics, crop category, water supply, and the climatic conditions in which it will be used. The primary objective of smart irrigation technology is to make the most efficient use of water by managing the distribution of irrigation water in such a way that water is applied precisely according to the actual demands of the plants at that moment. The other management that can be done by smart irrigation is the scheduling of irrigation cycles based on real-time weather conditions. Not only will crop production be improved, but the green area will also be developed with more aesthetic value and less water wastage [29].

Benefits of Smart Irrigation Systems for Farmers

Adopting smart irrigation systems provides key benefits to farmers by improving efficiency, sustainability, and overall agricultural productivity among others. The key benefits include:

a. Sensing and Monitoring Remotely: A major benefit of smart irrigation tech is offering remote monitoring. Workers can check on the fields from afar, lowering the need for on-site staff and reducing the costs of running the farm. With live sensor data, they can monitor how often irrigation is done, spot any unusual dryness in crops, and react quickly to any weather shifts. This tech cuts down on water waste, maximizes resource use, and betters farm management.

b. Use smart sensors and IoT-based monitoring to give real-time data regarding soil moisture and weather as well as crop health for the farmers. This would mean constant data flow enabling better detection and response for any environmental changes. With data analytics incorporated, precision agriculture can be made more accessible,

monitoring optimized planting schedules as well as fertilization and irrigation plans. This would mean enhanced productivity with higher crop yields following a sustainable way of farming.

c. Precision irrigation systems help the farmer to determine the right time and amount of water to be used on the farm by looking at environmental data in real time. Since they make sure there is no excess watering and that the plants get only what they need, these systems cut down on water waste by a big margin. This saves not just important water resources but also keeps the soil good and stops problems like too much water in the ground or salt buildup. In turn, smart irrigation helps with sustainable farming, mixing how much is grown with careful water use.

In general, this is a transformation of farming, a high-tech way to do things that makes work better, saves supplies and helps grow food in a sustainable way. With things getting better on the Internet of Things and sensor tools, smart irrigation systems are likely to join in strongly when it comes to dealing with not having enough water— all while keeping farming strong in changing weather.

Mechanism of Smart Irrigation System Operation

The smart irrigation system functions by letting different linked devices easily talk to each other, which helps them send live data to a main computer over the Internet. This setup depends on a group of sensors smartly put in place within farming fields to check key conditions like soil wetness and heat. When the data is gathered, a learning algorithm by machines deals with it to understand and say exactly how much water is needed for the best crop growth. That smart automation is done through communication between devices, electronic smarts, and specially made smart tools that help with good irrigation control [14]. The heart of smart farming tech lies in gathering huge amounts of farming data via wireless sensor networks, which keep talking over the internet all the time. The data collected is sent to a web server where it is processed and analyzed under an internet of things setup. This mix of IoT with smart farming systems allows for on-the-spot choices, making sure plants get the right amount of water at the proper time and stopping extra use.

Another global approach to the water crisis is the use of WSNs for irrigation management. This will have substituted the smart irrigation systems that were based on IoT, cloud computing, and AI installed to improve significantly water efficiency and agricultural productivity. Real-time monitoring to detect soil conditions and plant health against environmental stress factors, variability of climate, pest invasion, and plant diseases is also being supported by these new technologies. As it reduces dependency on labor, it also processes data and analyzes information for farmers to make decisions for better crop production. Also, such intelligent systems enhance the optimal application of essential agricultural inputs such as fertilizers, water, and pesticides by cutting waste and encouraging sustainable farming practices [30, 31].

Smart irrigation technology adopted fundamentally changes modern farming, allowing the resources to be controlled with the accuracy of irrigation schedules. Advanced IoT and AI insight help to monitor and control irrigation practices efficiently by farmers to ensure sustainable farming regarding water scarcity issues. Figure (2) depicts the incorporation of different monitoring functionalities that can be used in smart irrigation systems. Various roles can be played but put into

the proper perspective contribute significantly toward improving precision in irrigation, conservation of resources, and general sustainability in agriculture.

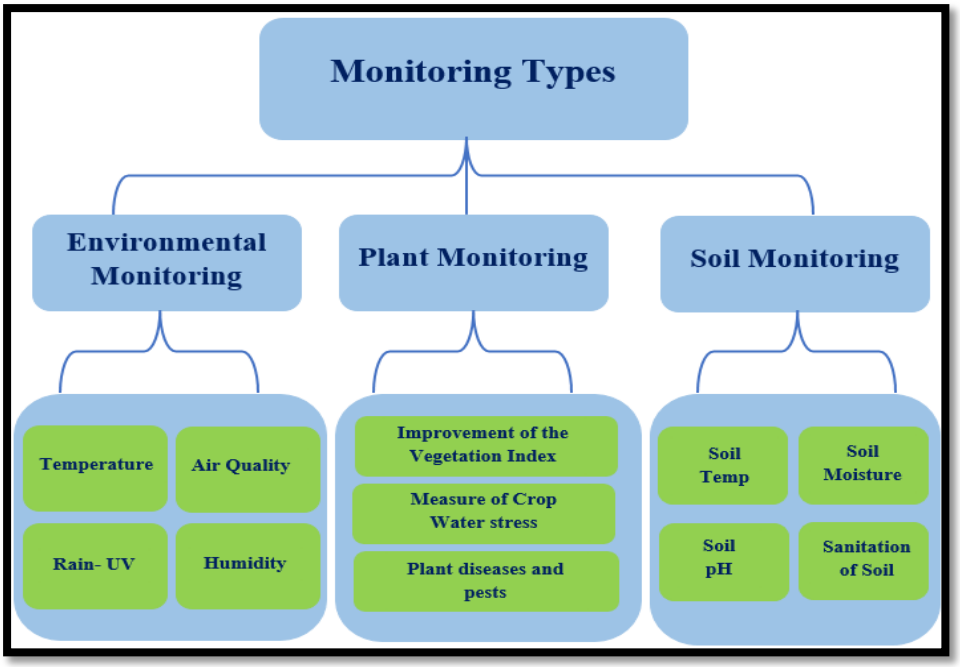

Figure (2): Types of Monitoring in Smart Irrigation Systems

Outcomes of Smart Irrigation System Applications

Smart irrigation systems are made up of several configurations, each designed for specific environments and agriculture needs. Some of the systems work with the use of solar power, this enables them to work continuously by transmitting and receiving data in real-time among the users. The diversity in types of sensors among these systems is influenced by primary goals, such as optimization of water distribution, improvement in soil moisture management, or crop yield enhancement.

A major use of smart water tech is with drip water systems, especially for plants like sunflowers. Research has shown that using smart water along with drip water leads to big improvements in plant growth while saving water. Studies suggest the use of smart water with new water methods, specifically subsurface drip water, to raise farm output to save water. This way is very helpful in places with little water, where good water ways are key for long-term farming [3, 32].

It has, therefore, been observed that smart irrigation systems based on IoT have relatively stabilized agricultural production while making adequate input in water-use efficiency. The moisture-based systems monitor and only initiate irrigation when it is necessary; hence, water is not wasted. Challenges involved include high-cost initial investments, regular system maintenance, and a need for special programming skills to work with such systems [33].

Moreover, the linkage of smart irrigation with center pivot irrigation systems has borne fruits. It is an automated irrigation approach that moistens plants in a circular path. Research points to this union as having benefits in that it triggers high crop productivity, enhanced water control, and lowered running costs. Accurate, up-to-the-minute

information empowers farmers with sound judgment on planning irrigation activities and the use of resources, thus making farming more efficient [34, 35, 36].

Advancing Smart Irrigation Through Integrated Monitoring and Energy Efficiency

To realize the full benefit of automated irrigation control and monitoring technologies, it has been recommended that an integrated approach in monitoring weather conditions, together with plant-soil-based monitoring, be adopted. This is especially important for open-field cultivation, as the system requires validation and constant adaptation considering the vagaries of weather. As a result, developing dynamic models in irrigation becomes imperative if smart irrigation systems are to become responsive and efficient under real-world conditions [37].

Because soil properties can change and are dynamic, then the devices of remote sensing incorporated within the smart irrigation networks should be able to adjust their operation parameters automatically. Acquiring knowledge on the interaction between soil physical properties and remote sensing technologies is essential toward optimizing sensor performance. Increased complexity in control mechanisms must be balanced with energy efficiency. The high real-time processing of data by smart irrigation sensors presents another area of solutions combating sustainable power sources since the advanced smart irrigation sensors are perceived to be high power consumers. Low-power operation is still at the core of the development of smart irrigation systems; hence, there is a need for innovation in low-power sensor technologies and renewable energy sources [38, 39].

AI-Driven Irrigation and the Future of Precision Agriculture

Smart irrigation systems, when integrated with centralized control units, can greatly reduce human intervention and the errors that were coming out of the traditional practices of irrigation. They gradually ensure that the crops receive only the amount of water they need to support and, hence, become a transformative step toward sustainable agricultural development and water conservation [40].

Also, changes in artificial intelligence are transforming smart watering by adding smart guesses using learning machines, synthetic brain networks, and deep understanding schemes. These AI-led systems can predict important things like how damp the soil is, its acidity, and if there is enough electrical flow, which all help make the watering schedule more accurate. Unlike the old ways of watering, AI-based watering systems use evapotranspiration models and live environmental data to improve water use. The predictive quality of these systems ensures that the right times for watering are chosen, making things better and saving resources [41, 42, 43, 44].

The demand for irrigation solutions that are sustainable and efficient is growing in importance; therefore, research in smart irrigation technologies should continue. Further refinements in future innovations to improve efficiency in the use of AI and IoT systems are highly necessary to meet the emerging needs of modern agriculture. These technologies will soon play a very vital role in the global scarcity of water-related issues and food security to make sure intelligent management of water resources is present.

Conclusions

Smart irrigation systems can adapt to varying environmental conditions, such as soil texture, climate change as well as changing weather patterns, this lead in end makes them very useful in the face of climate change.

References

[1]. Dawod SS, Ati AS, Abdujabbar IA. Management of using saline irrigation water and tillage systems on the soil mechanical and hydraulic. Iraqi Journal of Agricultural Sciences. 2024 Dec 29;55(6):2050-9.

[2]. Al Hasnawi RA, Ati AS, Tali AH. Study of water productivity of wheat and moisture distribution under the influence of center pivot irrigation and different tillage systems for desert soils. InIOP Conference Series: Earth and Environmental Science 2022 Dec 1 (Vol. 1120, No. 1, p. 012024). IOP Publishing.

[3]. Ati AS, Hassan A, Mohammed M. Effect of water stress and NPK fertilization on growth, yield of wheat and water use efficiency. J. of Agric. and Vetern. Sci. 2016;9(12):21-6.

[4]. García L, Parra L, Jimenez JM, Lloret J, Lorenz P. IoT-based smart irrigation systems: An overview on the recent trends on sensors and IoT systems for irrigation in precision agriculture. Sensors. 2020 Feb 14;20(4):1042.

[5]. Aoda MI, Ati AS, Al-Rawi SS. Subsurface Water Retention Technology (SWRT) for Water Saving and Growing Tomato in Iraqi Sandy Soils. J. Zankoy Sulaimani Part A. 2018;7:127-34.

[6]. Aoda MI, Ati AS. Morphology, quality and water use efficiency for tomato using subsurface water retention technology (swrt). Iraq Journal of Agricultural Research. 2017;22(7).

[7]. Ati AS, Dawod SS, Madlol KM. Sustainability of the water requirement of two cultivars of okra under the use of cover crop and minimum tillage system. Iraqi Journal of Agricultural Sciences. 2025 Jan 30;56(Special):161-8.

[8]. Ati AS, Dawod SS, Madlol KM. Sustainability of the water requirement of two cultivars of okra under the use of cover crop and minimum tillage system. Iraqi Journal of Agricultural Sciences. 2025 Jan 30;56(Special):161-8.

[9]. Ati AS, Dawod SS. Strategy for Management of Using Saline Irrigation Water and Tillage Systems in Water Productivity and Wheat. InIOP Conference Series: Earth and Environmental Science 2024 Jul 1 (Vol. 1371, No. 8, p. 082040). IOP Publishing.

[10]. Koech R, Langat P. Improving irrigation water use efficiency: A review of advances, challenges and opportunities in the Australian context. Water. 2018 Dec 2;10(12):1771.

[11]. Abdulrazzaq H, Ati A, Hassan A. The role of irrigation management processes and micronutrient fertilization on parameter of growth and yield of two wheat varieties. International Journal of Agricultural Statistical Sciences. 2018;14(1):125-8.

[12]. Ati AS, Wahaib HA, Hassan AH. Effect of irrigation management and fertilization on N, P and K concentration of two wheat varieties. Diyala Agricultural Sciences Journal, 12(special Issue): 402–417.

[13]. Jabbar FA, Jasim AA. Effect of the Distance between Irrigation Tubes in the Subsurface Drip Irrigation System on Rice Crop Production. Journal of Water Resources and Geosciences. 2024 Sep 24;3(2):1-7.

[14]. Jabbar HA, Ati AS, Hassan AH. FURROW IRRIGATED RAISED BED (FIRB) TECHNIQUE FOR IMPROVING WATER

PRODUCTIVITY IN IRAQ. Plant Archives. 2020;20(2):1017-22.

[15]. Nasr MM, Ati AS, Al-Mashhadani BM. If wildfire prevention doesn't work, what will be done?. Al-Kut University College Journal. 2024(Special issue).

[16]. Pandey AK, Mukherjee A. A review on advances in IoT-based technologies for smart agricultural system. Internet of Things and Analytics for Agriculture, Volume 3. 2022:29-44.

[17]. Khamees AA, Ati AS, Hussein HH. Effect of Surface and Subsurface Drip Irrigation and Furrows Irrigation System on Water Productivity, Growth and Yield of Lettuce (Lactuca Sativa L). InIOP Conference Series: Earth and Environmental Science 2023 Apr 1 (Vol. 1158, No. 2, p. 022009). IOP Publishing.

[18]. Level T, Ismail SM. The Egyptian-German Water Management Reform Programme (WMRP).

[19]. Mahmoud SH, Ati AS, Majeed SS. Calculating Water Productivity Using the Portal WaPOR. InIOP Conference Series: Earth and Environmental Science 2024 Jul 1 (Vol. 1371, No. 8, p. 082039). IOP Publishing.

[20]. Muñoz-Carpena R, Dukes MD. Automatic irrigation based on soil moisture for vegetable crops: Abe356/ae354, 6/2005. EDIS. 2005 Aug 11;2005(8).

[21]. Smajstrla AG, Locascio SJ, Weingartner DP, Hensel DR. Subsurface drip irrigation for water table control and potato production. Applied Engineering in Agriculture. 2000;16(3):225-9.

[22]. Pandit A. IoT based Smart irrigation system using soil moisture sensor and ESP8266 NodeMCU. July. 2019;15:2019.

[23]. Darshna S, Sangavi T, Mohan S, Soundharya A, Desikan S. Smart irrigation system. IOSR Journal of Electronics and Communication Engineering (IOSR-JECE). 2015 May;10(3):32-6.

[24]. Harmanny KS, Malek Ž. Adaptations in irrigated agriculture in the Mediterranean region: an overview and spatial analysis of implemented strategies. Regional environmental change. 2019 Jun 1;19:1401-16.

[25]. Ismail SM. Design and management of field irrigation system. Alex., Egypt. 2002.

[26]. Khriji S, El Houssaini D, Kammoun I, Kanoun O. Precision irrigation: an IoT-enabled wireless sensor network for smart irrigation systems. Women in Precision Agriculture: Technological Breakthroughs, Challenges and Aspirations for a Prosperous and Sustainable Future. 2021:107-29.

[27]. Pramanik M, Khanna M, Singh M, Singh DK, Sudhishri S, Bhatia A, Ranjan R. Automation of soil moisture sensor-based basin irrigation system. Smart Agricultural Technology. 2022 Dec 1;2:100032.

[28]. Vellidis G, Tucker M, Perry C, Kvien C, Bednarz C. A real-time wireless smart sensor array for scheduling irrigation. Computers and electronics in agriculture. 2008 Apr 1;61(1):44-50.

[29]. Farooq M, Hussain M, Ul-Allah S, Siddique KH. Physiological and agronomic approaches for improving water-use efficiency in crop plants. Agricultural Water Management. 2019 Jun 20;219:95-108.

[30]. Iglesias A, Santillán D, Garrote L. On the barriers to adaption to less water under climate change: Policy choices in Mediterranean countries. Water Resources Management. 2018 Dec;32:4819-32.

[31]. Jha SK, Tarafder M, Dhibar D, Pokharel B, Shrestha J, Koirala KB. Design and Development of Soil Moisture Based Automatic Irrigation System in Nepal. Journal La Multiapp. 2020 Dec 2;1(3):43-52.

[32]. Hamami L, Nassereddine B. Application of wireless sensor networks in the field of irrigation: A review. Computers and Electronics in Agriculture. 2020 Dec 1;179:105782.

[33]. Nikolidakis SA, Kandris D, Vergados DD, Douligeris C. Energy efficient automated control of irrigation in agriculture by using wireless sensor networks. Computers and Electronics in Agriculture. 2015 Apr 1;113:154-63.

[34]. Lakhwani K, Gianey H, Agarwal N, Gupta S. Development of IoT for smart agriculture a review. InEmerging Trends in Expert Applications and Security: Proceedings of ICETEAS 2018 2019 (pp. 425-432). Springer Singapore.

[35]. Nasr MM, Ati AS. Hysteresis in Soil, Its Causes and Influences. InIOP Conference Series: Earth and Environmental Science 2023 Dec 1 (Vol. 1262, No. 8, p. 082052). IOP Publishing.

[36]. Ragab MA, Badreldeen MM, Sedhom A, Mamdouh WM. IOT based smart irrigation system. International Journal of Industry and Sustainable Development. 2022 Jul 1;3(1):76-86.

[37]. Al-Lami AA, Al-Rawi SS, Ati AS. Evaluation of the AquaCrop model performance and the impact of future climate changes on potato production under different soil management systems. Iraqi Journal of Agricultural Sciences. 2023 Feb 22;54(1):253-67.

[38]. Mallikarathne T, Perera PM, GAHKM G, HT G, WVA U, SADHP M. Wireless Sensor Network Based Smart Irrigation System using IoT and Data Fusion. In2024 4th International Conference on Advanced Research in Computing (ICARC) 2024 Feb 21 (pp. 259-263). IEEE.

[39]. Vallejo-Gomez D, Osorio M, Hincapie CA. Smart irrigation systems in agriculture: A systematic review. Agronomy. 2023 Jan 25;13(2):342.

[40]. Mat I, Kassim MR, Harun AN, Yusoff IM. Smart agriculture using internet of things. In2018 IEEE conference on open systems (ICOS) 2018 Nov 21 (pp. 54-59). IEEE.

[41]. Al-Lami AA, Ati AS, Al-Rawi SS. Determination of water consumption of potato under irrigation systems and irrigation intervals by using polymers and bio-fertilizers in desert soils. Iraqi Journal of Agricultural Sciences. 2023 Oct 29;54(5):1351-63.

[42]. Alwazzan TT, Ati AS. Assessment of soil quality and health using some physical and biological properties for fadak farm project. Iraqi Journal of Agricultural Sciences. 2024 Jun 26;55(3):1011-24.

[43]. Shaheen SS, Priya SB, Harsha S. Smart Irrigation System Based on IoT. International Journal of Trend in Innovative Research (IJTIIR). 2021;3(3):28-31.

[44]. Ullah H, Santiago-Arenas R, Ferdous Z, Attia A, Datta A. Improving water use efficiency, nitrogen use efficiency, and radiation use efficiency in field crops under drought stress: A review. Advances in agronomy. 2019 Jan 1;156:109-57.