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The study explores the scheduling methods for irrigation water and its role in rationalizing water use in response to climate change.

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Abstract

The limited irrigation water in light of the prevailing climate changes bad management of water resources, as the excess additions of irrigation water are a waste of both water and efforts at the same time, in addition to the washing and loss of nutrients and the deterioration of soil characteristics. Rationalising water use by following irrigation scheduling has become an urgent necessity. This article included a review of the most important methods used in scheduling irrigation. The gravimetric method has practical problems that cannot be avoided. It is possible to rely on electrical resistance panels to schedule irrigation when manufacturing a reader for this sensor through an electronic card. The method of neutron meds has disadvantages, including the health risk associated with exposure to neutrons and gamma ray. The useful limits for most tensile gauges are up to 0.8 bar as the maximum for pulling force. The use of the GS3 sensor is the best, as it is the most accurate to monitor soil moisture changes. The Diviner 2000 soil moisture sensor is a fast and accurate device to follow the change in the volumetric moisture content of the soil directly. The use of Aqua Crop under conditions of climate change makes it possible to simulate actual water consumption and water productivity. The SEBAL algorithm, a remote sensing technology, can aid decision-makers, researchers, and farmers in estimating evapotranspiration and enhancing irrigation water management at the field level.

Keywords: Irrigation scheduling methods, Climate change, Irrigation water.

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Introduction

Climate change poses serious threats to global food security due to changes in water requirements as a result of the difference and instability of the spatial and temporal distribution of rainfall, the lack of water, and other factors of agricultural production [1]. This water stress impacts around 99 million hectares of wheat-growing land and can lower grain yields on Average by17–70% [2]. Water resources are the main pillar in agricultural development and have a key role in the establishment of agriculture. Securing an adequate amount of these water resources is important for plant growth and agricultural development. The goal of all workers in the agricultural sector, whether they are engineers, agricultural extensionists, academics, or researchers, is to achieve food security, which has become necessary with the increase in the rate of population growth, and to achieve food security through agricultural expansion or development of agriculture horizontally, which led at the same time to an increase in water consumption [3]. Recent studies indicate to a decrease in irrigation water quantity due to climate change and a continued decrease in the area suitable for agriculture due to soil degradation in most of its physical, chemical, and biological properties as a result of misuse of irrigation water [4]. Iraq is located within the arid and semi-arid regions, which suffer from high summer temperatures, which lead to increased evaporation rates, in addition to the fact that rainfall rates have decreased and fluctuated in recent years [5]. The Tigris and Euphrates rivers' water revenues have significantly decreased in recent years due to low rainfall rates, and the decline is expected to persist due to their 75% water sources outside Iraq [6]. Figure 1 shows the decline in river levels in different regions of Iraq.

Figure (1): Low river levels for different regions of Iraq

There are many uses of water, as it is used in human, health, and industrial consumption, in addition to its uses in irrigation, which increased the demand for available water resources, including groundwater, which is the strategic reserve store of water, so the scheduling of irrigation for the purpose of achieving rationalisation of its use has become an urgent necessity, Since the scheduling of appropriate irrigation is the most important factor for crop growth and depends on soil systems, crops and atmosphere, it is possible to achieve moisture conditions and good oxygen content in the root zone along the growing season [7]. The addition of small amounts of water when irrigating is not enough to deliver soil moisture to the limits of field capacity, which may make the plant's benefit from the added water limited, and thus the plant will remain in a state of continuous water stress that leads to plant weakness and lack of productivity. The excessive use of irrigation water may increase the susceptibility of the soil and the need of the plant and be a cause of high ground water levels and soil salinization and degradation in addition to washing nutrients from the soil and deteriorating fertility. By applying the irrigation scheduling method based on the estimation of the soil moisture characteristics curve, we ensure high water use efficiency (WUE) in the management of irrigation operations, optimal investment of water resources, reduction of soil degradation, and increased soil productivity [8].

Irrigation and its relationship to some physical soil properties:

The irrigation process is one of the main pillars on which it depends to increase agricultural production, especially in arid and semi-arid areas, as the rainfall is insufficient to meet the crops' need for irrigation water.

Water pollution and high salinity lead to a deterioration in its quality and thus a shortage or deficit in water resources [9]. Irrigation is the addition of water to provide the root area with the moisture necessary for plant growth and to ensure its protection during the stages of drought and according to the stages of growth in a manner other than natural rain to reach the best productivity, whether in terms of quantity or quality [10]. [12,13] defined irrigation as adding water to the soil to achieve one of the following purposes:

1. Preparing the soil with the moisture necessary for plant growth; 2. Securing the crop against short-term droughts 3. Moisturising the soil and the surrounding atmosphere and creating more favourable climatic conditions for plant growth 4: Washing or diluting the concentration of salts in the root zone 5: reducing the risk of hardening of the surface crust of the soil; 6: facilitating various agricultural operations to serve the crop. The main objective of irrigation is to supplement the amount of rainfall in areas that depend on rainfall for irrigation and where rainfall may not be sufficient in terms of quantity and temporal distribution [13].

The physical properties of the soil are of great importance in their agricultural and engineering uses, where they have a major role in the processes of soil preparation and fertilization, and the introduction of new lands under irrigation. The agriculture system requires those engaged in irrigation and agriculture to be familiar with many factors and characteristics, part of which relates to the study of the physical soil, and related to irrigation, so we find it necessary to take note of some of the properties directly related to irrigation, The soil texture is an important factor to a large degree in determining the depth of water that can be stored at a certain depth of the soil, where we can divide the soil into three basic groups:

1- Coarse weaving soils, including (sandy and sandy mixed soils)
2- The medium weaving soils group includes (mixture, alluvial mix, alluvial mixture, sand mixture, clay mixture, sandy clay mixture and alluvial clay mixture).
3- Group of soft weaving soils, including (clay, sandy clay and alluvial clay)

Scheduling irrigation and its importance:

The scarcity and limitations of water resources call for a focus on the optimal use of water. A good management method is to control the amount of water given in each irrigation and the number of irrigations (irrigation scheduling). Irrigation scheduling is defined as the process of organizing or programming through which the date of irrigation, i.e., the irrigation interval per day, is determined in order for the plant to obtain its water needs in a timely manner, as well as determining the amount of water to be added in each irrigation (irrigation time) and according to the ability of the soil to hold water and the plant's need at different stages of growth to reach the highest productivity [14]. Maintaining the moisture content of the soil within the moisture content close to the field capacity and giving the optimal amount of water is the goal of scheduling irrigation that achieves high productivity, thus controlling the water losses caused by deep percolation and runoff [15]. The successful management of the irrigation scheduling process involves knowing the water efforts affecting the relationship of water with the soil and the plant and knowing the readiness of water for the plant, as the best plant growth occurs when there is a quantity of ready-made water sufficient for plant growth and the formation of the yield. In order to know the appropriate timing for the irrigation process as well as the amount of water added in each irrigation, three basic things must be understood: the water needs of the crop, the availability of water with which the irrigation process will take place, and the ability of the soil in the area of the spread roots to store water. Some irrigated areas suffer from limited irrigation water during some times of the growing season, especially summer, so the farmer sometimes resorts to irrigating the crop even if he does not need it during that period in order to increase the amount of soil stock of water [16]. Irrigation scheduling can be defined as a process for determining the irrigation time and the amount of water added and is important in improving water use efficiency and achieving the highest profit by reducing deep leaching and runoff and pumping costs, as well as increasing the quality of yield [17]. [18] stated that irrigation scheduling depends on soil, yield, atmosphere, irrigation system, and operating systems. The basic rule of scheduling is to know the daily use of water by the crop, the amount of water stored in the soil, determine the least moisture in the soil for each crop, and per soil, measure the amount of water that can be added to the field and estimate the additional water that comes from the atmosphere or ground water [19].

Water consumption:

Water consumption is defined as the sum of the water consumed by a plant to build its tissues, what remains inside it, or what is carried from the leaves to the atmosphere, as well as what is lost by evaporation from the soil and adjacent water surfaces. Water consumption is expressed at an equivalent depth of water in a unit of time called evapotranspiration, as it is difficult to separate the amounts of evaporation from transpiration under field conditions [8]. 5: Methods of estimating water needs and methods used in determining the date of irrigation Determining the amount of water needed by a given field is very important for the design of any irrigation project and for answering the question (when to irrigate and how much water to add to the soil) as well as the design of channels that transport this water to agricultural fields [8].

First: Methods of soil moisture studies water consumption of different crops is determined by conducting detailed studies of soil moisture, a method that gives realistic results when the soil is homogeneous with the depth and when the ground water is so deep that it does not contribute to the supply of soil in the root zone with any part of the moisture. To find out when to irrigate, how to irrigate and how much to irrigate water to add, we assume that the soil has volumetric moisture at the field capacity of 0.34 and at the point of permanent wilting of 0.12. The depth of the first irrigation will be calculated based on the following equation and according to the study applied by [20].

1. The first irrigation is given a depth of water before planting to create a moisture balance to a depth of 30 cm $d = (\theta fc - \theta wp) \times D$ .... (1)

Whereas: d = depth of water added (mm). θfc = volumetric humidity at field capacity ($cm^3\ cm^{-3}$). θwp = initial volumetric humidity before planting ($cm^3 cm^{-3}$). D = depth of root zone

2. Second irrigation: It is done when 50% of the ready water is exhausted. To find the ready water, the data from the humid description curve is used.

$Aw = \theta fc - \theta pw$................................ (2)

If: Aw = ready water. θfc = volumetric soil moisture at field capacity (%)

θwp = volumetric soil moisture at the point of permanent wilting (%)

The result is subtracted from the field capacity: 0.34 – 0.11 = 0.23. It represents volumetric soil moisture before irrigation, and there are multiple ways to determine it (when to irrigate).

1. Gravimetric method: (direct, non-localized, non-continuous method)

$$Pw = \frac{Mw}{Ms} \times 100 \quad \ldots\ldots(3)$$

PW: weighted humidity. Mw: Lost water mass. Ms: dry soil mass. Then the gravimetric humidity is converted to volumetric using the following equation:

$$\theta = pw \times \frac{\rho b}{\rho w} \quad \ldots\ldots(4)$$

where ρb = bulk density of soil (g cm^{-3}) , ρw = density of water = 1 (g cm^{-3}) This method depends on the conditions of taking models, transporting, and re-weighing, so it is accompanied by practical errors that cannot be avoided as it is a lengthy laboratory method, and sometimes the amount of water remains adsorption on clay minutes even after 105 degrees Celsius and that oxidize organic matter and decompose it at a temperature of 105 degrees Celsius and calculate it with the weight lost on the basis of evaporated water. This method works to provoke the area taken from it and may distort the notes and change the results. The gravimetric method has been used in determining the date of irrigation by many researchers [21,3], and [22], and a large number of researchers still rely on this method to determine the date of irrigation despite the resulting errors.

3.Electrical resistance block method: (indirect, localized, continuous) This method has been used by [20] as the electrical resistance mold consists of a gypsum mold buried inside it a pair of electrodes connected to the current meter by wires, the porous molds work to equalize with the tension of soil moisture (tensile structure) and the problems of this method (the need to calibrate porous panels with different soils, the need for the board to be in direct contact with the soil, The sensitivity of the panels in the dry range due to the porous nature of the board, the melting of the gypsum board), the electrical conductivity depends on the volume of the penetrating fluid and the amount of salts (ionic concentration) .

Calibration of electrical resistance panels:

It is necessary to calibrate the resistance plates with the moisture content and moisture tension of the soil in order to draw a standard curve and is used to know the soil moisture.

Calibration with moisture content:

It is often done in the field where the resistance plates are placed in the soil at different moisture levels and when the equilibrium state occurs, samples are taken from the soil and the moisture content is estimated (by gravimetric method) and then the measured resistance to electrical conductivity is recorded at each moisture content, and the standard curve is drawn, which represents the relationship between the reading of the device (resistance) and the moisture content of the soil, and Figure 2 shows the calibration curve for two soils using the electrical resistance plates device [21].concluded that the gypsum sensor has overcome the moisture tensile scale and the estimated method (weight) with the following characteristics: germination rate, plant height, leaf area, field water use efficiency, fruit productivity, economic yield, soft weight, and root weight. It can be relied upon in scheduling irrigation when manufacturing a reader for this sensor through an electronic card that allows alternating current to be passed to stimulate the normal resistance reading gauge, which plays the main role in stabilizing the readings obtained from the sensor.3- Neutron meds method (indirect, localized, continuous method) You need less laboratory work, fast, do not crack the soil, and can make measurements repeated periodically (in the same locations and depths), do not depend on temperature and pressure and its determinants (the high initial cost of the device, the low degree of spatial stability, the difficulty of measuring moisture in the surface layer of the soil, the health risk associated with exposure to neutrons and gamma rays); and do not depend on the components of the device (meds or sources of rapid neutrons, a mixture of beryllium and radium, a slow neutron detector or meter, and an source . Hydrogen absorbs the energy of fast neutrons and lowers their speed, the density of slow neutrons around the meds is roughly proportional to the concentration of hydrogen in the soil.

4. Moisture Tensiometer device method This method was used to determine the moisture tension, which is equivalent to soil moisture before irrigation, for the purpose of scheduling irrigation [21, 23, 24]. As the moisture content of the soil can be estimated using a tensiometer that measures the moisture voltage arising from the effort of the material, the tension gauge consists of a porous ceramic container linked to a tube representing the body of the device located at the end of a cover linked to a pressure gauge, and usually the scale is included in atmospheric pressure units, bar, water poison, mercury poison, or kilopascal, where it measures a pressure of 0.85
at (Figure 3).

The basic idea of the device is based on the occurrence of a balance between the water potential inside the device and the moisture tension of the soil when it comes into contact through the porous vessel when the device is placed at suitable soil depths. The recorded pressure can be read. The device is used to indicate the extent to which the soil needs irrigation, it is suitable for sandy soils than clay soils because the largest part of the available moisture in them is held at a tension of less than 100 kPa. The useful limits of most tensile gauges (tensiometers) are within (0.8 bar) as a maximum of the pulling force. Because the high drag force can cause air to enter the porous head, which will equalize the internal pressure with the atmospheric pressure under these conditions, the drag force of the soil may stabilize or increase even when the tensiometer fails [25]. [21] concluded that the botanical and environmental characteristics and irrigation efficiencies were improved when using moisture sensors (gypsum sensor and moisture tensile meter) compared to the adoption of the estimated method for estimating soil moisture in the surrounding soil in the root system.

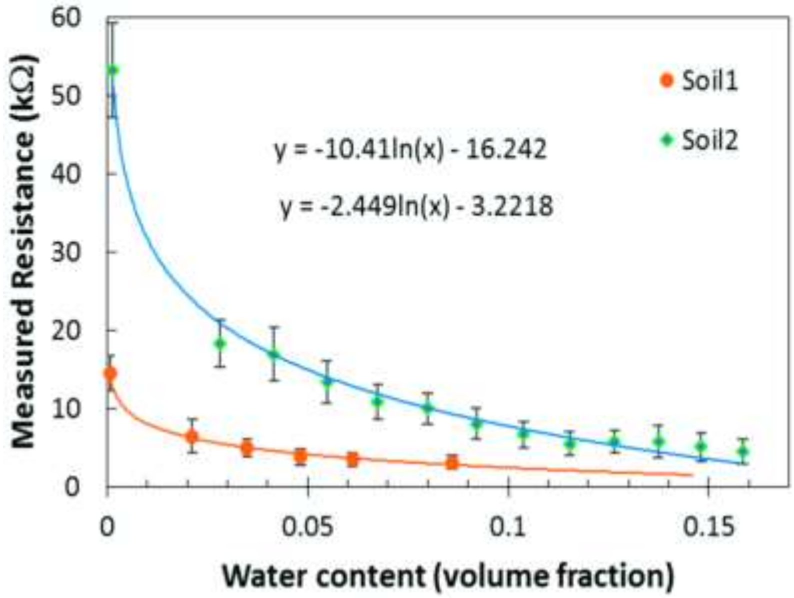

Figure (2): Calibration curve used with electrical resistance plates device to determine soil moisture before irrigation

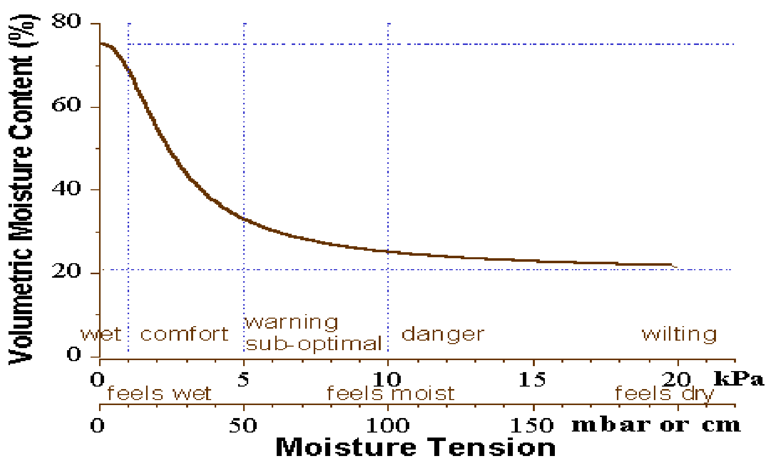

Figure (3): Calibration curve of the tensiometer used to determine soil moisture before irrigation

5- How to use sensors: This method was used to schedule irrigation using sensors to determine the soil moisture at which irrigation is carried out [26, 27]. A direct and continuous assessment of the moisture content of the soil is carried out using sensors to measure soil moisture in order to follow up on moisture changes in the soil and determine the irrigation time and the amount of water added. As The readings are taken from the soil by the sensor type GS3 from the area where the active roots of the plant are spread, and the process of taking the readings from the data logger devices is done with a computer. GS3 is the third generation of sensors that are more sophisticated, accurate, and to use and have the ability to measure three characteristics of soil: soil temperature, soil salinity, and soil moisture.

The sensor consists of a data storage box (EM50 Data Logger Figure 4). It contains an electronic panel connected to five electronic links through which five sensors can be connected via a 3.5 mm stereo cable, and these connect to a board containing a memory that has a high data storage capacity of 1MB and can store 360,000 readings for data entry. This panel also contains another link through which the computer communicates with the computer to output data, and this link is linked through a 3.5 mm stereo cable.

Figure (4): Em50 Data logger manufactured by the American company Decagon Devices

The device needs a very small power supply of 30 mA when the sensor is connected to the SDI-12. This box is programmed with Utility ECH2O, through which data can be stored and transferred to the computer, which in turn supports computer programs through which data can be represented through the 3 Data Trac program to draw and represent data during the study period. As for the installation and cultivation of the sensor in the place of measurement, the sensor is placed in the soil (Figure 5) either vertically or horizontally with the mass of roots or the area to know its characteristics, such as moisture, salt or thermal content [28].

Figure (5): Installing sensors used in scheduling irrigation in one of the greenhouse fields

[26] concluded that the use of the GS3 sensor is the best as it is the latest and most accurate to monitor the thermal, moisture and salt changes of the soil within the root zone during planting with its auxiliary programs, as the main goal of its use is to know the date and period of irrigation necessary to meet the water needs of the cultivated crop.

There are other types of sensors used in determining soil moisture before irrigation, such as the soil moisture sensor type Diviner 2000 [29], which is one of the modern devices that is fast and accurate in following up on the in the volumetric moisture content of the soil directly, (Figure 6). Among the researchers who relied on this type of sensor in determining volumetric soil moisture before irrigation [30], who recommended the need to use advanced soil moisture sensors such as (Diviner 2000 and Decagon) in directly predicting the depletion of ready-made water in the root zone and according to the stages of growth and determining the timing of irrigation in order to reduce water losses and rationalize water use in the agricultural sector.

After the volumetric soil moisture (0.23) is determined by one of the methods referred to above, the depth of water added in each irrigation is calculated. When relying on the method of soil moisture studies, and assuming the depth of the root zone (D = 30 cm), the following equation is used as mentioned in [31].

Figure (6): Diviner 2000 Parts

Second: - The use of the evaporation basin as evidence of the date of irrigation The class A evaporation basin used by the United States Bureau of Meteorology is the most common and consists of a round galvanized iron bowl with a diameter of 120 cm and a depth of 25 cm, placed with a wooden clip to allow air to move, and filled to a depth of 20 cm [8]. The water level is measured by a scale placed in a cooling well attached to Figure (12), and evaporation is calculated from the difference in levels after taking into account the amount of rainfall falling. This method was applied by [32,33,34], and to clarify the method of using the basin as an indicator to determine the date of irrigation, we assume that the crop to be irrigated is sorghum in the vegetative growth stage, that the coefficient of conductivity (Kc = 0.65) is mentioned in [35], that the depth of the root zone (D = 20cm), volumetric soil moisture at field capacity, and the point of permanent wilting are (0.34, 0.12) cm^3 cm^{-3} , respectively, and that the crop is irrigated when 50% of the ready water is exhausted, as follows:

1. The depth of the added irrigation water is calculated.

$D = (\theta fc - \theta ir) \times D$

θir = the volumetric moisture of the soil before irrigation has been determined by predetermined calculation steps.

2. The evaporation-reference transpiration (ET_0) is calculated according to the equation mentioned in [7] as follows:

$$ET0 = \frac{ETa}{Kc} \quad \ldots\ldots(5)$$

ETo= Evaporation – Reference transpiration ($mmday^{-1}$),

ETa = Evaporation – Actual Transpiration = 22 mm

Kc = yield coefficient = 0.65

3. The timing of irrigation is done by knowing the amount of water lost from the basin Epan as in the equation mentioned in [8] as follows:

$$Epan = \frac{ET0}{Kpan} \quad \ldots\ldots(6)$$

Epan = Evaporation from the aquarium ($mm.day^{-1}$),

Kpan = is a coefficient for the evaporation basin that varies according to the type of basin, the vegetation surrounding the basin, and the nature of the soil surface. In a study carried out by [19], the value was adopted at 0.85, as mentioned in [36].If the irrigation process is carried out when 40 mm evaporates, equivalent to a volumetric humidity of 0.23, and the evaporation basin is used as a preliminary indicator in order to instruct taking soil samples from the field and estimating the remaining moisture in the soil actually by the gravimetric method, and the process is repeated, until 50% of the available water is exhausted for the plant, then the soil moisture is determined when actually irrigating [37].

Figure (7): Evaporation basin used to determine the irrigation date in a research experiment [20]

Third: indirect or estimated methods Various mathematical equations and formulas were used to estimate evaporation and transpiration from climate data, such as :

1. as Equation Kharrufa, which was relied upon in scheduling irrigation by [39], where a fixed irrigation interval (3 days) was adopted throughout the growing season and seasonal water consumption reached 467.40 mm season^{-1} and as in the following equation:

$$NDI = II \times Kc \times (UP)Tc^{1.3} \quad \text{.........\ ....(7)}$$

Whereas: NDI= net irrigation depth (mm), II = irrigation interval (day), Kc = yield coefficient U = local coefficient calculated for each site from the available climate data rates for the months of December, January, February March, and April and is equal to 0.34 for the central location of Iraq. P = the ratio of the number of daylight hours per month to the number of hours per year. TC1.3= average monthly temperature, °C. [23] studied water consumption in different ways under the drip irrigation system and found that the evaporation basin treatment gave the highest value to seasonal water consumption compared to the rest of the coefficients, reaching 772, 723, 668, and 595 mm season^{-1} for the treatment of the evaporation basin, Najib Kharrufa, the tensiometer, and the moisture sensor, respectively. The half-tensiometer treatment gave the highest water use efficiency of 8.53 kg m^{-3} for the potato crop compared to the rest of the treatments. It was recommended to adopt the tensiometer (tensioner) and moisture sensor in calculating water consumption in coarse weaving soils.

2. FAO modified Penman–Monteith equation for the estimation of ET_0 [35] using Cropwat computer software [40]. It was applied by the researcher [1] as the climate data for the time period 2009-2019 (climate data period) was calibrated to simulate and calibrate the Aqua Crop program under climate change conditions and assess climate change adaptation actions. This step was carried out according to [41]. One of the most important findings of [1] is that the AquaCrop model was able to simulate the biomass above the soil surface, dry matter yield, harvest index, water productivity, grain yield, and actual water consumption, as the statistical comparison values indicated a high agreement between the measured values and the predicted values. The Pennman-Monteith equation was also adopted by [42] in the calculation of evaporation-transpiration.

$$ET_0 = \frac{\left[o.408 \times \Delta(Rn - G) + \gamma\left[\frac{900}{T+273} U2(ea - ed)\right]\right]}{\Delta + \gamma(1 + 0.34U2)} \quad \ldots$$

Whereas: ET_0 = evaporation-transpiration of the reference crop (mm day^{-1}).
Rn = net radiation at the crop surface (Megajoule, m^{-2}, day^{-1}).
ea–ed = decrease in vapor pressure (kPa).
T = average daily air temperature at 2°C (m□).
= EA saturated vapor pressure (kPa). ed = real vapor pressure (kPa). U2 = wind speed measured at an altitude of 2 m (m, s^{-1}). = slope of vapor pressure curve (kPa, m□). Y = the psychometric constant (kPa, m□). 900 is the conversion factor.

3. Estimation of evaporation and transpiration using remote sensing techniques: - This technique was applied by [43], as satellite views were taken for the study area, and the Earth's surface energy balance algorithm (SEBAL) was used to estimate transpiration evaporation for the months of the study and compare it locally and temporally. One of the most important results reached by it is the existence of a good linear regression relationship between the ET_0 values estimated from CEBAL with both the ET_0 values recorded from the atomometer and from the Pennman Monteith equation, as the regression values were 0.9508 and 0.9913 on Relay. The results of this study can be used by decision makers, researchers, and farmers to estimate evapotranspiration and improve field-level irrigation water management using both the Sibal remote sensing (remote sensing) satellite method and the automometer method.

Conclusions

1-The goal of irrigation scheduling is to maintain the moisture content of the soil within the limits of field capacity, which achieves high productivity, and reduces water losses.
2-The addition of small amounts of water when irrigating is not enough to deliver moisture to the limits of field capacity may make the plant's benefit from the added water limited and thus the plant will remain in a state of continuous water stress
3-The adoption of the gravimetric method in determining the soil moisture at which irrigation is carried out is a long method and is accompanied by practical errors that cannot be avoided.
4-It is possible to rely on the gypsum sensor in scheduling irrigation when manufacturing a reader for this sensor through an electronic card that allows alternating current to be passed to stimulate the resistance reading meter
5- Plant and environmental characteristics and irrigation efficiencies improve when using moisture sensors (gypsum sensor and moisture tensile meter) compared to the adoption of the gravimetric method.
6- The useful limits of most tensile gauges are within (0.8 bar) as a maximum for the drag force, because the high drag force can cause air to enter the porous head, which will equalize the internal pressure with atmospheric pressure.
7- The use of the GS3 sensor is the best being the latest and most accurate to monitor the moisture changes of the soil with its auxiliary programs
8- The AquaCrop model was well able to simulate water productivity and actual water consumption, as the statistical comparison values indicated a high compatibility between the measured values and the predicted values.
9-The use of both the Sibal remote sensing model method by satellites and the atomometer method can be used by decision makers, researchers and farmers to estimate evapotranspiration and improve irrigation water management at the field level.

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دراسة جدولة مياه الري ودورها في ترشيد استخدام الماء في ظل التغيرات المناخية

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الخلاصة

ان محدودية مياه الري في ظل التغيرات المناخية السائدة وسوء ادارة الموارد المائية اذ تعد الإضافات الزائدة من مياه الري تبذيراً لكل من المياه والجهود في آن واحد، فضلاً عما تسببه هذه العملية من غسل وفقدان للمغذيات وتدهور صفات التربة. ولذا اصبح ترشيد استخدام المياه باتباع جدولة الري ضرورة ملحة. تضمنت هذه المقالة مراجعة لاهم الطرق المتبعة في جدولة الارواء. ان الطريقة الوزنية لها مشاكل عملية لا يمكن تجنبها. من الممكن الاعتماد على الواح المقاومة الكهربائية في جدولة الارواء عند تصنيع قارئ لهذا المتحسس عن طريق كارت الكتروني ، ان لطريقة المدس النيتروني مساوئ منها الخطورة الصحية المرافقة للتعرض للنيوترونات واشعة كاما . الحدود المفيدة لمعظم مقاييس الشد تكون بحدود (0.8 بار) كحد اعلى لقوة السحب. ان استخدام المتحسس GS3 هو الافضل كونه الادق لمراقبة التغيرات الرطوبية للتربة . ان متحسس رطوبة التربة نوع Diviner 2000 من الاجهزة السريعة والدقيقة في متابعة التغير في المحتوى الرطوبي الحجمي للتربة بشكل مباشر. ان استخدام برنامج Aqua Crop تحت ظروف التغيرات المناخية تمكن وبشكل جيد من محاكاة الاستهلاك المائي الفعلي وانتاجية المياه. ان استخدام تقانات التحسس النائي (خوارزمية SEBAL) يمكن ان يستعملها صناع القرار والباحثين والمزارعين لتقدير التبخر نتح وتحسين ادارة مياه الري على مستوى الحقل.

الكلمات المفتاحية: جدولة الارواء–التغيرات المناخية–مياه الري.