UNIVERSITÀ DEGLI STUDI FIRENZE
DEPARTMENT OF AGRICULTURAL, FOOD AND FORESTRY SYSTEMS

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UNIVERSITÀ DEGLI STUDI DI FIRENZE
FIRST LEVEL MASTER DEGREE IN

IRRIGATION PROBLEMS IN DEVELOPING COUNTRIES

"Assessment of water requirement and Irrigation scheduled by using of subsurface drip irrigation for *Tomato*(*Solanaceae)* with support of FAO cropwat in Abu Ghraib "

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DEDICATION *To*

My father and mother

My wife and children

Brother and sister

All my friends

All the students

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LIST OF ABBREVIATION AND ACRONYMS

CWR	Crop Water Requirements
Dec.	Decade
ET	Evapotranspiration
ETc	Crop Evapotranspiration
ETo	Reference Evapotranspiration
FAO	Food and Agriculture Organization
FC	Field capacity
Ha	Hectare
HWSD	Harmonized World Soil Database viewer 1.2
IAO	Istituto Agronomico per l’Oltremare
IRR	Irrigation Requirements
Kc	Crop coefficient
Kcb	Basal crop coefficient
Ke	Evaporation coefficient
α	Sorptivity
Sat.	Saturation
TAW	Total available water
USAD	United States of America, Agriculture Department
WPW	Permanent wilting point
KCb (Tab)	the value for KCb mid or KCb end (if ≥0.45)
Kc	crop coefficient
KCb	Basal crop coefficient
Ke	soil evaporation coefficient
Ks	water stress coefficient
h	crop height [m]
RHmin	daily minimum relative humidity [%]
U2	wind speed at 2 m above ground surface [m s-1]

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ABSTRACT:

a study was carried out to Assessment of water requirement and Irrigation scheduled by using of subsurface drip irrigation for Tomato with support of FAO cropwat in Abu-Ghraib with using information technologies models, by Google earth was located the study area, Then CLIMWAT 2.0 was used to import climate data from Baghdad station which is near to Abu-Ghraib, and collected soil Characteristics data by HWSD 1.2 model, with choose Tomato crop properties in FAO CROPWAT 8.0 model. Estimating irrigation water requirements accurately is important for water project planning and management also maximum yield per unit water applied should be more efficient use of irrigation water that mean the provision of additional quantities of water to increase the irrigated area with optimum Tomato yield production and Improving water productivity by using subsurface drip irrigation. Assess production of Tomato under new techniques and predicated the water requirement and irrigation scheduled by used of Cropwat to increase the water productivity and Iraqi farmers applied of huge quantity of irrigation water for Tomato because of hot climate in particular at summer season. Huge quantity of irrigation water will lose by evaporation into the soil. Recently some researchers were introduced the subsurface drip irrigation as new technology to save the irrigation water applied but this new technology need more knowledge regard to water requirement and scheduling of irrigation by use of cropwat.

I- INTRODUCTION

1.1 General Objective

In an agriculture in constant evolution, irrigation needs to adapt to new, more stringent requirements: the supply of water within large irrigated systems needs to be much more reliable and flexible than in the past. The last 50 years have seen remarkable developments in water resources and in agriculture Massive developments in hydraulic infrastructure have put water at the service of people while the world population grew from 2.5 billion in 1950 to 6.5 billion today the irrigated area doubled and water withdrawals tripled Agricultural productivity grew thanks to new crop varieties and fertilizers, fueled by additional irrigation water. World food production outstripped population growth. And the greater use of water for irrigated agriculture benefited farmers and poor people propelling economies, improving livelihoods and fighting hunger. But much unfinished business remains. In 2003, 850 million people in the world were food insecure, 60% of them living in South Asia and Sub-Saharan Africa, and 70% of the poor live in rural areas. In Sub-Saharan Africa the number of food-insecure people rose from 125 million in 1980 to 200 million in 2000. FAO has developed a multi-language training package for modernization and rehabilitation of large scale irrigation schemes and has applied it in 20 countries (fao2013/Natural resources /irrigation)

The new challenges in water management posed by the increase in population and the pressure to use water resources efficiently mean that the institutions in charge of water management should be either reformed or created so that countries are able to cope with these new demands. These institutional reforms might take different forms depending on the local conditions and the specific aims of the reform. In order to illustrate different alternatives on how these reforms can be pursued NRLW has published guidelines on the transfer of irrigation management transfer. More recently, an International E-mail Conference on Irrigation Management Transfer was organized by **FAO and INPIM**. Irrigation advisory services can play an importantly role in assisting users to adopt new techniques and technologies for more efficient water use and increased production. Such services can be provided by private, public or co-operative agencies. Increasingly commercial agencies can take over the traditional role of the public agencies, although often restricted to the more lucrative parts of irrigation sector. Critical in the promotion of irrigation advisory services is the financial sustainability of such institutes, as in particular in many developing countries inadequate funding is available to finance public services. In order to focus attention on the vital role irrigation advisory services can play in achieving a more effective water use for sustainable crop production, FAO and ICID organized an International workshop on Irrigation Advisory Services and Participatory Extension in Irrigation Management in Montréal on the 24 July, 2002, during the ICID conger Water productivity means growing more food or gaining more benefits with less water to feed a growing and wealthier population with more diversified diets will require more water for agriculture on an average annual basis. There is considerable scope for improving physical water productivity, but not everywhere increasing water productivity, especially the value produced per unit of water, can be an important pathway for poverty reduction in water productivity. The adoption of techniques to improve water productivity requires an enabling policy and institutional environment that aligns the incentives of producers, resource managers, and society and provides a mechanism for dealing with tradeoffs An assessment of the potential for reducing water needs and increasing production and values requires an understanding of basic biological and hydrological crop-water relations. Answering the question of how much more water will be needed for agriculture requires understanding the connections among water, food, and diets. The amount of water that we consume when eating food depends on diet and on the water productivity of the agriculture production system. (Fao/Natural resources and environment department 2013)

1.2 Specific Objective :

- Improving water productivity by using subsurface drip irrigation.
- Assess production of tomato crop under new techniques and predicated the water requirement and irrigation scheduled by used of Cropwat to increase the water productivity.
- Estimating Reference Evapotranspiration.
- Estimating of crop water requirements for tomato production.
- Estimating Irrigation scheduling for tomato crop production.

1.3 Background and Justification

Iraq is one of the Middle East and North African countries (MENA region). The country is currently facing a serious water shortage problem. This problem is expected to be more severe in the future where the supply is predicted to be 43 and 17.61 Billion Cubic Meters (BCM) in 2015 and 2025 respectively while current demand is estimated to be between 66.8 and 77 BCM. It has been estimated that the Tigris and Euphrates river discharges will continue to decrease with time, and they will be completely dry by 2040. Serious, prudent and quick measures need to be taken to overcome this problem. The government should take measures to have a strategic water management vision, including regional cooperation and coordination, research and development, improving agriculture and sanitation sector as well as public awareness program (Nadhir A. AL-Ansari2013).

The total area of Iraq about 435 million hectare (m/ha) with 6 m/ha under cultivable is 12 m/ha with breakdown of 8 m/ha in the irrigation area and 4 m/ha in rain feed area. The Mesopotamian forming about 25% of the total area of Iraq. The salts affected soils were occupied about 75% of this area in various degrees. Iraq has many problem in agriculture sector which are salinity, declining in physical, chemical and fertility properties. As well as Iraqi soil has high level of water table and has different source of irrigation water for irrigated their cultivable land which are mainly Tigris and Euphrates River and Iraqi agriculture economy by these twin river. At the present time the practices of farm crop irrigation has utilized several source of relevant water like ground water, and drainage water, especially after a shortage in water resource income from Turkey.

The problem of irrigation water in Iraq is a concept covering several items which are: low water productivity, declining of water quality, shortage in water resources when new dams a long two rivers in Turkey and Syria are developed. Meanwhile primitive of irrigation methods used and low rainfall. All these issues are synchronized with researches of water used as well as the defect in water regulation which controlling on use of water by communities.

Climate and soil diversity in Iraq makes it good for tomato production over the whole year through the use of modern cultivation techniques and hybrid seeds. In the winter, tomatoes are produced in the desert area of al-Zubayr and Samawa and in spring from Diwaniya plantations, together with and Najaf and Karbala. In the summer, tomatoes are produced in the Kut areas, in Nu'maniyah and also areas of Diyala and Al khales. In autumn production is from Kirkuk, Mosul and Sinjar, Tomato ranks first among vegetable crops in terms of planted area, production and consumption. Tomatoes are consumed either fresh or processed and have significant nutritional value and are an important source of lycopene, which is a powerful antioxidant that acts as an anti-carcinogen. They also provide Vitamins A, B and C, potassium, iron and calcium. It production in Iraq is challenging due to the lack of water resources, the high salinity of some irrigation water, a lack of suitable pesticides and chemical fertilizers and can be successfully cultivated in a range of soils including sand and even heavy clay.(Bayer Crop Science Company /Iraq).

1.4 Iraq information

- **Topographical :**

Iraq is located in the Middle East along the Iran and between Iran and Kuwait. It has an area of 169,235 square miles (438,317 sq. Km). The topography of Iraq varies and consists of large desert plains as well as rugged mountainous regions along its northern borders with Turkey and Iran and low elevation marshes along its southern borders. The Tigris and Euphrates Rivers also run through the center of Iraq and flow from the northwest to the southeast.

(Amanda Briney /master degree California State University).

The geography of Iraq is diverse and falls into four main regions: the desert (west of the Euphrates), Upper Mesopotamia (between the upper Tigris and Euphrates rivers), the northern highlands of Iraqi Kurdistan, and Lower Mesopotamia, the alluvial plain extending from around Tikrit to the Iran , The mountains in the northeast are an extension of the alpine system that runs eastward from the Balkans through southern Turkey, northern Iraq, Iran, and Afghanistan, eventually reaching the Himalayas. The desert is in the southwest and central provinces along the borders with Saudi Arabia and Jordan and geographically belongs with the Arabian Peninsula (Wikipedia.org/ geography of Iraq).

- **Climate:**

The temperatures are more or less similar throughout the country except in the mountain areas in the northeast. The monthly mean maximum temperatures for July range from 38 C° at Rutba to 43 C° in Baghdad. The highest maxima in June, July, and August range between 43 C° and 50 the monthly mean minima for January range between 1 C° in the south western desert and the north eastern foothills to 8 C° in the central part of the river plain. The lowest minimum is about -14.5 C° in the northern desert, -11 C° in the foothills and -8 C° in the central part of the river plain. Even at Basra near the coast the lowest minimum is -4.5 C°, showing the effect of cold waters.

The dominant winds are from the northwest and north in the central and northern parts of the country. In the south they are from the west and northwest, so north-westerly winds are the most dominant. Dust storms are quite common in the desert and the Mesopotamian plain, occurring mainly in the early summer months but also in midsummer as well. The wind speed may reach 100 km per hour. Baghdad has on an average 23 major dust storms in a year. Sometimes the whole country is enveloped in a cloud of very fine dust. According to an estimate, 2.5 mm of dust falls on the whole area of Iraq every year on the average. Comprises the flood plains and the old flood plain (an old river terrace) in the lower Mesopotamian plain, lying north of Hila and Kut and south of Adhaim River but including a small area north of this river.

The climate is arid subtropical continental with very hot and completely dry summers and cold winters having some rain. The mean maximum temperature in July and August is about 43 C° but during heat waves the temperature shoots up to 49 C° Dust storms are common in summer. High temperature and winds combine to cause very high evaporation, about 10 mm per day during June, July, and August. The winter is cool with mean minimum temperature of 4.5 C° in December and January but the minimum temperature dips down to – 7 C° during cold waves which are experienced intermittently during December and January. The mean annual rainfall ranges from about 120 mm in the south to about 160 mm in the northeast, occurring in winter and spring.

The soils are mostly silt clay loams and silty clays formed in river basins. They are layered with soil materials ranging in textures from silty clay loam and silty clay to very fine sand. The surface layer 20 to 50 cm thick has usually poor physical condition with low porosity and slow permeability. Most of the area is saline with a water table of 2-3 meters deep. However, some parts have only a minor salinity problem.

Apart from basin soils there are loamy soils formed on river levees which are three to four meters higher than the basins. Being well drained and non-saline, these are mostly under fruit orchards (dates, oranges, pomegranate, grapes, figs etc.) and vegetables. Under irrigation, they are amongst the most productive soils in the world. Then there are basin depressions surrounded by medium level basin soils or irrigation silt deposits. (fao.org/ tarah mohamad)

- **Water Resource**:

Water Supply and Sanitation in Iraq is characterized by poor water and service quality. Three decades of war, combined with limited environmental awareness, have destroyed Iraq's water resources management system. Thus, Iraq faces difficulties to realize the target of 91% of households using safe drinking water supply by 2015. Currently, 16% of households report daily problems with supply and 20% use an unsafe drinking water source. Furthermore, leaking sewage pipes and septic tanks pollute the drinking water

Iraq is generally divided into three river basins: the Tigris, the Euphrates, and the Shatt Al-Arab. The average annual flow of the Euphrates as it enters Iraq is estimated at 30 km3 and that of Tigris at 21.2 km3. While 50% of the Tigris water comes from within Iraq, more than 90% of Euphrates water comes from outside the country. Unlike the Euphrates, the Tigris has few tributaries all located on its left bank including the Greater Zab which generates 13.18 km3 at its confluence with Tigris, the Lesser Zab which generating 7.17 km3, the Al-Adhaim generating 0.79 km3 and Diyala river generating 5.74 km3. The total length of the running rivers in Iraq is about 4,773 km, with the Tigris and Euphrates accounting for 1,290 km and 1,015 km, respectively.

The gross irrigation water requirements, estimated at 75 billion m3 annually, are usually supplied from surface water resources, namely the Euphrates and Tigris rivers and their tributaries. In order to increase the water transport efficiency, minimize losses and water logging, and improve water quality, the River was constructed. the river functions as a main out-fall drain collecting drainage waters between the two main rivers the Euphrates and the Tigris for more than 1.5 million ha of agricultural land from north of Baghdad to the Gulf. It has a watercourse of 565 km and a total discharge of 210 m3 per sec. Other watercourses were constructed to reclaim new lands or to reduce water logging. Major watercourses are also under construction including East Al-Gharraf Drain and Tigris East Drain originating from south of Hila and south of Al-Kut respectively; both ending in Nasiriya.

The recent severe shortage in rainfall in the basin areas of Iraq's major rivers and lack of snow cover over the catchments areas of these rivers, in addition to the reduction in water released downstream from dams constructed in the riparian state in Turkey has altogether diminished the volumes of water flowing in the Iraqi rivers. The total flow in all Iraqi rivers recorded during 98/99 and 99/00 was about 40% of the general total average. Consequently, irrigated cropping areas were diminished for the two growing seasons with production and productivity severely affected.(fao.org)

- **Agriculture:**

Since ancient days Iraq was known as the valley of the two rivers Mesopotamia. Its bountiful land, fresh waters, and varying climate contributed to varying climate contributed to the creation of deep-rooted civilization that had festered humanity from its affluent fountain since thousands of years.

Iraq is situated between longitudes (38° 48'E) and between latitudes (29°37 N). In length from north-west to south-east it approximates (1 000 Km) and in width it approximates (1 000 Km) and in width about (500 Km), The widest region from the Jordan to the Persian border near Rawandoz will be about 750 Km. In area it covers about 4 444 500 sq. Km. more than half of this area, comes strictly under the end zone. Being not far away (about 400 Km.). From the Mediterranean Sea on the west, about 1 000 Km. from the Red Sea on the south-west and almost same distance from Black Sea on the north and practically touching the Arabian Gulfat its southern limit. Its climate is considerably influenced by the atmospheric condition of these vast water sheets.

The climate of Iraq in general is arid and continental having very hot summers and sever cold winters with less rainfall in the south and in the middle and much rainfall in the north. The precipitation on the northern part of the country is sufficient to support the winter crops, while in the middle and in the south part of Iraq cultivation depends on irrigation both in the winter and in the summer, In the desert area precipitation is very low and usually it rains during the winter months, No doubt, Iraq occupies an excellent geographic position where it encompasses mountainous areas in which temperature drops below zero, desert areas of very high temperatures, and pelagic humidity impregnated areas. All these factors gave large a special geographic characteristic scarcely acquired by any other country. The enjoyment of such a peculiar geographic position by Iraq led to the creation of different environments that helped considerably in the diversification of its agriculture .The major agricultural crops constitute :(Wheat, Barely, Maize, little Rice, while Cotton stopped now, and other industrial crops),Many vegetables are grown by individual farmers(2003-2007) like(Tomatoes, Potatoes, Egg-plant, Cauliflower, Cabbage, Lettuce, Melon and water melon, Cucumber, Beans, Okra, Onion, Pepper, etc..),(Mrs.S.A.ALSheick/Baghdad, october2007).

Tomato (**Solanum lycopersicum**) the edible fruit of the tomato plant has a range of uses in fresh and processed form. Breeding and selection techniques have yielded hundreds of cultivars that are suited for the myriad purposes for which the fruit is cultivated. Tomatoes have significant nutritional value and are an important source of lycopene, which is a powerful antioxidant that acts as an anti-carcinogen. They also provide Vitamins A, B and C, potassium, iron and calcium cultivated tomatoes vary in size, with the most widely grown commercial types producing red, globe-shaped fruit that tend to be in the 5–6 centimeters diameter range. The ultimate on-farm choice of cultivar is often based on the marketable yield potential, adaptability and disease resistance, fruit quality, market acceptability, time to maturity, size, shape, color, firmness, shipping quality and plant habit. Greenhouse tomato cultivars are indeterminate and require constant maintenance and physical support of the plants to allow for long-term fruit production. (UNCTAD2009-2014).

II- LITERATURE REVIEW

2.1 Water balance for plant *:*

Water plays a crucial role in the life of plant. It is the most abundant constituents of most organisms. Water typically accounts for more than 70 percent by weight of non-woody plant parts. The water content of plants is in a continual state of flux. The constant flow of water through plants is a matter of considerable significance to their growth and survival. The uptake of water by cells generates a pressure known as turgor. Photosynthesis requires that plants draw carbon dioxide from the atmosphere, and at the same time exposes them to water loss. To prevent leaf desiccation, water must be absorbed by the roots, and transported through the plant body. Balancing the uptake, transport, and loss of water represents an important challenge for land plants. The thermal properties of water contribute to temperature regulation, helping to ensure that plants do not cool down or heat up too rapidly. Water has excellent solvent properties. Many of the biochemical reactions occur in water and water is itself either a reactant or a product in a large number of those reactions.

The practice of crop irrigation reflects the fact that water is a key resource limiting agricultural productivity. Water availability likewise limits the productivity of natural ecosystems (**Figure 1**). Plants use water in huge amounts, but only small part of that remains in the plant to supply growth. About 97% of water taken up by plants is lost to the atmosphere, 2% is used for volume increase or cell expansion, and 1% for metabolic processes, predominantly photosynthesis. Water loss to the atmosphere appears to be an inevitable consequence of carrying out photosynthesis.

The uptake of CO_2 is coupled to the loss of water (**Figure 2**). Because the driving gradient for water loss from leaves is much larger than that for CO_2 uptake, as many as 400 water molecules are lost for every CO_2 molecule gained.(Source: Taiz L., Zeiger E. (2010): Plant Physiology. p. 68.)

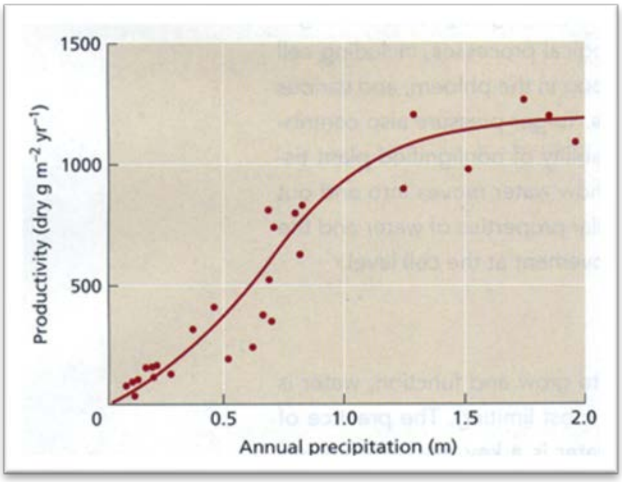

Figure 1: Productivity of various ecosystems as a function of annual precipitation (*source: Taiz L., Zeiger E., 2010*)

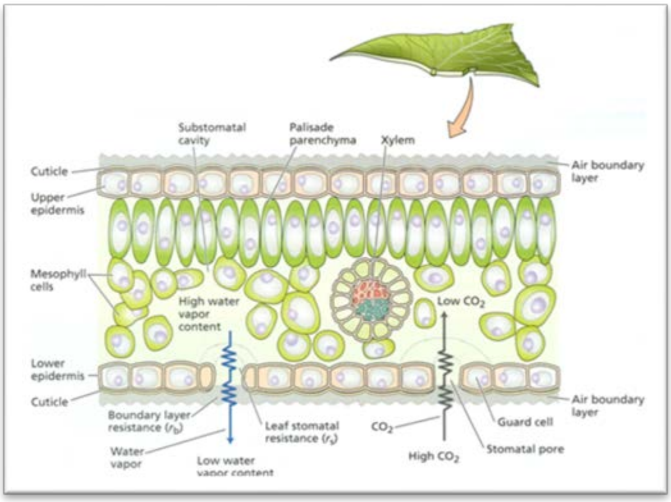

Figure 2: Water pathway through the leaf (source: Taiz L., Zeiger E., 2010)

❖ **Evapotranspiration:**

Evaporation from vegetation is generally given a more specific term evapotranspiration or ET for short. By definition, ET is the loss of water from a vegetated surface through the combined processes of soil evaporation and plant transpiration (**Fig.3**) The term evapotranspiration comes from combining the prefix "**evapo**" (for soil evaporation) with the word transpiration. Both soil evaporation and plant transpiration represent evaporative processes; the difference between the two rests in the path by which water moves from the soil to the atmosphere. Water lost by transpiration must enter the plant via the roots, then pass to the foliage where it is vaporized and lost to the atmosphere through tiny pores in the leaves known as stomata. In contrast, water lost through soil evaporation passes directly from the soil to The atmosphere. Evapotranspiration data are usually presented as a depth of water loss over a particular time period in a manner similar to that of precipitation. Common units for ET are inches/day or millimeters/day. he rate of ET for a given environment (vegetation) is a function of four critical factors. The first and most critical factors soil moisture, Evaporation (ET) simply cannot take place if there is no water in the soil. However, if adequate soil moisture is available, three additional factors plant type, stage of plant Development and weather affect ET rate. (*Paul Brown, university of Arizona)*

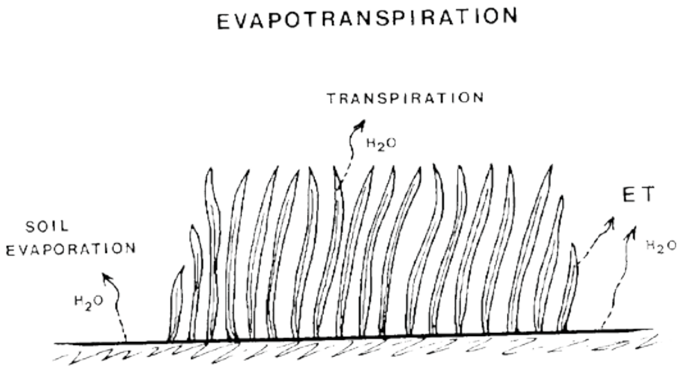

Figure 3. Evapotranspiration(ET) is the loss of water (H O) from vegetation through the combined processes of soil evaporation and plant transpiration.

❖ **Reference evapotranspiration**:

The reference evapotranspiration (ETo) was defined as the rate of evapotranspiration from a hypothetic crop with an assumed crop height (12 cm) and a fixed canopy resistance (70) [s·m−1], and albedo (0.23). This would closely resemble evapotranspiration from an extensive surface of green grass cover of uniform height, actively growing, completely shading the ground and not short of water [3,5]. Evapotranspiration is the combination of soil evaporation and crop transpiration. Weather parameters, crop characteristics, management and environmental aspects affect evapotranspiration. The evapotranspiration rate from a reference surface is called the reference evapotranspiration and is denoted as-ETo-(**Figure 4**)

The concept of the reference evapotranspiration was introduced to study the evaporative demand of the atmosphere independently of crop type, crop development, and management practices. As water is abundantly available at the reference evapotranspiration surface, soil factors do not affect ETo.

Relating Evapotranspiration to a specific surface provides a reference to which evapotranspiration from other surfaces can be related. ETo values measured or calculated at different locations or in different seasons are comparable as they refer to the evapotranspiration from the same reference surface. The only factors affecting ETo are climatic parameters. Consequently, ETo is a climatic parameter and can be computed from weather data. ETo expresses the evaporating power of the atmosphere at a specific location and time of the year and does not consider the crop characteristics and soil factors.

Good estimation of evapotranspiration is vital for proper water management. Evapotranspiration can be obtained by many estimation methods such as (Penman, Penman-Monteith, Pan Evaporation, Kimberly-Penman, Priestley-Taylor, Hargreaves, Samani-Hargreaves, and Blaney-Criddle). Some of these methods need many weather parameters as inputs while others need fewer. Numerous methods have been developed for evapotranspiration estimation out of which some techniques have been developed partly in response to the availability of data. An Expert Consultation held in May 1990, the FAO Penman-Monteith method is now recommended as the standard method for the definition and computation of the reference evapotranspiration ETo

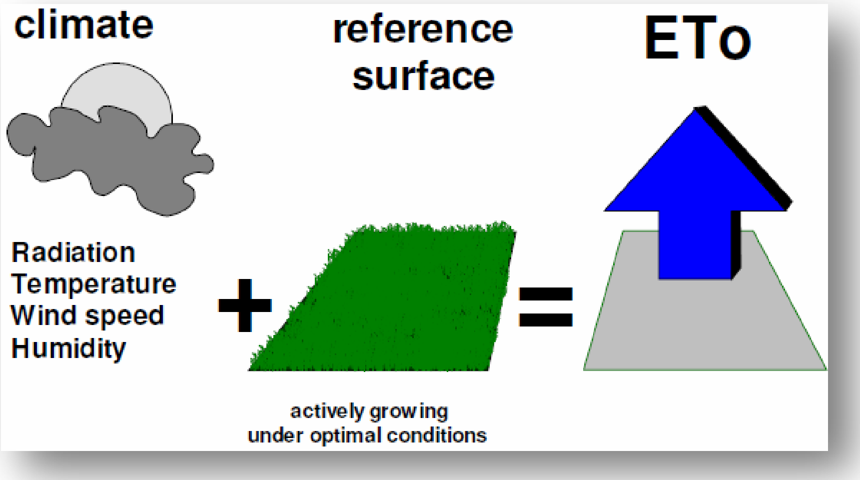

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Figure 4: Reference evapotranspiration (*ETo*) by FAO

❖ Crop evapotranspiration:

Crop evapotranspiration is calculated by multiplying ETo by Kc, a coefficient expressing the difference in evapotranspiration between the cropped and reference grass surface. The difference can be combined into one single coefficient, or it can be split into two factors describing separately the differences in evaporation and transpiration between both surfaces. The selection of the approach depends on the purpose of the calculation, the accuracy required, the climatic data available and the time step with which the calculations are executed. (**Figure5)** presents the general selection criteria the largest difference between Kc and Kcb is found in the initial growth stage where evapotranspiration is predominantly in the form of soil evaporation and crop transpiration is still small. Because crop canopies are near or at full ground cover during the mid-season stage, soil evaporation beneath the canopy has less effect on crop evapotranspiration and the value for Kcb in the mid-season stage will be nearly the same as Kc. Depending on the ground cover, the basal crop coefficient during the mid-season may be only 0.05-0.10 lower than the Kc value. Depending on the frequency with which the crop is irrigated during the late season stage, Kcb will be similar to (if infrequently irrigated) or less than the Kc value. Presents typical shapes for the Kcb, Ke and single Kc curves. The Kcb curve in the figure represents the minimum Kc for conditions of adequate soil water and dry soil surface. The Ke ‘spikes’ in the figure represent increased evaporation when precipitation or irrigation has wetted the soil surface and has temporarily increased total ETc. These wet soil evaporation spikes decrease as the soil surface layer dries. The spikes generally reach a maximum value of 1.0-1.2, depending on the climate, the magnitude of the wetting event and the portion of soil surface wetted **(Figure 6) .FAO56**

	Single crop coefficient K_c	Dual crop coefficient $K_{cb} + K_e$
Purpose of calculation	- irrigation planning and design - irrigation management - basic irrigation schedules - real time irrigation scheduling for non-frequent water applications (surface and sprinkler irrigation)	- research - real time irrigation scheduling - irrigation scheduling for high frequency water application (microirrigation and automated sprinkler irrigation) - supplemental irrigation - detailed soil and hydrologic water balance studies
Time step	daily, 10-day, monthly (data and calculation)	daily (data and calculation)
Solution method	graphical pocket calculator computer	computer

Figure 5: General selection criteria for the single and dual crop coefficient approaches

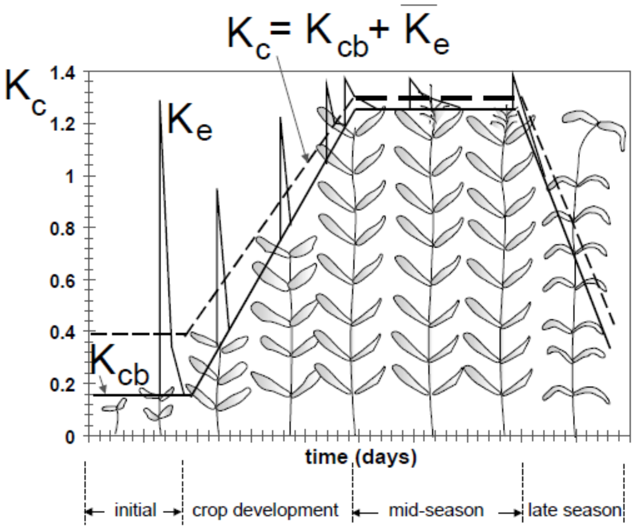


Figure 6: Crop coefficient curves showing the basal Kcb (thick line), soil evaporation Ke (thin line) and the corresponding single Kc = Kcb + Ke curve (dashed line)--- (fao56)

❖ Crop water requirements

Crop water requirements (CWR) encompass the total amount of water used in evapotranspiration. FAO (1984) defined crop water requirements as 'the depth of water needed to meet the water loss through evapotranspiration of a crop, being disease-free, growing in large fields under non restricting soil conditions, including soil water and fertility, and achieving full production potential under the given growing environment , CWR is equal to ETc The Irrigation requirements (IR) refer to the water that must be supplied through the irrigation system to ensure that the crop receives its full crop water requirements. If irrigation is the sole source of water supply for the plant, the Irrigation requirement will always be greater than the crop water requirement to allow for inefficiencies in the irrigation system. If the crop receives some of its water from other sources (rainfall, water stored in the ground, underground seepage, etc.), then the irrigation requirement can be considerably less than the crop water requirement.(fao1984)

❖ **Irrigation requirements:**

Irrigated agriculture is facing new challenges that require refined management and innovative design, formerly, emphasis centered on project design; however, current issues involve limited water supplies with several competing users, the threat of water quality degradation through excess irrigation, and Narrow economic margins. Meeting these challenges requires improved prediction of irrigation water requirements. Irrigation water requirements can be defined as the quantity, or depth, of irrigation water in addition to precipitation required to produce the desired crop yield and quality and to maintain an acceptable salt balance in the root zone. This quantity of water must be determined for such uses as irrigation scheduling for a specific field and seasonal water needs for planning, management, and development of irrigation projects.

The amount and timing of precipitation strongly influence irrigation water requirements. In arid areas, annual precipitation is generally less than 10 inches and irrigation is necessary to successfully grow farm crops. In semiarid areas (those typically receiving between 15 to 20 inches of annual precipitation), crops can be grown without irrigation, but are subject to droughts that reduce crop yields and can result in crop failure in extreme drought conditions. Sub humid areas, which receive from 20 to 30 inches of Annual precipitation, are typically characterized by short, dry periods. Depending on the available water storage capacity of soils and the crop rooting depth, irrigation may be needed for short periods during the growing season in these areas. In humid areas, those receiving more than 30 inches of annual precipitation, the amount of precipitation normally exceeds evapotranspiration throughout most of the year. However, drought periods sometimes occur, which reduce yield and impair quality, especially for crops grown on shallow, sandy soils or that have a shallow root system. Irrigation is not needed to Produce a crop in most years, but may be needed to protect against an occasional crop failure and to maintain product quality. A unified procedure is needed to predict irrigation water requirements for the diverse soils, climates, and crops that are of interest to the Soil Conservation Service and its clients. Irrigation water requirement information is needed in all aspects of irrigation design and management. Procedures to estimate the irrigation water requirement for this broad range of need the primary objective of irrigation is to provide plants with sufficient water to obtain optimum yields and a high quality harvested product. The required timing and amount of applied water is determined by the prevailing climatic conditions, the crop and its stage of growth, soil properties (such as water holding capacity), and the extent of root development. Water within the crop root zone is the source of water for crop evapotranspiration. Thus, it is important to consider the field water balance to determine the irrigation water requirements. Plant roots require moisture and oxygen to live. Where either is out of balance, root functions are slowed and crop growth reduced. All crops have critical growth periods when even small moisture stress can significantly impact crop yields And quality. Critical water needs periods vary crop by crop. Soil moisture during the critical water periods should be maintained at sufficient levels to ensure the plant does not stress from lack of water. (USDA1993).

❖ **Net irrigation requirements :**

The assessment of the irrigation potential, based on soil and water resources, can only be done by simultaneously assessing the irrigation water requirements (IWR).

Net irrigation water requirement (NIWR) is the quantity of water necessary for crop growth. It is expressed in millimeters per year or in m3/ha per year (1 mm = 10 m3/ha). It depends on the cropping pattern and the climate. Information on irrigation efficiency is necessary to be able to transform NIWR into gross irrigation water requirement (GIWR), which is the quantity of water to be applied in reality, taking into account water losses. Multiplying GIWR by the area that is suitable for irrigation gives the total water requirement for that area. (www.Fao.org) Chapter 5: Irrigation water requirements

❖ **Irrigation criteria and irrigation scheduling:**

Irrigation criteria are the indicators used to determine the need for irrigation. The most common irrigation criteria are soil moisture content and soil moisture tension. Less common types are irrigation scheduling to maximize yield and irrigation scheduling to maximize net return. The final decision depends on the irrigation criterion, strategy and goal. Irrigators need to define a goal and establish an irrigation criterion and strategy. To illustrate irrigation scheduling, consider a farmer whose goal is to maximize yield. Soil moisture content is the irrigation criterion. Different levels of soil moisture trigger irrigation. For example, when soil water content drops below 70 percent of the total available soil moisture, irrigation should start, Soil moisture content to trigger irrigation depends on the irrigator's goal and strategy. In this case, the goal is to maximize yield. Therefore, the irrigator will try to keep the soil moisture content above a critical level. If soil moisture falls below this level, the yield may be lower than the maximum potential yield. Thus, irrigation is applied whenever the soil water content level reaches the critical level, how much water to apply depends on the irrigator's strategy. For example, the irrigator can replenish the soil moisture to field capacity or apply less. If no rain is expected and the irrigator wishes to stretch the time between irrigations, it is advantageous to refill the soil profile to field capacity. If rain is expected, it may be wise not to fill the soil profile to field capacity, but leave some room for rain. If the irrigator's goal is to maximize net return, an economic irrigation criterion is needed, such as net return. This is the income from the crop less the expenses associated with irrigation. (Colorado state university extension agricultural engineer and associate professor2014)

2.2 Soil and water relationship

Plant growth depends on the use of two important natural resources, soil and water. Soil provides the mechanical and nutrient support necessary plant growth, Water is essential for plant life processes, Effective management of these resources for crop production requires the producer to understand relationships between soil, water, and plants, Knowledge about available soil water and soil texture will make deciding what crops To plant and when to irrigate.(Danny H.Rogers1996).

❖ **Soil Profile:**

A soil horizon is a layer generally parallel to the soil surface, whose physical characteristics differ from the layers above and beneath. Each soil type usually has three or four horizons. Horizons are defined in most cases by obvious physical features, chiefly colour and texture. These may be described both in absolute terms (particle size distribution for texture, for instance) and in terms relative to the surrounding material, i.e. 'coarser' or 'sandier' than the horizons above and below. The differentiation of the regolith into distinct horizons is largely the result of influences, such as air, water, solar radiation, and plant material, originating at the soil-atmosphere interface. Since the weathering of the regolith occurs first at the surface and works its way down, the uppermost layers have been changed the most, while the deepest layers are most similar to the original regolith (i.e., parent material).**(**Wikipedia.org**).**

❖ **Soil structure:**

Soil structure is determined by how individual soil granules clump or bind together and aggregate, and therefore, the arrangement of soil pores between them. Soil structure has a major influence on water and air movement biological activity, root growth and seedling emergence .(Wikipedia.org/soil structure).

❖ **Soil texture:**

Soil texture and soil structure are both unique properties of the soil that will have a profound effect on the behavior of soils, such as water holding capacity, nutrient retention and supply, drainage, and nutrient leaching .In soil fertility, coarser soils generally have a lesser ability to hold and retain nutrients than finer soils. However, this ability is reduced as finely-textured soils undergo intense leaching in moist environments. (University of Hawaii 2007/2014).

❖ **Soil moisture:**

Water content or moisture content is the quantity of water contained in a material, such as soil (called soil moisture), rock, ceramics, fruit, or wood. Water content is used in a wide range of scientific and technical areas, and is expressed as a ratio, which can range from 0 (completely dry) to the value of the materials' porosity at saturation. It can be given on a volumetric or mass (gravimetric) basis, When the soil moisture content is optimal for plant growth, the water in the large- and intermediate-sized pores can move about in the soil and can easily be used by plants. The amount of water remaining in a soil drained to field capacity and the amount that is available are functions of the soil type. Sandy soil will retain very little water, while clay will hold the maximum amount The time required to drain a field from flooded condition for a clay loam that begins at 43% water by weight to a field capacity of 21.5% is six days, whereas a sandy loam that is flooded to its maximum of 22% water will take two days to reach field capacity of 11.3% water. The available water for the clay loam might be 11.3% whereas for the Sandy loam it might be only 7.9% by weight. (Wikipedia.org)

2.3Tomato Crop

The tomato is now grown worldwide for its edible fruits, with thousands of cultivars having been selected with varying fruit types, and for optimum growth in differing growing conditions, Cultivated tomatoes vary in size, about 5 mm in diameter, through cherry tomatoes, about the same 1–2 cm (0.4–0.8 in) size as the wild tomato, up to beefsteak tomatoes 10 cm (4 in) or more in diameter.

The most widely grown commercial tomatoes tend to be in the 5–6 cm (2.0–2.4 in) diameter range. Most cultivars produce red fruit, but a number of cultivars with yellow, orange, pink, purple, green, black, or white fruit are also available. Multicolored and striped fruit can also be quite striking. Tomatoes grown for canning and sauces are often elongated, 7–9 cm (3–4 in) long and 4–5 cm (1.6–2.0 in) diameter; they are known as plum tomatoes, and have a lower water content. Roma-type tomatoes are important cultivars in the Sacramento Valley, Tomatoes are one of the most common garden fruits in the United States and, along with zucchini, have a reputation for out producing the needs of the grower; Quite a few seed merchants and banks provide a large selection of heirloom seeds. The definition of an heirloom tomato is vague, but unlike commercial hybrids, all are self-pollinators that have bred true for 40 years or more, About 150 million tons of tomatoes were produced in the world in 2009. China, the largest producer, accounted for about one quarter of the global output, followed by United States and India. For one variety, plum or processing tomatoes, California accounts for 90% of U.S. production and 35% of world production, According to FAOSTAT, the top producers of tomatoes (in tons) in 2012.

III- MATERIALS AND METHODS

3.1 Geographical location of project

Fig. 7 show that the Abu- Ghraib Project (AGP) is situated **20 Km** west of Baghdad in Mesopotamian plain between the Tigris and Euphrates rivers, AGP boundaries are, Alfaluja city (Anbair governorate) in the west, Baghdad governorate in east, salah Aldin governorate in the north and Babylon in the south.(longitude **44° 12' 41.76" E**) and (latitude **33° 19' 56.64" N**)

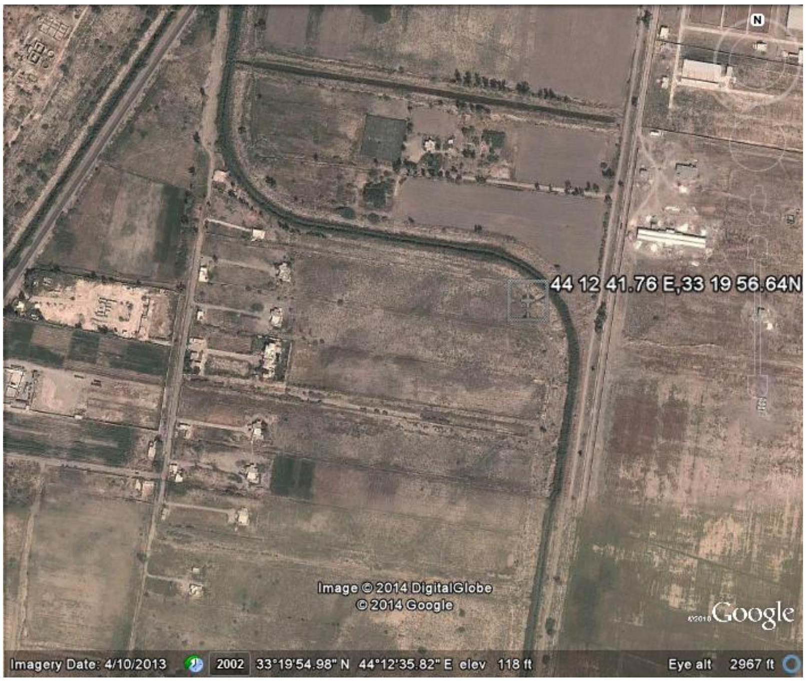


Figure 7: Abu- Ghraib Project field location by Google earth model

3.2 Input Data CROPWAT 8.0

FAO's CROPWAT 8.0 model is a computer program for calculation of Crop water requirements and Irrigation requirements based:

1- Soil 2- climate 3- Crop data.

The program allows the development of irrigation schedule for different management conditions and the calculation of scheme water supply for different areas under different crops.

The feature of the program includes:

- Monthly, decade and daily input of climate data for calculation of ETo.
- Monthly and daily calculation of crop water requirements including crop coefficients
- Daily soil water balance

3.2.1 Climate Data:

Figure 8: Import data by using **CLIMWAT2.0 FAO model**, select Baghdad meteorology station.

- Average minimum and maximum temperature Celsius degrees monthly.
- Average Relative Humidity monthly, percentage.
- Average wind speed monthly, kilometer per day.
- Average sunshine hours/ day.
- Average solar radiation monthly, mega joule per square meter $MJ/m^2/day$.
- Average ETO monthly, millimeter per day mm/day.

Country	iraq				Station	baghdad	
Altitude	34 m.		Latitude	33.23 °N		Longitude	44.23 °E

Month	Min Temp	Max Temp	Humidity	Wind	Sun	Rad	ETo
	°C	°C	%	km/day	hours	MJ/m²/day	mm/day
January	3.9	16.0	91	190	5.7	10.3	1.19
February	5.5	18.7	74	216	6.6	13.4	2.19
March	8.8	22.7	62	233	6.9	16.5	3.45
April	13.8	28.7	67	216	7.9	20.2	4.43
May	19.3	35.7	38	233	9.0	23.1	7.20
June	22.7	41.0	26	259	11.0	26.4	9.43
July	24.3	43.4	25	277	10.7	25.7	10.13
August	24.3	43.2	28	251	10.5	24.3	9.28
September	21.1	39.7	32	216	9.8	21.0	7.41
October	16.1	33.4	46	173	8.2	15.9	4.75
November	10.6	24.6	77	173	6.6	11.6	2.38
December	5.5	17.6	94	173	5.7	9.7	1.17
Average	14.7	30.4	55	217	8.2	18.2	5.25

Figure 8: CLIMWAT2.0 FAO model, select Baghdad meteorology station.

3.2.2 Rainfall Data:

Figure 9: Import rainfall and effect rainfall data by using CLIMWAT 2.0 FAO model,

Country	iraq				Station	baghdad	
Altitude	34 m.		Latitude	33.23 °N		Longitude	44.23 °E

Month	Min Temp	Max Temp	Humidity	Wind	Sun	Rad	ETo
	°C	°C	%	m/s	hours	MJ/m²/day	mm/day
January	3.9	16.0	91	2.2	5.7	10.3	1.19
February	5.5	18.7	74	2.5	6.6	13.4	2.19
March	8.8	22.7	62	2.7	6.9	16.5	3.45
April	13.8	28.7	67	2.5	7.9	20.2	4.43
May	19.3	35.7	38	2.7	9.0	23.1	7.20
June	22.7	41.0	26	3.0	11.0	26.4	9.43
July	24.3	43.4	25	3.2	10.7	25.7	10.13
August	24.3	43.2	28	2.9	10.5	24.3	9.28
September	21.1	39.7	32	2.5	9.8	21.0	7.41
October	16.1	33.4	46	2.0	8.2	15.9	4.75
November	10.6	24.6	77	2.0	6.6	11.6	2.38
December	5.5	17.6	94	2.0	5.7	9.7	1.17
Average	14.7	30.4	55	2.5	8.2	18.2	5.25

Figure 9: Rainfall data, Abu- Ghraib Project, used in the CROPWAT8.0 model

3.2.3 Soil Data:

Figure 10 below, Impart soil data by using FAO’s Harmonized world soil database viewer 1.2 (HWSD) model, **Abu- Ghraib Project.** (Longitude **44° 12’ 41.76” E**) and (latitude **33° 19’ 56.64” N**). Figure 10 and table1

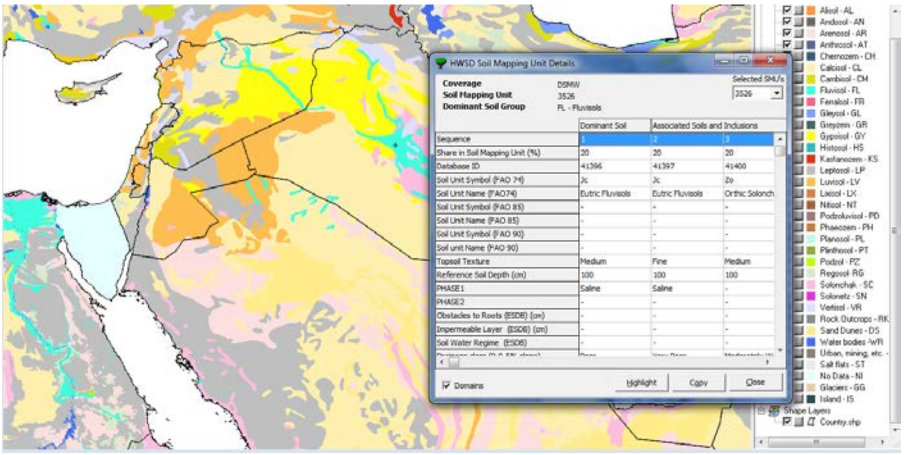


Table 1: Soil data for Abu-Ghraib Project HWSD model

Topsoil (0-30cm)	Dominant soil
Topsoil Sand Fraction (%)	35
Topsoil Silt Fraction (%)	47
Topsoil Clay Fraction (%)	18
Topsoil USDA Texture Classification	loam
Topsoil Gravel Content (%)	10
Topsoil Organic Carbon (% weight)	0.6
Topsoil Gypsum (% weight)	0.2
Topsoil Salinity (ECe) (dS/m)	0.7

- ➢ Calculate soil moisture properties data for **Abu- Ghraib Project** by Soil water Characteristics model of USDA. See figure 11
- ➢ Soil texture (USDA classification) loam
- ➢ Total available water TAW = FC – PWP = 130mm/m.
- ➢ Maximum Rain Infiltration rate 199 mm/day.
- ➢ Maximum rooting depth 900 cm.
- ➢ Initial soil moisture depletion (as % TAW) 100%.
- ➢ Initial available soil moisture 65.0 mm/m.

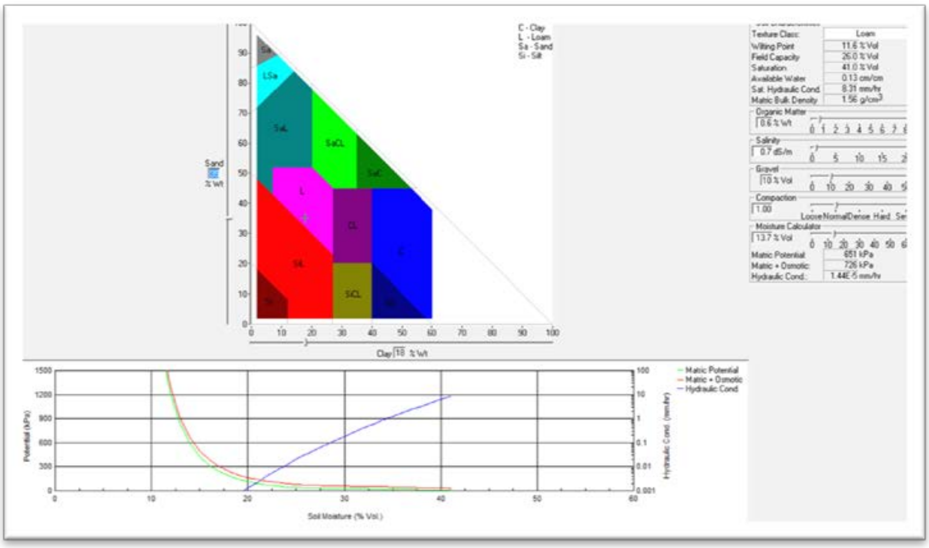


Figure 11: Soil water Characteristics model of USDA

3.2.4 Tomato crop data:

From the FAO database (FAO56, 1998) with CROPWAT8.0 mode the information crop name (Tomato):

- ➢ Crop Name Tomato.
- ➢ Planting date 15 March, Harvest 06/08.
- ➢ Stages of growth period. Initial 30 days, development 40 days, mid-season 45 days and late season 30 days. Total growth period 145 days.

- Crop coefficient (Kc). Initial (1.1), development (1.2), mid- season (1.2) and late season (1.05).
- Yield response factor (f). Initial (0.50), development (0.60), mid-season (1.10) and late season (0.80).
- Rooting depth. Initial (0.25) and development to the late season (1.00).
- Critical depletion (fraction0.30, 0.40, 0.50).
- Irrigation efficiency 95 %, by subsurface drip irrigation .

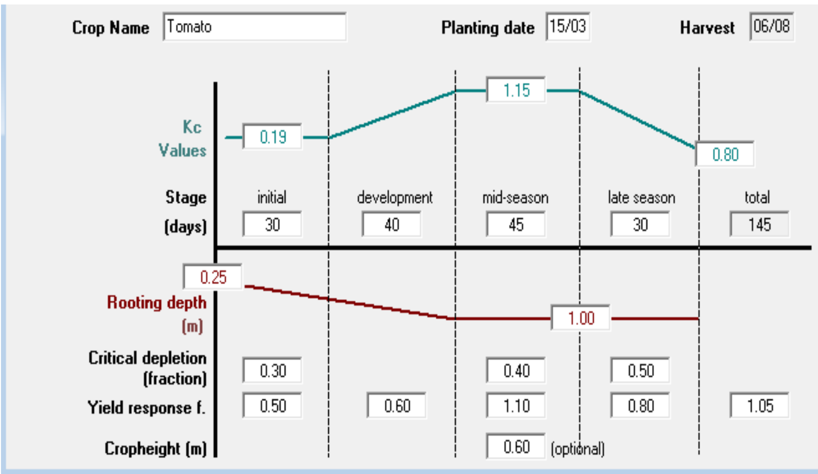


Figure 12: Tomato crop data used in CROPWAT8.0 model

3.2.5 Estimation of crop coefficient under subsurface irrigation system.

Under subsurface system we reduce the water loss because we lose less water from evaporation. To estimate the evaporation contribution to Kc we use together the dual crop coefficient method developed by FAO in paper 56 and to adapt this method to subsurface System we use the Philip (1991) formula that gives to us the relationship between dripline depth, type of soil (sorptivity) and evaporation. By this combination we were able to estimate the reduction of Kc due to the reduction of evaporation.

Kc = Kcb + Ke

So we need to estimate this to component

1 step) ⟶ Estimation of Kcb

Using FAO methodology we determine the Basal crop coefficient (Kcb), by tabulated Kcb and the formula:

$$K_{cb}=K_{Cb(Tab)}+[0.04(u_2-2)-0.004(RH_{min}-45)](h/3)^{0.3}$$

$K_{Cb(Tab)}$: the value for $K_{Cb\ mid}$ or $K_{Cb\ end}$ (if ≥0.45) taken from **Figure 13**.

u_2 : the mean value for daily wind speed at 2m height over grass during the mid or late season growth stage[ms^{-1}] for 1 ms^{-1} ≤ u_2 ≤6 ms^{-1}

RH_{min} : the mean value for daily minimum relative humidity during the mid or late season growth stage [%] for 20% ≤ RH_{min}≤ 80%.

h : the mean plant height during the mid or late season stage [m] from the **Figure 14**) for 20% ≤ RH_{min}≤ 80%.

Basal crop coefficients, K_c, for non stressed, well-managed crops in subhumid climates (RH_{min} ≈ 45%, u_2 ≈ 2 m/s) for use with the FAO Penman-Monteith ET_o.

Crop	$K_{cb\ ini}$ [1]	$K_{cb\ mid}$ [1]	$K_{cb\ end}$ [1]
a. Small Vegetables	**0.15**	**0.95**	**0.85**
Broccoli		0.95	0.85
Brussel Sprouts		0.95	0.85
Cabbage		0.95	0.85
Carrots		0.95	0.85
Cauliflower		0.95	0.85
Celery		0.95	0.90
Garlic		0.90	0.60
Lettuce		0.90	0.90
Onions - dry		0.95	0.65
- green		0.90	0.90
- seed		1.05	0.70
Spinach		0.90	0.85
Radishes		0.85	0.75
b. Vegetables – Solanum Family (*Solanaceae*)	**0.15**	**1.10**	**0.70**
EggPlant		1.00	0.80
Sweet Peppers (bell)		1.00[2]	0.80
Tomato		1.10[2]	0.60-0.80

Figure 13: Basal crop coefficients K_C FAO Penman-Monteith Et_0

Single (time-averaged) crop coefficients, K_c, and mean maximum plant heights for non stressed, well-managed crops in subhumid climates ($RH_{min} \approx 45\%$, $u_2 \approx 2$ m/s) for use with the FAO Penman-Monteith ET_o.

Crop	$K_{c\ ini}$ [1]	$K_{c\ mid}$	$K_{c\ end}$	Maximum Crop Height (h) (m)
a. Small Vegetables	**0.7**	**1.05**	**0.95**	
Broccoli		1.05	0.95	0.3
Brussel Sprouts		1.05	0.95	0.4
Cabbage		1.05	0.95	0.4
Carrots		1.05	0.95	0.3
Cauliflower		1.05	0.95	0.4
Celery		1.05	1.00	0.6
Garlic		1.00	0.70	0.3
Lettuce		1.00	0.95	0.3
Onions - dry		1.05	0.75	0.4
- green		1.00	1.00	0.3
- seed		1.05	0.80	0.5
Spinach		1.00	0.95	0.3
Radish		0.90	0.85	0.3
b. Vegetables – Solanum Family (*Solanaceae*)	**0.6**	**1.15**	**0.80**	
Egg Plant		1.05	0.90	0.8
Sweet Peppers (bell)		1.05[2]	0.90	0.7
Tomato		1.15[2]	0.70-0.90	0.6

Figure 14: single time crop coefficients K_C FAO Penman-Monteith Et_0

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
Initial (days)			15	15				
crop dev. (days)				15	25			
middle (days)					5	30	10	
last (days)							20	10
Humidity %	72	61	52	42	31	24	24	26
Et0 mm/day			3.45	4.4	7.2	9.43	10.1	9.28

Table 2: information about Tomato.

		mid	end
Et0 (mm7day)	3.9	9.3	9.8
KC	0.6	1.15	0.8
Kcb (tab)	0.15	1.1	0.7
u2	3.25	3.65	4.3
Rhmin	36.5	24.8	24.7
h	0	0.6	0.6
Kcb	0.15	1.15	0.80

Table 3: Calculate the kcb

Step 2) ⟶ Estimation of Ke

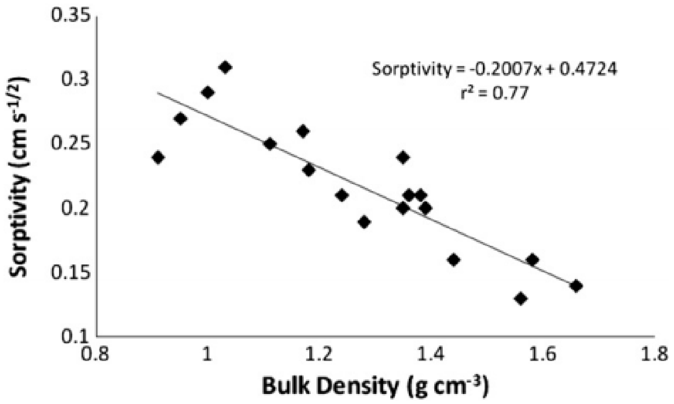
To estimate the **Ke** we use the **Philips formula** that gives to us the possibility to make a relationship between soil characteristics, depth of driplines of our subsurface system and evaporation.

$$\frac{E}{q} = \left(\frac{m}{2+m}\right)\exp^{-d\alpha}$$

Evaporation losses E/q depend on irrigation system. When irrigation water is injected into the subsurface of the soil, the soil surface evaporation decreases. Philip (1991) found that evaporation loses are related to the emitter depth [d] and the soil sorptivity parameter [α] through the simple equation:
Where m is calculated from the maximum evaporation demand from wet soil Es (expressed as evaporative flux per unit area) and saturated hydraulic conductivity Ks, as:

$$m = \frac{2Es}{Ks}$$

To estimate evaporation we need to estimate sorptivity, and to do this we use the relationship find from Shaver (2012) between bulk (from Soil w Water Char) density and sorptivity. We know that is empirical data and its limit **figure** below:



Ke	0.043	0.000	0.000
m	0.43	0	0
d	0.3	0.3	0.3
Bulk density (g cm³)	1.56	1.56	1.56
α	0.159308	0.159	0.159308
Etc.	2.4	10.7	7.9
Es	1.773	0	0
Ks (mm/hr.)	8.31	8.31	8.31

By this analysis we can know that evaporation have significant contribution in initial developed stages. And we have a good reduction of initial and develop Kc (0.6 to 0.19).

KC sub irrigation ⟶ (KCb+Ke) ⟶ 0.15 +0.043=**0.193**

3.3 CWR calculates:

CROPWAT 8.0 model calculate ETc in mm/day and mm/decade for every stage, with total ETc mm/decade, as a shown **figure 15**

ETo station: baghdad | Crop: Tomato
Rain station: baghdad | Planting date: 15/03

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Mar	2	Init	0.19	0.66	3.9	6.0	0.0
Mar	3	Init	0.19	0.72	7.9	9.3	0.0
Apr	1	Init	0.19	0.75	7.5	8.6	0.0
Apr	2	Deve	0.26	1.10	11.0	8.2	2.8
Apr	3	Deve	0.50	2.63	26.3	6.1	20.2
May	1	Deve	0.76	4.75	47.5	3.6	43.9
May	2	Deve	1.01	7.25	72.5	1.5	71.1
May	3	Mid	1.19	9.45	104.0	1.0	103.0
Jun	1	Mid	1.20	10.48	104.8	0.1	104.7
Jun	2	Mid	1.20	11.41	114.1	0.0	114.1
Jun	3	Mid	1.20	11.65	116.5	0.0	116.5
Jul	1	Late	1.19	11.86	118.6	0.0	118.6
Jul	2	Late	1.10	11.25	112.5	0.0	112.5
Jul	3	Late	0.98	9.71	106.8	0.0	106.8
Aug	1	Late	0.88	8.50	51.0	0.0	51.0
					1005.0	**44.4**	**965.1**

Figure 15: tomato water requirements for Abu- Ghraib Project field, by CROPWAT 8.0 model

3.4 irrigation scheduling:

CROPWAT 8.0 model calculate irrigation scheduling, and give amount of water daily in mm/day, with total gross Irrigation mm /annual, as a shown **figure 16** below.

Totals

Total gross irrigation	1119.6	mm	Total rainfall	45.2	mm
Total net irrigation	1063.6	mm	Effective rainfall	45.2	mm
Total irrigation losses	0.0	mm	Total rain loss	0.0	mm
Actual water use by crop	995.8	mm	Moist deficit at harvest	17.0	mm
Potential water use by crop	996.5	mm	Actual irrigation requirement	951.3	mm
Efficiency irrigation schedule	100.0	%	Efficiency rain	100.0	%
Deficiency irrigation schedule	0.1	%			

Figure 16: tomato irrigation scheduling for Abu- Ghraib Project field, by CROPWAT 8.0 model

IV- RESULT AND DISCUSSION

4.1 Crop evapotranspiration ETc

- The maximum ETc occurs in July =11.86 mm/day
- The minimum ETc occurs in march = 0.66 mm/day
- The annual ETc = 1005 mm/annual.

4.2 Crop water requirements of Tomato

CROPWAT8.0 model calculate Etc. (**CWR**) in the below table 2:

- Water required for initial stage =**19.3** mm.
- Water required for development stage **157.3** mm.
- Water required for middle season =**439.4** mm.
- Water required for late season stage =**388.9** mm.
- Total CWR 1535.7 mm/ha/annual = **1004.9**

4.3 Irrigation Requirements of tomato:

CROPWAT8.0 model calculate IRR for the Tomato crop:

- IRR for development stage=**135.2**mm /dec
- IRR for middle season =**438.3** mm/dec
- IRR for late season stage =**962.4** mm/dec
- Total IRR =**1005.1** mm/annual
- Total gross irrigation requirements = **1119.6** mm.

Month	Decade	Stage	ETc mm/day	ETc mm/dec	Irr. Req. mm/dec
Mar	2	Init	0.66	3.9	0.0
Mar	3	Init	0.72	7.9	0.0
Apr	1	Init	0.75	7.5	0.0
Total Initial season stage mm			**2.13**	**19.3**	**0.0**
Apr	2	Deve	1.10	11.0	0.0
Apr	3	Deve	2.63	26.3	20.2
May	1	Deve	4.75	47.5	43.9
May	2	Deve	7.25	72.5	71.1
Total development season stage mm			**15.73**	**157.3**	**135.2**
May	3	Mid	9.45	104.0	103.0
Jun	1	Mid	10.48	104.8	104.7
Jun	2	Mid	11.41	114.1	114.1
Jun	3	Mid	11.65	116.5	116.5
Total Mid-season stage mm			**42.99**	**439.4**	**438.3**
Jul	1	Late	11.86	118.6	118.6
Jul	2	Late	11.25	112.5	112.5
Jul	3	Late	9.71	106.8	106.8
Aug	1	Late	8.50	51.0	51.0
Total Late season stage mm			**41.32**	**388.9**	**962.4**
Total (mm)/ha/ annual			**102.17**	**1004.9**	**1005.1**

Table 4: ETc and IRR per decade for Tomato crop in **Abu- Ghraib**

4.4 Irrigation Scheduling of Tomato :

- Irrigation scheduling show the **table 5** below:

15-Mar	1	Init	0	0	0	100	33.9	0	0	35.7
26-Mar	12	Init	0	0.99	100	32	15.7	0	0	16.5
10-Apr	27	Init	0	1	100	30	21.3	0	0	22.4
25-Apr	42	Dev	0	1	100	35	31.7	0	0	33.3
4-May	51	Dev	0	1	100	37	38.7	0	0	40.7
11-May	58	Dev	0	1	100	38	42.9	0	0	45.1
17-May	64	Dev	0.7	1	100	41	49.8	0	0	52.4
23-May	70	Dev	0.5	1	100	43	56	0	0	59
29-May	76	Mid	0	1	100	43	56.2	0	0	59.2
4-Jun	82	Mid	0	1	100	47	60.8	0	0	64
9-Jun	87	Mid	0	1	100	40	52.3	0	0	55.1
14-Jun	92	Mid	0	1	100	43	56.1	0	0	59.1
19-Jun	97	Mid	0	1	100	44	57.1	0	0	60.1
24-Jun	102	Mid	0	1	100	45	58	0	0	61.1
29-Jun	107	Mid	0	1	100	45	58.2	0	0	61.3
4-Jul	112	Mid	0	1	100	45	59.1	0	0	62.2
9-Jul	117	End	0	1	100	46	59.3	0	0	62.4
14-Jul	122	End	0	1	100	44	56.8	0	0	59.8
20-Jul	128	End	0	1	100	52	67.5	0	0	71
27-Jul	135	End	0	1	100	52	68	0	0	71.6
3-Aug	142	End	0	1	100	50	64.4	0	0	67.7
6-Aug	End	End	0	1	0	13				

Table 5: irrigation scheduling by cropwat8.0 model.

V- CONCLUSIONS AND RECOMMENDATION

- Using subsurface irrigation systems we estimate a water requirement reduction for tomato like 8%**.**
- Inside the methodology developed for this work the weak point is the estimation of sorptivity, using the relationship between bulk density and sorptivity. Would be appropriate to conduct studies in order to have sufficient data describe correlation between the soil texture, and sorptivity
- At the moment the best software developed to estimate Irrigation Water Requirement, CROPWAT and AquaCrop developed by FAO, hasn't inside subsurface irrigation system routine. And the only approach is to estimate the evaporation reduction by changing the KC. It will be a good if in the future FAO will be improve is model introducing also this irrigation technology so interesting in country like Iraq.
- There are studies in the literature correlating the production of the tomato and the depth of the drip lines. It should, however, to start this technology on a large scale have further investigations for different soil types (different sorptivity) and different climates.
- This study was based in computer model with general data for Tomato crop properties, local climate and local soil characteristics.
- Improved Water productivity by using subsurface drip irrigation.
- Estimate the actual water requirement by used of subsurface drip irrigation comparing with water requirement which will estimated by CROPWAT, as well as appointed the irrigation scheduled according for the result which obtained from CROPWAT 8.0 model tools.

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