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Precision Irrigation Management Using Automatic Scheduling Techniques under Environmental Drought Stress Conditions in Egypt: A Review

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Abstract

Water resources are a limiting factor for the country's agricultural production, and saving water becomes a necessary prerequisite. In this logic, irrigation technologies appear to play a major role in supporting Egypt's agro-economy. However, using such modern means of irrigation control can help in scheduling both irrigation and fertigation processes very accurately, providing different cultivated crops with their exact requirements of water and fertilizers at the correct time for the plant. Moreover, it will consume the minimum water, fertilizers energy, and labor as well. Also, it will render the plant avoid any stress of water deficiency. This review article aims to present some automated scheduling techniques for accurate irrigation management in Egypt, as one of the solutions to overcome the impact of climate change. This can be done through several methods such as irrigation scheduling using the data required for irrigation scheduling or by using irrigation scheduling programs and models. As well as the use of automatic irrigation, whether by means of ground humidity or controlling the time and amount of water. Precision agriculture using the Internet of Things (IoT) is a broad class of related technologies that will maintain precise control over farm decisions. This method of planting decisions is intended for specific crops and not for an entire region. Precision farming combines agricultural machinery and efficient agricultural operations to meet the specific needs of farmers. For example, making the best decision to manage irrigation systems by automatically scheduling irrigation and knowing the plants' needs for water in actual amounts and in real-time.

Keywords: Scheduling irrigation, Irrigation management, IoT technologies, Smart irrigation, Precision irrigation, Automatic irrigation..

1. Introduction

Life in Egypt depends entirely on the water drawn from the Nile River. Under the 1959 agreement, a fixed and specified limit for Egypt's share of the Nile's water was established at 55.5 billion cubic meters annually. This water represents about 97% of the natural water resources in Egypt and about 68% of the water footprint of Egypt. According to the statistics of the Central Agency for Mobilization and Statistics, the population of Egypt reached 101 million people for the year 2021, which led to a decrease in the per capita share of water to about 560 m^3 / year, at a time when the United Nations defined water poverty as 1000 cubic meters per person per year. Hence, the per capita share of water decreases annually, in inverse relationship with the increase in population. Consequently, water requirements increased to meet the increasing demand for food [1, 2, 3].

Due to the limited water resources and the population explosion, water must be used as a scarce commodity [4, 5, 6]. Therefore, many measures must be taken to maximize the efficiency of water use. Providing crops with the ideal amount of water and nutrients throughout the growing season in the most effective manner is one of the biggest difficulties confronting sustainable agriculture. Pressurized irrigation methods of all kinds work to raise irrigation efficiency and rationalize water use [7, 8].

However, if these methods are automatically scheduled and adjusted to give exactly the calculated or estimated amount of water appropriate to the needs

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of the plant during the different growth stages, then this will save any water losses and give the plant the exact basic needs of water and nutrients for optimal growth and production. The use of an automatic irrigation system is a way to enhance irrigation techniques while also achieving water-saving goals. The ability of agricultural systems to promote food security is therefore improved through smart irrigation. Therefore, the main objective of this review is to present precision irrigation management using automatic scheduling techniques under environmental drought stress conditions in Egypt.

1- What is the definition of precision irrigation?

There are three sides to designing a precision irrigation system. The first is the evaluation of the irrigation system to detect potential deficiencies in the irrigation system and its management. The second focuses on precise scheduling irrigation based on (1) the actual crop water requirements and (2) the design of the ideal pulse irrigation. The third side is, developing an irrigation system using new technologies as shown in Fig. 1. As well as, developing new irrigation supported by new techniques for precision irrigation with full control of the amount of water and assistance with information and decision-making [9].

[10] designed a precision irrigation method based on a multi-platform model, to give farmers the actual amount of water in the strawberry sector. So, precision irrigation is defined as a method or a technique of applying the actual amount of water according to the quantities and requirements of crops, with a low effect on the environment [11].

2- Irrigation scheduling

Irrigation scheduling is defined as some successive estimate to determine the time of irrigation and the amount of water used [12, 13]. Establishing an irrigation schedule in time to match the water demand of crops is important for increasing water use efficiency in arid regions [14]. [15] defined irrigation scheduling as adding water to crops at the correct time and in the specified amount, without losses or increases in water, and is an important management factor. Many factors such as plant evaporation, soil characteristics, profile, and spread roots are also taken into consideration to estimate an appropriate irrigation schedule. To calculate irrigation scheduling, climate data for the area, soil, and plant information are used, in order to irrigate with quantities of water consumed by plants, soil surface losses, and deep percolation [16, 17].

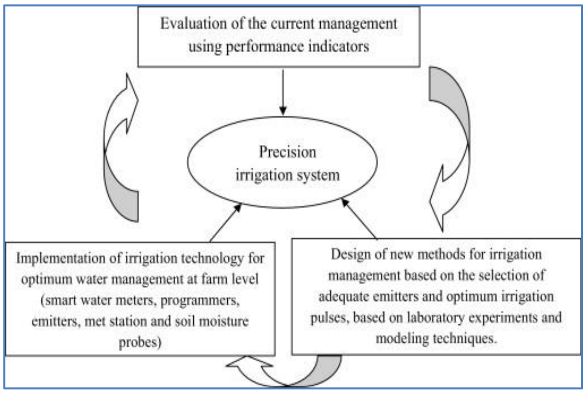


Fig. 1. The different sides of the precision irrigation system; source: [9].

The irrigation schedule determines the actual amount of irrigation water and the real-time irrigation. Moreover, evapotranspiration (ET) and crop coefficient (Kc) are used to estimate actually applied water in real-time for good growth and further water saving.

This depends on the radiation, temperatures, wind speed, and air humidity of the area. Regular distribution of water across the field is also important to achieve the greatest benefits from irrigation scheduling [18, 19].

2-1 The required data for irrigation scheduling

2-1-1 Reference Evapotranspiration

[20] mentioned that, Reference Evapotranspiration (ETo) can be estimated using the following equation (1)

$$\boldsymbol{ETo = \frac{0.408\Delta(Rn - G) + \gamma \frac{900}{T+273} u2(es - ea)}{\Delta + \gamma(1 + 0.34\, u2)}} \quad \mathbf{(1)}$$

Where:

ETo: The Reference evapotranspiration (mm day^{-1}).

T: The average air temperature/day (°C) at 2 m height.

u2: The average wind speed at 2 m height (m s^{-1}).

es and ea: the saturation and actual vapor pressure (kPa).

2-1-2 Crop Water Requirement (CWR)

The quantity of water requirement for crops is determined by the rate of ET in mm day^{-1} and is equal to the amount of water lost from a planted field by ET. Crop evapotranspiration (ETc), which may be computed using the following equation, is used to estimate CWR [21]:

$$ETc = Kc \times ETo \qquad (2)$$

Where: Kc: crop coefficient. The albedo (reflectance) of the crop-soil surface, crop height, canopy resistance, and evaporation from the soil are the four key characteristics that set the crop apart from reference grass. This ratio measures the crop's ETc to ETo and integrates their impacts.

The crop's Kc will change during the growing period, which may be classified into four separate stages: initial, crop development, mid-season, and late season, as a result of ET variations over the growth stages [22].

2-1-3 Irrigation Water Requirement (IR)

The amount of root zone depletion at the end of the day is used to get the daily root zone water balance by the following equation [23]:

$$D_{ri} = D_{ri-1}(P_i - Ro_i) - I_i - CR_i + ET_{ci} + DP_i \qquad (3)$$

where: Dri: the root zone depletion per day i (mm), D_{ri-1}: the moisture content in the root zone at the previous day (mm), P_i: the precipitation on day i (mm), Ro_i: the surface soil runoff on day i (mm), Ii: the irrigation depth per day i which infiltrates the soil (mm), CR_i: the capillary rise from the groundwater table per day i (mm), ET_{ci}: the crop evapotranspiration per day i (mm), and DPi: the lost water of the root zone on day i (mm). Moisture deficit is the amount of water (mm) below field capacity before irrigation.

2-2 Irrigation scheduling models and software calculations

There are two methods for calculating irrigation scheduling, the first is the manual method, which is inaccurate and needs time in the calculation, and the second is using computer programs, which is more accurate.

2-2-1 IrrSch program

IrrSch software is a program used as part of the RZWQM2 model [24] for irrigation scheduling calculation. [25] developed an irrigation scheduling. The program is dependent on consists of two main interfaces as shown in Fig. 2. The first interface contains seven processes through which users can enter information into the program.

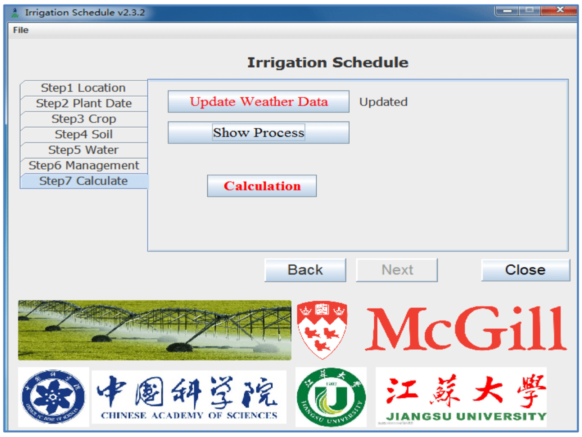


Fig. 2. Main-interface-of IrrSch program; source: [24].

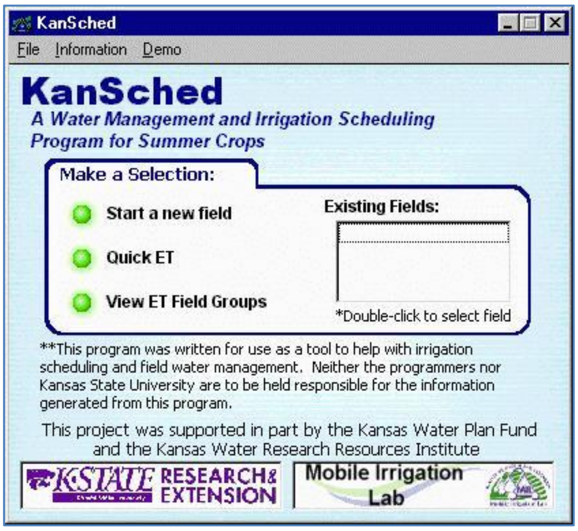
Operations one to six enter and validate pre-calibrated information regarding parameters of another model RZWQM2. Users only need to update the planting date because some parameters (planting intensity, tillage, etc.) do not require annual updating. Three additional processes are contained in the seventh process, but only two of them are under the user's control: 1) User can modify weather information. 2) Determine the button that will cause IrrSch to switch to the second interface while the RZWQM2 model is running. The irrigation process interface, the second interface, is used to see all irrigation data.

Based on water stresses anticipated by an agro-hydrological model, [14] created and assessed the Decision Support System for Scheduling Irrigation (DSSIS) model for real-time irrigation scheduling. The irrigation scheduling program was evaluated with three irrigation scheduling methods, one based on experience, the second using soil moisture sensor and DSSIS for irrigation scheduling to improve water productivity for cotton crop. There is a significant result for the water productivity of DSSIS program compared to other irrigation scheduling methods. The results indicated that DSSIS is a practical method for scheduling irrigation.

2-2-2 KanSched program

[26, 27] used KanSched for irrigation scheduling calculation. KanSched computer program was created to assist in monitoring and tracking the water balance in the root zone, soil layers' and during irrigation intervals using evapotranspiration (ET).

The program may be used to track the amount of water in the soil under non-irrigated fields. You can use an instrument ET-based irrigation scheduling to assist you to choose when and how much irrigation water to utilize. To determine when an irrigation event is required and how much water may be utilized, the basic procedure uses data on crop water use (crop evapotranspiration, or ETc), precipitation, and soil water storage. KanSched was created to be simple to use with few operational inputs and training needs. Fig. 3 shows the program interfaces. [28] tested the performance evaluation of KanSched's irrigation scheduling program that was used in Kansas City. The data indicated that, KanSched is a good tool for irrigation scheduling, mainly when using on-site recorded rain.



**This program was written for use as a tool to help with irrigation scheduling and field water management. Neither the programmers nor Kansas State University are to be held responsible for the information generated from this program.

This project was supported in part by the Kansas Water Plan Fund and the Kansas Water Research Resources Institute

Fig. 3. KanSched program; source: [27].

2-2-3 CROPWAT computer model

Irrigation scheduling for the crop was calculated using the CROPWAT computer model. According to daily climate data is used to calculate ETo using the Penman-Monteith based method in a file and loaded into the CROPWAT-8 model, as well as a precipitation file [29]. After that, the user adds the crop data, crop characteristics such as plant height, growth cycle, root depth, and Kc values presented in the program and also illustrated in [22]. Additionally, the software includes soil properties such as the initial soil water content, maximum root depth, maximum rain infiltration rate, and total available soil moisture (FC-WP). Fig. 4 shows the steps for calculating an irrigation schedule using a CROPWAT program.

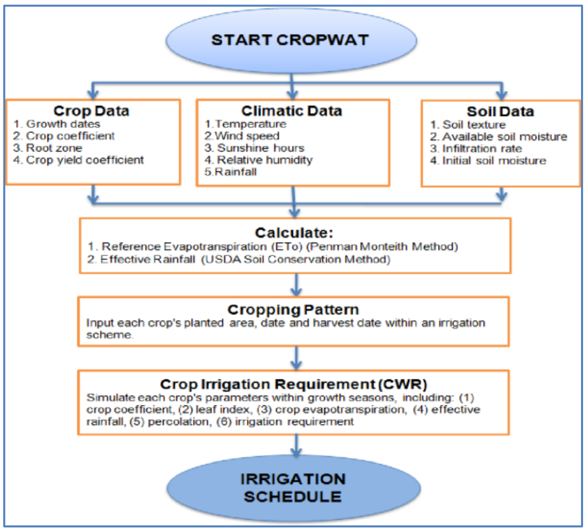


Fig. 4. Flow chart of the CropWat model for irrigation scheduling; source: [29].

2-2-4 Aquacrop computer model

Aquacrop is one of the models used to schedule irrigation for different crops. On the other hand, the model is also used to predict the soil moisture content, canopy cover, yield, and biomass, as shown in Fig. 5 schematic representation of the evolution of the Aquacrop model [30].

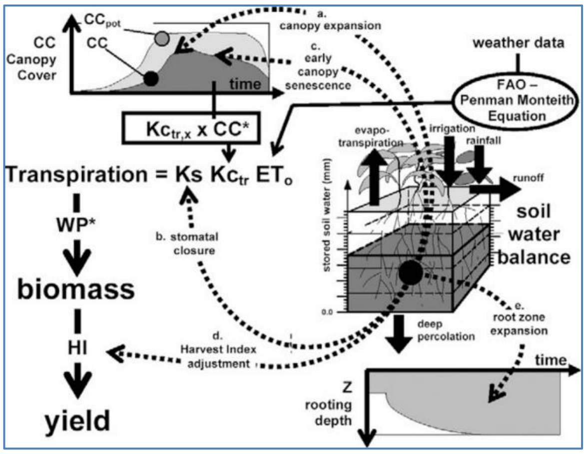


Fig. 5. Schematic representation of the evolution of Aquacrop model; source: [30].

[31] used the Aquacrop model as a tool to maximize irrigation scheduling using actual and future climate data for improving water productivity and maintaining the saline water balance of the wheat crop in the Khuzestan region. According to the model's data, it may be used to estimate various irrigation scheduling scenarios under field conditions and predict the water and salt balance in the soil as well as wheat yield.

3- Automatic irrigation

An automatic irrigation system is defined as a method of operating an irrigation system without or with minimal manual intervention and monitoring system. Automatic irrigation can be used with all irrigation systems, with the addition of timers, sensors, computers, or measuring devices. So, the large areas can be divided into small parts and irrigation areas, and the parts are irrigated in succession and a specific sequence in proportion to the disposal rate available from the water source. Automatic irrigation is more accurate but more complex than manual irrigation. So, it must be replaced the manual irrigation which depends on labourers, with the use of automatic irrigation scheduling techniques. It is noteworthy that the process of estimating evapotranspiration of plants, is based on different weather factors such as air humidity, wind speed and solar radiation, as well as various factors specific to crops such as growth stage, plant density and also soil characteristics were taken into account during the application and implementation of the automatic irrigation scheduling. Water consumption is decreased by (1) measuring irrigation consumption, (2) improving irrigation network efficiency, and (3) creating new frameworks and tools for water management. So, the application and implementation of automatic irrigation systems are encouraged to ensure a more rational allocation of water in the fields according to crop conditions [32].

There are many methods of automatic irrigation some of them can be shown as follows:

3-1 Automatic tensiometers

It is an instrument to record soil moisture. The indication needle on the Irrometer's gauge detects a vacuum when soil moisture is depleted. An adjustable selector switch can be set to any desired moisture level as shown in Fig. 6 [33]. [7] used automatic tensiometers for irrigation scheduling for pea crop. The tensiometer monitors soil moisture tension using the tension operation. The vacuum that the plant creates in the soil as it absorbs water for nutrition is known as soil moisture tension. The tension range for this force is 0-100 kilopascals (kPa), with a high value representing the dry end of the scale and a low reading suggesting the wet end.

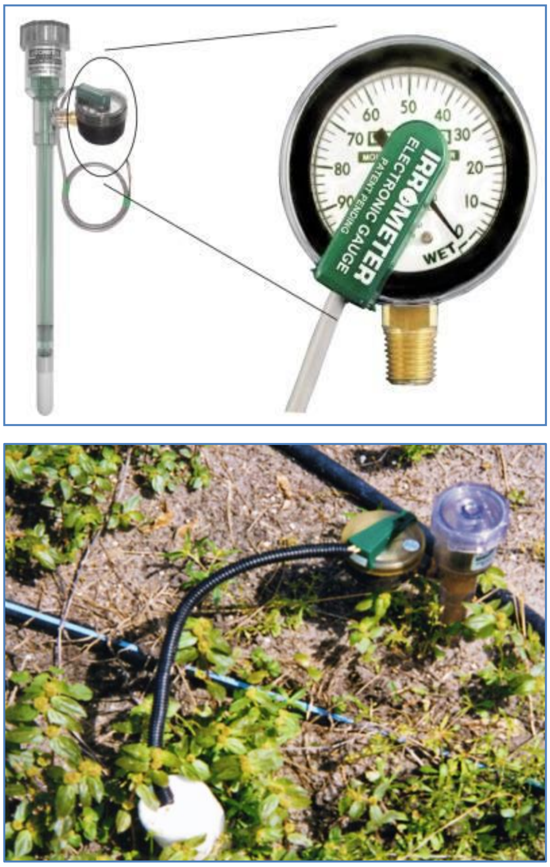
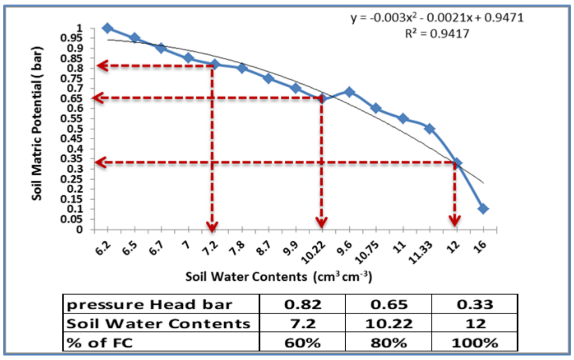


Fig. 6. Automatic Tensiometer; source: [7, 33].

3-1-1 Calibration of tensiometers

[7] calibrated the tensiometer (type of IRROMETER) to estimate soil water content versus moisture tension pressure (bar or kPa). Whereas, when the specified moisture content is reached, then this indicates the identical pressure, the automatic tensiometer gives the order to the solenoid valve to open or close.

[34, 35] recommended using the automatic tensiometer, to find the pressure that corresponds to the water content as a percentage of the field capacity. Whereas, at (100, 80, and 60%) soil moisture of FC the water content in soil is (12, 10.22, and 7.2 cm3 cm-3) and the identical pressure is 0.33, 0.65, and 0.82 bar, respectively. Fig. 7 shows the relationship between the negative pressure head and the moisture content in the soil.



pressure Head bar	0.82	0.65	0.33
Soil Water Contents	7.2	10.22	12
% of FC	60%	80%	100%

Fig. 7. Determination of pressure head meeting soil water contents; source: [34, 35].

3-2 Automatic using control panel

Irrigation controllers are sometimes called irrigation timers Fig. 8. There are more designs, a range of easy-to-use features and smart controller water saving options designed to fit any irrigation system. The automatic control panels are a modular design so that they are easy to use and expandable. Some controllers offer predictive water management features and access from anywhere in the world. Automatic irrigation control is preferred as an alternative to manual control as a tool for adding irrigation water. The use of automatic irrigation technology improved the water application efficiency and water productivity of cucumber yield under greenhouse conditions [36]. The same trend is obtained in water application efficiency, yield, and water productivity was obtained by [37, 38].

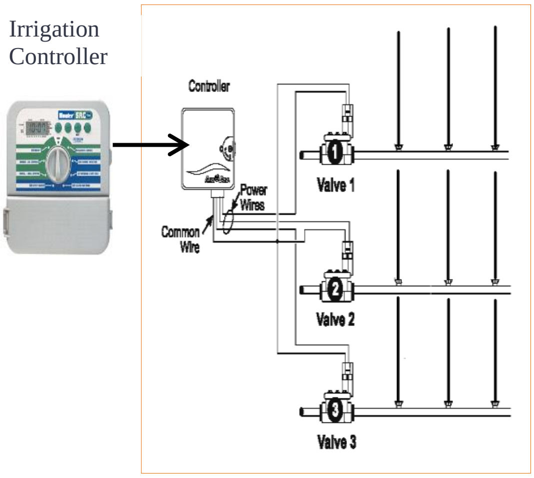


Fig. 8. Automatic irrigation system using control panel; source: [36].

4- Smart automatic irrigation and IOT

Smart irrigation technology has been developed to increase production without involving a large number of the workforce through detection of water level, soil temperature, nutrient content, and weather forecasting. Operation according to the microcontroller by operating or closing the irrigation pump. By utilizing several sensors, [39] created an automated model for the detection of moisture content and temperature as shown in Fig (9).

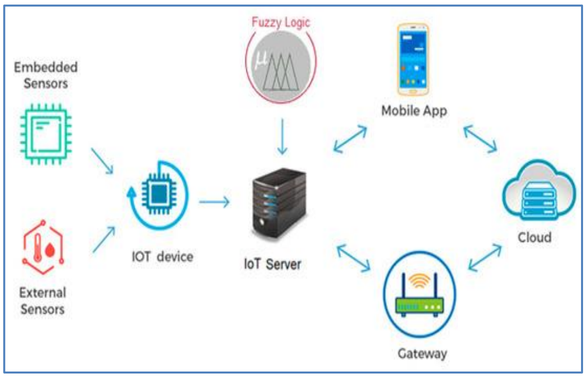


Fig. 9. Smart irrigation system for farming; source: [39].

[40] suggested a smart irrigation system that has software to provide daily irrigation needs of more crops and give details of crop water requirements based on actual soil moisture, humidity, and irrigation scheduling. This approach supports smart energy consumption along with saving water used Fig. 10 illustrates the smart farming system design tools.

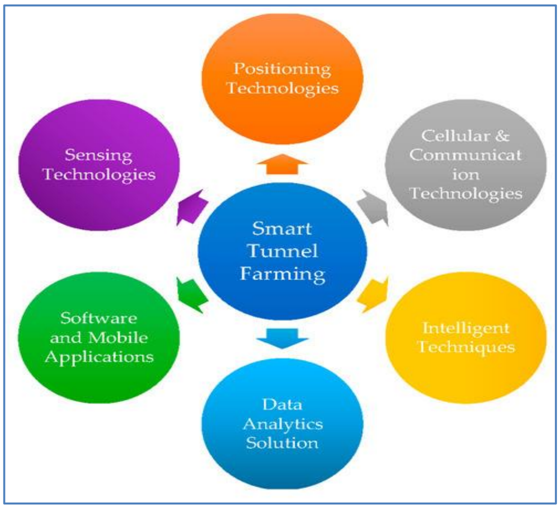


Fig. 10. The smart farming system design tools; source: [40].

An autonomous irrigation system that employs a GPRS unit as a communication tool was created by [41]. The system's microprocessor is configured to regulate water usage and carry out precise irrigation scheduling. It was established that the water savings exceeded the irrigation system's utilization by 90%. [42] also recommended the application of an Arduino automatic irrigation system to reduce labor usage and save time in the irrigation process. By updating and upgrading remote sensors with the use of Arduino technology, [43] developed a method of automatic irrigation systems, which may increase productivity by up to 40%. [44] created a different automatic irrigation system.

In order to increase crop growth and conserve water, several instruments and sensors are created for multiple purposes, such as the moisture sensor to measure the soil moisture content, another sensor to measure temperature, and a third sensor to regulate pressure. The output of all of these devices is turned into a digital signal and transferred to the multiplier over a wireless network like Zigbee or a hotspot, and digital cameras are also placed. Additionally, smart irrigation systems have uses outside agriculture, including the management of landscapes, gardens, and lawns to better control irrigation water consumption [45].

[46] contend that, given the physical limitations of natural resources such as land and water, the necessity for optimal use of land, water resources, and food security is inevitable. Therefore, all new technologies are necessary and required to address the problems of water management and use in addition to raising the performance of agricultural production operations. These techniques aim to reduce the volume of excess irrigation water through accurate estimation of soil moisture content as well as atmospheric humidity, or in different words estimation of air humidity surrounding plants in order to ensure the optimal use of water resources.

One of the most commonly used types of sensors for irrigation water management is the capacitive type soil water sensors [47].

Among the weaknesses of localized irrigation systems is the heterogeneous distribution of soil water, unlike sprinkler and flood irrigation systems, where irrigation water infiltrates and permeates most parts of the soil surface, while local irrigation leakage occurs directly in the area surrounding the emitter [48].

Therefore, one way to deal with the difference and disparity between sensors is the actual calibration in the implantation area for each sensor individually to have an operation after fixation [49].

[50, 51] emphasized that automated software tools are highly required for performing the repetitive functions and tasks of irrigation scheduling. One of the big problems with this issue is how to integrate the sensors into an automatic irrigation scheduling approach. This study demonstrated that the water balance method based on capacitive soil moisture sensors provides and gives a sound basis for scheduling automatic irrigation in different orchards.

[52] noted that using the Losant farm monitoring platform and informing the farmer by SMS or email is important if the system notices any problems. Losant is a simple platformer based on IoT. It gives real-time monitoring of the data stored in it regardless of the field location. The sustainability of the strawberry industry in Spain depends on increasing water usage efficiency due to the high demand for water and the rising demand for strawberries as an export product. Its sandy soil, however, makes irrigation management challenges. In order to schedule irrigation precisely under strawberry farming in Spain, [10] created a multi-platform program. In this paper, a multi-platform application has been built for a computer desktop program and a mobile application. It is a good tool that is easy to use for scheduling irrigation in the strawberry sector. The program uses climate data, soil data, and irrigation system information and provides farmers with irrigation scheduling. The application has been used on private export farms. The results showed that there is a saving in irrigation water between 11% to 33%, and it is clear from this that the efficient use of water is actually possible in strawberry production.

CONCLUSION AND RECOMMENDATIONS

Due to the limited water resources, the agriculture sector is the main consumer of water. It is one of the imperatives that the agricultural policy must adopt to work in all directions and by all means to rationalize water use and raise the water use efficiency in all aspects of use, especially agriculture.

Therefore, using automatic scheduling techniques for precision irrigation seems to be a promising smart approach for irrigation water control and saving. More experiments and improvement of the system are required to facilitate and prevail in its employment. The development of an automatic scheduling techniques system certainly has a positive effect on irrigation economics, which can save water and increase crop production.

REFERENCES

[1] Hozayn, M., Abdallha, M.M., AA, A.E.M., El-Saady, A.A. and Darwish, M.A., 2016. Applications of magnetic technology in agriculture: A novel tool for improving crop productivity (1): Canola. African journal of agricultural research, 11(5), pp.441-449.

[2] Abdelraouf, R.E., El-Shawadfy, M.A., Ghoname, A.A. and Ragab, R., 2020a. Improving crop production and water productivity using a new field drip irrigation design. Plant Archives, 20(1), pp.3553-3564.

[3] Abdelraouf, R.E., El-Shawadfy, M., Fadl, A. and Bakr, B., 2020b. Effect of deficit irrigation strategies and organic mulching on yield, water productivity and fruit quality of navel orange under arid regions conditions. Plant Archives, 20(1), pp.3505-3518.

[4] El-Shafie, A.F., Marwa, M.A. and Dewedar, O.M., 2018. Hydraulic performance analysis of flexible gated pipe irrigation technique using GPIMOD model.Asian Journal of Crop Science, 10(4), pp.180-189.

[5] Dewedar, O., Plauborg, F., El-Shafie, A. and Marwa, A., 2021a. Response of potato biomass and tuber yield under future climate change scenarios in Egypt. Journal of Water and Land Development, (49), pp.139-150.

[6] Dewedar, O.M., Plauborg, F., Marwa, M.A., El-shafie, A.F. and Ragab, R., 2021b. Improving water saving, yield, and water productivity of bean under deficit drip irrigation: Field and modelling study using the SALTMED model. Irrigation and Drainage, 70(2), pp.224-242.

[7] Abd El-Baset, M.M., Eid, A.R., Wahba, S., El-Bagouri, K. and El-Gindy, A.G., 2017. Scheduling Irrigation using automatic tensiometers for pea crop. Agricultural Engineering International: CIGR Journal, 2017, pp.174-183.

[8] Youssef, E.A., Abd El-Baset, M.M., El-Shafie, A.F. and Hussien, M.M., 2017. Study the applications of water deficiency levels and ascorbic acid foliar on growth parameters and yield of summer squash plant (Cucurbita pepo L.). Agricultural Engineering International: CIGR Journal, 2017, pp.147-158.

[9] Morillo, J.G., Martín, M., Camacho, E., Díaz, J.R. and Montesinos, P., 2015. Toward precision irrigation for intensive strawberry cultivation. Agricultural Water Management, 151, pp.43-51.

[10] Perea, R.G., García, I.F., Arroyo, M.M., Díaz, J.R., Poyato, E.C. and Montesinos, P., 2017. Multiplatform application for precision irrigation scheduling in strawberries.Agricultural Water Management, 183, pp.194-201.

[11] Al-Samarrai, K.I. and Sadeg, S.A., 2020. Precision irrigation efficient technologies practice in libya from the water and energy point of view. International Journal of Applied and Natural Sciences, 9(6), pp11:20.

[12] Abdulhadi, J.S. and Alwan, H.H., 2021. Evaluation of the scheduling of an existing drip irrigation network: Fadak Farm, Karbala, Iraq. In IOP Conference Series: Materials Science and Engineering (Vol. 1067, No. 1, p. 012024). IOP Publishing.

[13] Eid, A.R. and Negm, A., 2019. Improving agricultural crop yield and water productivity via sustainable and engineering techniques. Conventional Water Resources and Agriculture in Egypt, pp.561-591.

[14] Chen, X., Qi, Z., Gui, D., Gu, Z., Ma, L., Zeng, F., Li, L. and Sima, M.W., 2019. A model-based real-time decision support system for irrigation

scheduling to improve water productivity.Agronomy, 9(11), p.686.

[15] Dukes, M.D., Zotarelli, L. and Morgan, K.T., 2010.Use of irrigation technologies for vegetable crops in Florida.HortTechnology, 20(1), pp.133-142.

[16] Asif.M., Ahmad, M., Mangrio, A., Akbar, G. and Memon, A.H., 2015. Design, evaluation and irrigation scheduling of drip irrigation system on citrus orchard. Pakistan J. Meteorol.12 (23), pp.1–12.

[17] El-Shafie, A.F., Osama, M.A., Hussein, M.M., El-Gindy, A.M. and Ragab, R., 2017. Predicting soil moisture distribution, dry matter, water productivity and potato yield under a modified gated pipe irrigation system: SALTMED model application using field experimental data. Agricultural Water Management, 184, pp.221-233.

[18] Ewaid, S.H., Abed, S.A. and Al-Ansari, N., 2019. Crop water requirements and irrigation schedules for some major crops in Southern Iraq.Water, 11(4), p.756.

[19] Abdelraouf, R.E., El-Shawadf, M.A., Dewedar, O.M. and Hozayn, M., 2020. Improving yield and water productivity of canola under sprinkler irrigation and high frequency of N-fertigation. Asian Journal of Plant Sciences, 20(1), pp.143-156.

[20] FAO, Land and Water Division. 2018. CROPWAT Software, (accessed on 20 August 2022), Available online: http://www.fao.org/landwater/databases-and-software/cropwat/en/

[21] Pereira, L.S.; Allen, R.G.; Smith, M.; Raes, D., 2015. Crop evapotranspiration estimation with FAO 56: Past and future. Agricultural Water Management.147, pp.4–20.

[22] Allen, R.G.; Pereira, L.S.; Raes, D.; Smith, M., 1998. Crop Evapotranspiration—Guidelines for Computing Crop Water Requirements—FAO Irrigation and Drainage Paper 56; FAO: Rome, Italy.

[23] Valiantzas, J.D., 2013. Simplified forms for the standardized FAO-56 Penman–Monteith reference evapotranspiration using limited weather data. J. Hydrol., 505, 13–23.

[24] Liu, C.; Qi, Z.; Gu, Z.; Gui, D.; Zeng, F., 2017.Optimizing irrigation rates for cotton production in an extremely arid area using RZEWM2-simulated water stress. Trans. ASABE, 60, 114.

[25] Gu, Z., Qi, Z., Ma, L., Gui, D., Xu, J., Fang, Q., Yuan, S. and Feng, G., 2017. Development of an irrigation scheduling software based on model predicted crop water stress. Computers and Electronics in Agriculture, 143, pp.208-221.

[26] Clark, G.A., Rogers, D.H. and Briggeman, S., 2000, March.KanSched An ET-based irrigation scheduling tool for Kansas summer annual crops.In Proceedings for 2004 Central Plains irrigation conference, Kearney Nebraska, February 17-18.Colorado State University.Libraries.

[27] Cahn, M.D. and Johnson, L.F., 2017.New approaches to irrigation scheduling of vegetables.Horticulturae, 3(2), p.28.

[28] Martins, R.G., 2018. Analysis of irrigation scheduling technologies in maize.M. SC. Thesis, Agricultural Engineering Program, Federal University of Viçosa, Brazil.

[29] Lobell, D.B., Thau, D., Seifert, C., Engle, E. and Little, B., 2015. A scalable satellite-based crop yield mapper. Remote Sensing of Environment, 164, pp.324-333.

[30] Li, F., Yu, D. and Zhao, Y., 2019. Irrigation scheduling optimization for cotton based on the AquaCrop model. Water resources management, 33(1), pp.39-55.

[31] Goosheh, M., Pazira, E., Gholami, A., Andarzian, B. and Panahpour, E., 2018. Improving irrigation scheduling of wheat to increase water productivity in shallow groundwater conditions using AquaCrop.Irrigation and drainage, 67(5), pp.738-754.

[32] Masseroni, D., Moller, P., Tyrell, R., Romani, M., Lasagna, A., Sali, G., Facchi, A. and Gandolfi, C., 2018. Evaluating performances of the first automatic system for paddy irrigation in Europe.Agricultural water management, 201, pp.58-69.

[33] Boman, B., Smith, S. and Tullos, B., 2006. Control and automation in citrus microirrigation systems. Document No. CH194. Institute of Food and Agricultural Science, University of Florida Gainesville, Florida.

[34] Hozayn, M., Ali, H.M., Marwa, M.A. and El-Shafie, A.F., 2020.Influence of magnetic water on french basil (Ocimumbasilicum l. Vargrandvert) plant grown under water stress conditions. Plant Archives, 20(1), pp.3636-3648.

[35] Marwa, M.A., El-Shafie, A.F., Dewedar, O.M., Molina-Martinez, J.M. and Ragab, R., 2020. Predicting the water requirement, soil moisture distribution, yield, water productivity of peas and impact of climate change using SALTMED model. Plant Archives, 20(1), pp.3673-3689.

[36] El-Shafie, A.F., Marwa, M.A., Dewedar, O.M., Ghoname, A.A. and Abdelraouf, R.E., 2021. Assessment of Automatic Pulse Drip Irrigation Technique on Water Application Efficiency and Water Productivity of Cucumber Crop.Middle East Journal of Applied Sciences.11(1), pp.63-75.

[37] El-Shawadfy, M.A., Abdelraouf, R.E., El-Shafie, A.F. and Marwa, M.A., 2020. A new and innovative method for saving water, energy, fertilizers, reducing of soil salts accumulation and weeds growth under greenhouses conditions. Plant Archives, 20(2), pp.3126-3137.

[38] Abdelraouf, R.E.; Ghanem, H.G., A Bukhari, N. and El-Zaidy, M., 2020 c. Field and Modeling Study on Manual and Automatic Irrigation Scheduling under Deficit Irrigation of Greenhouse Cucumber.Sustainability, 12(23), p.9819.

[39] Shekhar, S., Colletti, J., Muñoz-Arriola, F., Ramaswamy, L., Krintz, C., Varshney, L. and Richardson, D., 2017. Intelligent infrastructure for smart agriculture: An integrated food, energy and water system. arXiv preprint arXiv:1705.01993.

[40] Munir, M.S., Bajwa, I.S., Naeem, M.A. and Ramzan, B., 2018. Design and implementation of an IoT system for smart energy consumption and smart irrigation in tunnel farming.Energies, 11(12), p.3427.

[41] Gutiérrez, J., Villa-Medina, J.F., Nieto-Garibay, A. and Porta-Gándara, M.Á., 2013. Automated irrigation system using a wireless sensor network and GPRS module. IEEE transactions on instrumentation and measurement, 63(1), pp.166-176.

[42] Jha, K., Doshi, A., Patel, P. and Shah, M., 2019. A comprehensive review on automation in agriculture using artificial intelligence.Artificial Intelligence in Agriculture, 2, pp.1-12.

[43] Savitha, M. and UmaMaheswari, O.P., 2018. Smart crop field irrigation in IOT architecture using sensors.International Journal of Advanced Research in Computer Science, 9(1).

[44] Varatharajalu, K. and Ramprabu, J. 2018. Wireless irrigation system via phone call & SMS. International Journal of Engineering and Advanced Technology. 8 (2S), 397–401.

[45] Snyder, R.L., Pedras, C., Montazar, A., Henry, J.M. and Ackley, D., 2015. Advances in ET-based landscape irrigation management. Agricultural Water Management, 147, pp.187-197.

[46] Todorovic, M., Lamaddalena, N., Jovanovic, N. and Pereira, L.S., 2015. Agricultural water management: Priorities and challenges. Agricultural Water Management Vol. 147: pp.1–3.

[47] Domínguez-Niño, J.M., Bogena, H.R., Huisman, J.A., Schilling, B. and Casadesús, J., 2019. On the accuracy of factory-calibrated low-cost soil water content sensors. Sensors, 19(14), p.3101.

[48] Irmak, S., Djaman, K. and Rudnick, D.R., 2016. Effect of full and limited irrigation amount and frequency on subsurface drip-irrigated maize evapotranspiration, yield, water use efficiency and yield response factors. Irrigation Science, 34, pp.271-286.

[49] Singh, J., Lo, T., Rudnick, D.R., Dorr, T.J., Burr, C.A., Werle, R., Shaver, T.M. and Muñoz-Arriola, F., 2018.

[50] Performance assessment of factory and field calibrations for electromagnetic sensors in a loam soil. Agricultural Water Management, 196, pp.87-98.

[51] Domínguez-Niño, J.M., Oliver-Manera, J., Girona, J. and Casadesús, J., 2020. Differential irrigation scheduling by an automated algorithm of water balance tuned by capacitance-type soil moisture sensors. Agricultural Water Management, 228, p.105880.

[52] Ramadan, A., Abdelbaset, M.M., Dewedar, O. and El-Shafie, A.F., 2022. Smart techniques for improving water use under the conditions of arid and semi-arid environmental areas: a review. Egyptian Journal of Chemistry, 65(132), pp.835-844.

[53] Kodali, R.K. and Sahu, A., 2016, December. An IoT based soil moisture monitoring on Losant platform. In 2016 2nd International Conference on Contemporary Computing and Informatics (IC3I) (pp. 764-768). IEEE.