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DETERMINING OF REFERENCE EVAPOTRANSPIRATION BY DIFFERENT EQUATIONS FOR DUHOK PROVINCE

MASTER’S THESIS

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DEDICATION

This thesis is dedicated to:

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My great teacher and messenger, Mohammed (May Allah bless and grant him), who taught us the purpose of life.

I would like to dedicate this thesis to my parents for their love and support throughout my life. I appreciate the willingness they have shown me in pursuing what interests me in life and I know I would not be accomplishing this today without their support and encouragement.

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Hozan Jasim Yahya SHARAFANI
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CONTENT

LIST OF SYMBOLS AND ABBREVIATIONS

ET : Evapotranspiration.

ET_o : Reference evapotranspiration.

TD : The difference between maximum and minimum daily temperature in (°C).

R_a : The extraterrestrial radiation expressed in equivalent evaporation units.

ET_{ok} : Potential evapotranspiration in the k_{th} month (mm).

N_k : The max. possible time of sunshine in the k_{th} month (hours).

T_k : The average air temperature in the k_{th} month (°C) and $k = 1, 2, \ldots, 12$.

T_{mean} : Average air temperature (°C).

RH_{mean} : Average relative humidity (%).

$R's$: Solar radiation$(cal\ /\ cm^2\ /\ day)$.

λ : The latent heat of vaporization (MJ/kg). It can be estimated using mean air temperature as: $\lambda = 2.501 - 0.002361T_{mean}$.

G : Soil heat flux density$(MJ\ m^{-2}\ day^{-1})$.

T : Mean daily air temperature at 2 m height (°C).

U_2 : Wind speed at 2 m height$(m\ s^{-1})$.

e_s : Saturation vapour pressure(kPa).

e_a : Actual vapour pressure(kPa).

$e_s - e_a$: Saturation vapour pressure deficit(kPa).

Δ : Slope vapour pressure curve$(kPa\ °\mathrm{C}^{-1})$.

$\boldsymbol{\gamma}$: Psychrometric constant(kPa ℃$^{-1}$).

$\boldsymbol{a}$: 0.0023 is a parameter.

$\boldsymbol{p}$: Percentage of total daytime hours for the used period (daily or monthly) out of total daytime hours of the year (365×12).

$\boldsymbol{k}$: Monthly consumptive use coefficient.

$\boldsymbol{R_s}$: The total solar radiation (MJ/m^2/day) is known, it can be calculated as: $R's= R_s/0.041869$.

$\boldsymbol{e^o_{mean}}$: Saturation vapor pressure at mean temperature (kPa).

$\boldsymbol{R_n}$: Net Radiation (MJ/m^2/day).

$\boldsymbol{R_{ns}}$: Net shortwave radiation (MJ/m^2/day).

$\boldsymbol{R_{nl}}$: Net long wave radiation (MJ/m^2/day).

$\boldsymbol{R_{so}}$: Clear sky radiation (MJ/m^2/day).

$\boldsymbol{N}$: Maximum possible duration of sunshine.

$\boldsymbol{G_s}$: Solar constant (0.0820 MJ/m^2/day).

$\boldsymbol{d_r}$: Inverse relative Earth-Sun distance.

$\boldsymbol{\omega_s}$: Sunset hour angle (rad).

$\boldsymbol{\delta}$: Solar declination angle (rad).

$\emptyset$: Latitude of station (rad).

$\boldsymbol{J}$: The number of the day in calendar year.

$\boldsymbol{\sigma}$: Stefan-Boltzman constant (4.903 ×10^{-9} MJ/K^4/m^2/day).

$\boldsymbol{W_\int}$: Wind function.

LIST OF FIGURES

LIST OF TABLES

DUHOK BÖLGESI İLLERI IÇIN REFERANS BITKI SU TÜKETIMININ FARKLI EŞITLIKLERLE ELDE EDILMESI

ÖZET

Kürdistan bölgesinde tarımsal üretim için su yönetimi en önemli kaynaktır. Bitki su gereksinimi ve evapotranspirasyonun (*ET*) (yani terlemesinden kaynaklanan su tüketimi ve toprak buharlaşmasının) belirlenmesi tarımsal verim üzerinde doğrudan etkilidir. Öncelikle bu araştırma Duhok bölgesinde yer alan Duhok, Zakho, Akre, Amedi, Sumeel, Bardarash, Bamerne, Kanimase ve Mangesh illerinde bitki su tüketiminin belirlenmesi için yürütülmüştür. Bu amaçla söz konusu illerin iklim istasyonlarından uzun yıllık ve 2018 yılı iklim verileri temin edilmiştir. Doğrudan ET değerlerinin belirlenmesindeki güçlükler nedeniyle tahmin yöntemlerinin kullanılması tercih edilmiştir. Bu amaçla Hargreaves, Blaney-Criddle(FAO), Turc, Priestly-Taylor, Makkink, FAO-56 Penman-Monteith ve Kimberly-Penman yöntemleri kullanılmıştır. Genel olarak, Blaney-Criddle daha yüksek Makking yöntemi ise daha düşük sonuçlar verdiği görülmüştür. Kimberly PM, Hargreaves, Turc ve Priestly-Taylor metodları FAO56 PM metodu ile istatistiksel olarak çoğunlukla aynı grupta toplanmıştır. Sözkonusu 5 yöntem sonuçlarının ortalaması model çıktısı; ortalama sıcaklık, maksimum sıcaklık, minimum sıcaklık, oransal nem, rüzgar hızı ve güneşlenmesi süresi parametreleride model çıktısı olarak alınmış ve çoklu regresyon analizleri yapılmıştır. Çok farklı kombinasyonların denendiği analizde ortalama sıcaklık, oransal nem ve güneşlenmesi süreleri kullanılarak elde edilen model (R^2: 0,932) istatistiksel olarak en iyi model olarak belirlenmiştir. Uzun yıllık iklim verileri ile üretilen model 2018 yılı verileri ile test edilmiştir. Sonuç olarak yöre iklim koşulları için üretilen bu model, yüksek doğrulukta ve pratik kullanımı ile hem çiftçilere hem araştırmacılara önemli katkı sağlayacaktır.

Anahtar kelimeler: Referans Evapotranspirasyon, Bitki su tüketimi, Duhok, Ref-ET, İklim.

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DETERMINING OF REFERENCE EVAPOTRANSPIRATION BY DIFFERENT EQUATIONS FOR DUHOK PROVINCE

ABSTRACT

Water management for agricultural production is the most important source in Kurdistan region. Crop water requirement and determining of evapotranspiration (*ET*) namely (the water consumption from the plant transpiration, and evaporation of soil surface), which has a direct impact on the agriculture yield. First of all, this research was conducted to determine reference evapotranspiration in Duhok, Zakho, Akre, Amedi, Sumeel, Bardarash, Bamerne, Kanimase and Mangesh city in Duhok region. For this purpose, long-term and 2018 climate data were obtained from the climate stations of these provinces. Estimation methods have been preferred because of difficulties in directly determining ET values. For this purpose, Hargreaves, Blaney-Criddle (FAO), Turc, Priestly-Taylor, Makkink, FAO-56 Penman-Monteith and Kimberly-Penman methods were used. In general, Blaney-Criddle method gave the highest values, while Priestly-Taylor and Makking methods gave lower values. Kimberly PM, Hargreaves, Turc and Priestly-Taylor methods were in the same group with FAO-56 PM method. Average of ET values obtained by these 5 methods were taken as input parameter and, the mean temperature, maximum temperature, minimum temperature, relative humidity, wind speed and sunshine duration were taken as input parameters for Multiple regression analyses. As a result; the model obtained by average temperature, humidity and sunshine times (R^2: 0,932) was determined as the best model. The model, which was tested with annual data, was presented by both farmers and researchers as an easy and highly accurate model.

Keywords : Reference Evapotranspiration, Plant water consumption, Duhok, Ref-ET, Clim.

1. INTRODUCTION

Agricultural production is the most important source in Kurdistan region. The water resource should be used with high efficiency for development in agriculture sector. But there isn't detailed policy and strategies for using water depend of water sources and plant water requirements. In the other hand, population pressure lead to increase and demand for food has increased, although, the country is facing a big challenge of water shortage due to the project and policy that are prorated by the riparian countries for water storage. In the other hand, the drought that arose during the last few decades, leads the government to make a plan to go forward to resolving the problem of water in the region.

Water is one of the most valuable natural resources, and the preservation of water resources is still a major national priority (Vickers, 2001; TWDB, 2007). Due to population growth, current drinking water supplies will be insufficient by 2050 in Texas (TWDB, 2003). Currently, 7.8 billion gallons, or about 30% of all drinking water, are used outdoors (USGS, 2006), primarily for landscape irrigation (Kjelgren *et al*., 2000; Vickers, 2001; White *et al*., 2004). Evapotranspiration ET is the amount of water lost as a result of evaporation from the soil and surface of plants, as well as a result of plant transpiration. The water loss rate as a result of reference ET is based on environmental requirements for a short, green perennial crop that completely covers the soil. Landscape irrigation based on ET is a new area for water conservation, since irrigation based on ET links water use in plants to regulations and irrigation water replacement schedules. There is evidence that reference data of weather stations with reference ET can be a determining factor when irrigating landscape plants (Shaw and Pittenger, 2004; White *et al*., 2004). Evapotranspiration is one of the main components of the hydrological cycle. About 64% of the average annual rainfall on land is returned to the atmosphere as a result of the evaporation process (Fisher *et al*., 2005; Sumner *et al*., 2005; Ngongondo *et al*., 2013). Evapotranspiration not only plays an important role in the world water balance, but also significantly affects the world energy balance. Therefore, a quantitative assessment of ET is necessary for water source management, environmental studies and irrigation systems (Jensen *et al*., 1990).

A complete understanding of the water balance for irrigation fields is necessary for the effective and proper management of the irrigation system (Jensen, 2007). Inefficient irrigation programs, in addition to being wasteful, increase the number of diseases and weeds in lawn (Harivandi, 1998). Limited water resources are not optimally distributed and used, and, as a result, a lot of water goes to waste, and less land can be irrigated; and low overall irrigation efficiency creates harmful side effects such as rising groundwater levels and soil salinization (Bos, 1990).

Irrigation is a technology that provides a good balance of moisture in the soil, which leads to the creation of favorable conditions for crop growth. There are many irrigation methods that have been used and that have been adopted for different places depending on certain conditions (Akinyi, 2010). Drip irrigation may be preferable on the surface or subsurface preferable on high soils. It was also reported that the yield and irrigation efficiency were, respectively, 18% and 30% higher than that of surface irrigation (Khalifa, *et al*., 2012). Surface irrigation, as the oldest and most common method of supplying water to arable land, surface irrigation has developed into a vast array of configurations. Surface irrigation delivers water from a source to a field in aligned or unaligned open channels or pipelines with low pressure (Walker, 2003).

Determination of the effectiveness of water is depends on two parameters, the volume of applied water and the amount of water stored in the root zone. Measuring the amount of irrigation water delivered to the farm with volume or flow measurements. The stored volume is measured in terms of the soil moisture can be measured by soil sampling before and after irrigation or modern sensors (Irmak *et al*., 2011).

The aim of this research first based on the increasing awareness about climate change effects on environment and creating water crisis in Duhok province and surrounding areas. For this reason, the goal of this study is to determine ET (the water consumption from the plant transpiration, and soil evaporation), which has a direct impact on the agriculture yield. For this purpose, reference evapotranspiration in Duhok, Zakho, Akre, Amedi, Sumeel, Bardarash, Bamerne, Kanimase and Mangesh city in Duhok region. Hargreaves, Blaney-Criddle (FAO), Turc, Priestly-Taylor, Makkink, FAO-56 Penman-Monteith and Kimberly-Penman methods were used. Secondly a new model were obtained with Multiple regression analyses by using climate parameters.

2. LITERATURE REVIEW

More than 80% of rainfed crops covers of the crop area in the world and make up 60–70% crop production of the world, but production is often limited by drought and lack of soil moisture (Wood *et al.*, 2000). The average precipitation of the world 750 mm per year, at least 60% which is returned to the atmosphere as ET, for this reason ET consider the largest component of the terrestrial hydrological cycle (Baumgartner and Reichel, 1975; Droogers, 2000). Additional irrigation is often offered to increase the yield of rainfed crops, reduce soil moisture during periods of drought and reduce poverty (Oweis *et al.*, 1998; Pereira *et al.*, 2002; Brugere and Lingard, 2003; Fox and Rockstrom, 2003). Also, irrigation may not be required every year, so this is a risk reduction strategy, and its benefits are best suggested in a probabilistic context (Fox *et al.*, 2005).

Drought is a significant lack of precipitation compared to “normal” over a long period of time, which leads to a lack of water for some activities, groups or sectors of the environment (FAO, 2008). It is stated that there are two types of definitions of drought, namely the conceptual definition and the operational definition (Nguyen, 2006). The conceptual definition, made in general terms, facilitates the understanding of the concept of drought and makes it more important for developing a policy to combat drought. An operational agent helps people understand more details about the same drought, such as duration, frequency and intensity at different time scales. Differences in the concept of drought have not led to the adoption of various definitions, which are not universally accepted and have no universal application capabilities (Wilhite and Glantz, 1987; Tate and Gustard, 2000).

As a recurring temporary phenomenon, it should, as a rule, be defined relative to some medium-term conditions, such as precipitation and evaporation, and should be reflected in most common definitions of drought (Smakhtin and Hughes, 2003).

Drought is a time interval, usually of the order of months or years, during which the actual humidity in a given place is constantly below the expected climate or climatically supplies (Palmer, 1965). Drought conditions specify that when the amount of water that cannot be expected or relied on and consumed for any reason and can be used for any human activity (Takeuchi, 1974).

All droughts are caused by insufficient rainfall. There are many reasons for this lack of rain (Nicolas *et al.*, 2012). It may be due to patterns of global air circulation, such as in the Sahara Desert where the winds are very strong, naturally too dry and too sunny. Drought in other parts of the world can occur if high-pressure air systems last several weeks. When there is a high pressure system, no clouds form because water cannot evaporate. When a high-pressure system is over an area for a very long time, there is no rainfall (snow and rain). Similarly, it showed that drought was defined as a deficiency in water supply; may be linked to a number of factors. The most important of these is the amount of water vapor in the atmosphere, because this is precipitation. Where there is humid, low pressure air systems, more rain, sleet, snow and snow may occur. If there is a dry, high-pressure air system above the average, less moisture is available to produce precipitation (Briney, 2012).

On the other hand, the direct cause of the drought was identified as air movement (landing) that resulting in high pressure or high temperature, which prevents the formation of clouds and leads to low relative humidity and low precipitation. Areas that fall under the influence of high pressure semi-rigid throughout the year or most of the days of the year is usually deserts, such as desert and desert Kalahari desert in Africa and the Gobi desert in Asia (NDMC, 2012).

In fact, usually the meteorological measurements are often the first indicators of drought development (Common Wealth of Kentucky, 2008). It is usually determined by the precipitation deficit threshold for a predetermined period of time. The selected threshold, such as 75% of normal precipitation, and the duration period, for example, six months, will vary depending on the location depending on the needs of the user or applications. This is often exacerbated by high temperature and / or high evaporation (Kirono *et al.*, 2011). Meteorological drought is a natural occurrence and is due to a variety of reasons, which vary by region (WMO, 2012). Assessing such a drought requires taking into account such factors as the total amount of precipitation for a certain period (week, month, year) and the period between significant rains, as well as the time they occur (The Canadian Encyclopedia, 2012). This meteorological drought is usually measured by how much rainfall falls below the norm for a certain period of time. As a rule, these definitions refer to a particular region and are based on an in-depth understanding of the so-called regional climate. Examples of meteorological drought from different countries at different times show why the definition of drought developed in a part of the world should not be applied to another: United States (1942): hours less than one inch after 48 hours; Great Britain (1936): fifteen consecutive days of rainfall less than fifteen inches per day; Libya (1964): Annual rainfall is less than 7 inches; India (1960): true seasonal precipitation is not less than twice the average deviation; Bali (1964): A six-day period without rain (IFAS, 1998).

A better understanding of water balance is necessary to explore water saving techniques. One of the most important concepts of water balance in semi-arid areas is the evaporation of crops ET, a key factor for determining appropriate irrigation scheduling and improving water use efficiency in irrigated agriculture. It is the amount of water lost through evaporation from the soil and plant surface, and through plant spores. The rate of water loss from evaporation is based on the environmental requirements of a short green permanent crop covering the entire land. ET based surface irrigation is an emerging area of water conservation as ET based irrigation links water use to irrigation water replacement rates and time scales (Jensen *et al*., 1990; Hanson, 1991; Shaw and Pittenger, 2004; White *et al*., 2004; El-Bourady, 2010).

Evapotranspiration ET depends on many variables, including humidity, net solar radiation, and wind speed, type of vegetation, soil moisture, root depth, characteristics of the earth's surface and season (Hanson, 1991; Clifford and Doesken, 2009). Depending on the state of the soil water, more or less important biological control is carried out with respect to water loss. In addition, the overhang resistance counteracts the transfer of water vapor to the atmosphere (Perrier, 1984; Lhomme, 1997). Evapotranspiration is largely dependent on sunlight, the absence of vapor pressure at any given time, and wind speed. It is also affected by the water content of the soil and the rate of water uptake from the soil (Pereira *et al*., 2014). Readers (Allen *et al*., 1998; Pereira *et al*., 1999) are targeted to further discuss the evapotranspiration ET process (Figure 2.1).

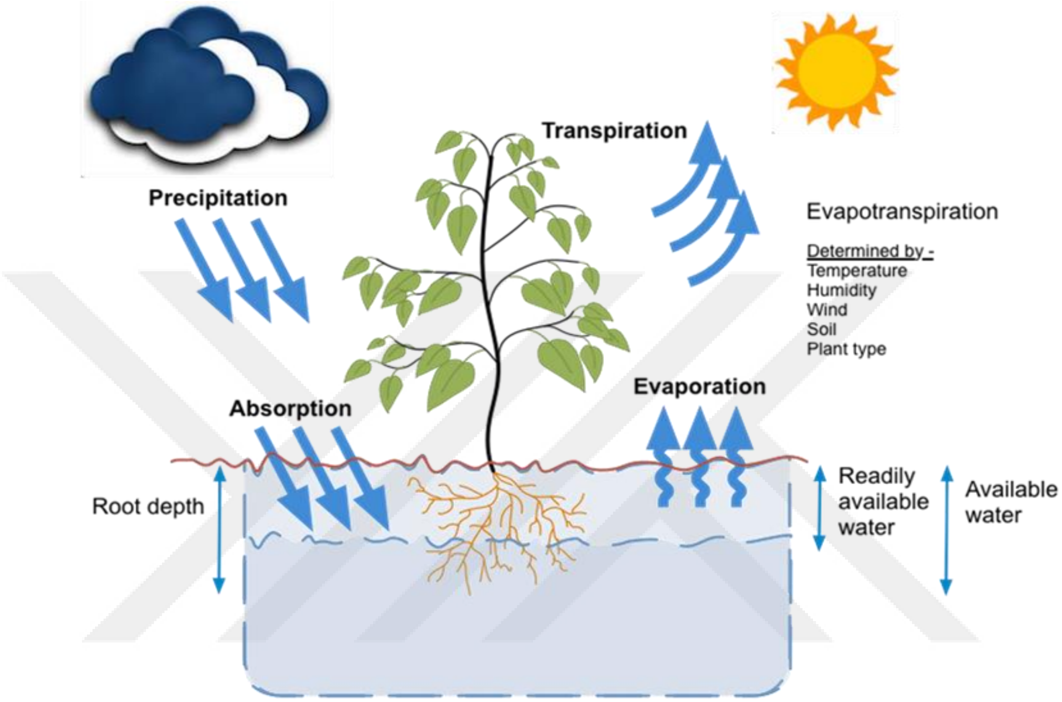

Figure 2.1. Evapotranspiration (ET) Process (Allen *et al*., 1998)

Water consumption by a plant ET is defined as the sum of evaporation (*E*) from the soil surface and the amount of transpiration (*T*) from the leaves of the plant. Water consumption by plants is an important parameter that is affected by climatic, soil and plant factors and should be determined for different conditions. Here are the most complete effective climatic factors and parameters, such as solar radiation, temperature, air humidity, wind speed, sunshine duration and daylight hours, play a role in ET changes (Hanson, 1991; Clifford and Doesken, 2009). For this reason, water consumption by plants is estimated either directly in practice or using climate data. Although direct measurement methods are useful, they are expensive and time consuming. For this reason, plant water consumption is usually determined using prediction equations based on climate data (Güngör *et al.*, 1996).

Evapotranspiration on the Earth's surface transfers large amounts of water from the soil (evaporation, *E*) and vegetation (transpiration, *T*) to the atmosphere. Measuring water consumption in large areas and irrigated projects is important for water rights management, water resource planning, hydrological balance and water management.(Allen *et al*., 2007). ET consumes a significant proportion of total precipitation, estimating the local rate of ET is crucial for accurate water balance assessment (Senay *et al*., 2011; Wilcox *et al*., 2008; Yeh and Famiglietti, 2009; Huxman *et al*., 2005). Some studies have shown that annual rates of ET exceed annual precipitation, which indicates that plants gain access to groundwater during dry periods (Kochendorfer *et al*., 2011; Yeh and Famiglietti, 2009; Gazal *et al*., 2006). ET is plays a significant role in local hydrology, changes in land use, such as the conversion of grassland into forests, can affect the amount of rainfall that is the flow (Yeh and Famiglietti, 2009). When ground cover is converted from low ET (usually grass) to high ET (forest) vegetation, the net release of water from the streams can be reduced (Wilcox *et al*., 2008). Therefore, quantifying ET for different types of land cover within a catchment can provide information useful for an informed water resource management decisions (Twine *et al*., 2004). ET accounts for more than half of the total water loss from most terrestrial plant ecosystems (Zhang *et al*., 2001; Lu *et al*., 2003). For example, in semi-arid and arid areas with limited water, ET may be an even larger percentage of the total water loss and may be equal to the amount of precipitation (Wang *et al*., 2010).

Measurement and estimation of evapotranspiration

There are many methods to measure ET; some methods are more appropriate than others for accuracy and cost, or are particularly suitable for given spatial and temporal scales. For multiple applications, it is necessary to estimate ET, so it should be evaluated by the model. The methods of determining ET are discussed separately when measuring and modeling elements are considered (Rana and Katerji, 2000). A method set is designed primarily for quantitative determination of evaporation from weeks to months and over a long period of time during the growing season. Another set of methods has been developed to understand the process governing the transfer of energy and matter between the surface and the atmosphere. The second group of methods is used to examine the water relationships of individual plants or parts thereof (Rose and Sharma, 1984).

This information is then used to determine the amount of water available for use by the plant and its temporal dynamics. Weather sensing includes the use of ET of crops to determine the temporary water consumption of crops. ET is determined using climate variables such as radiation, rainfall and wind speed (Allen *et al*., 1998; Leib *et al*., 2002). A plant-based sensation involves determining the state of water in plants, which is usually related to plant physiology. Measurement of canopy temperature, stomata resistance, juice consumption, leaf turgor pressure, as well as stem diameter and leaf thickness are used to determine the water status in the plant (Pardossi *et al*., 2011). As a result, various methods for evaluating ET have been developed, which are usually classified into direct and indirect methods (Sharma, 1985; Hatfield, 1990). Direct ET estimation methods include those using weighted lysimeters, while indirect methods include those based on the actual evapotranspiration concept AET versus potential evapotranspiration AET and use meteorological data (Sharma, 1985; Hatfield, 1990).

Reference evapotranspiration

ET is a combination of soil evaporation and product perspiration. Air parameters, crop characteristics, management and environmental aspects affect ET. The ET ratio from the reference surface is called reference evapotranspiration and is called ET_0. A large, homogeneous grass field (or alfalfa) is considered the worldwide reference surface. The reference grass completely covers the soil; it remains short, well watered and grows actively under optimal agronomic conditions (Allen *et al*., 1998).The concept of ET_0 was introduced to study the need for evaporation in the atmosphere, regardless of the type of crop, the development of crop and management practice. Since there is a lot of water on the reference evapotranspiration ET_0 surface, soil factors does not (ET_0). The ratio of ET to a specific surface provides a link to which ET from other surfaces can be associated. Reference evapotranspiration values, measured or calculated in different places or at different times of the year, are comparable, since they refer to the ET from the same reference surface. The only factors affecting ET_0 are climatic parameters. Therefore, ET_0 is a climatic parameter and can be calculated based on weather data. Reference evapotranspiration expresses the evaporating capacity of the atmosphere at a specific place and time of year and does not take into account the characteristics of the crop and soil factors (Allen *et al*., 1998) (Figure 2.2).

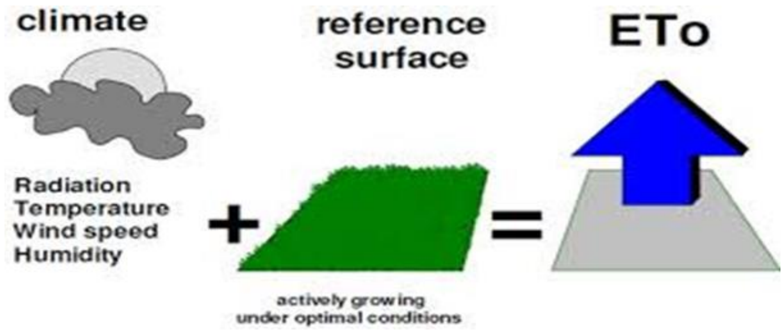

Figure 2.2. Definition of reference evapotranspiration (ET_0) (Allen *et al.,* 1998)

Because of the difficulty of obtaining accurate field measurements, ET_0 is generally calculated based on weather data. Numerous empirical or semi-empirical equations have been developed to estimate ET_0 from meteorological data. Numerous researchers have analyzed the effectiveness of various calculation methods for different locations. As a result of expert interviews in May 1990, the Penman-Monteith FAO method is now proposed as a standard method for the determination and calculation of reference evaporation transpiration ET_0 (Allen *et al.,* 1998).

Effect factors of ET_0

Effective ET quantification is a key aspect of efficient and accurate irrigation management (Irmak, 2009). This knowledge will allow users to deliver the right amount of water to the field at the right time, in turn saving water (Irmak, 2009).

The accuracy of any ET calculation depends on the quality of weather data, which requires good quality control and quality assurance procedures. Where possible, weather data should be measured at stations located in open, well-watered plants (preferably grass). Preferred locations have low-growing, irrigated vegetation in the immediate vicinity of the weather station (~ 50 m), and essentially the same or other irrigated vegetation a few hundred meters away from it (Allen, 1996). The ET of crops is influenced by various weather parameters, crop factors, environmental conditions, and management methods (Allen *et al.*, 1998). Because of their interdependence, spatial and temporal variability, the compilation of one specific equation for the actual estimation of ET for different crops in different conditions is difficult.

Requiring ET_0 equation

Reference evaporation is the rate of evaporation of soil water which can be easily obtained from the specified plant surfaces (Jensen *et al*. 1990). In terms of reproducibility and convenience, the reference surface has recently been described as a hypothetical vegetative surface with specific properties (Smith *et al*., 1991; Allen *et al*., 1994a; Allen *et al*., 1998). ET is the only term that occurs both in the surface energy balance equation and in the water balance equation. Reliable ET estimates are often required to solve problems in hydrology, agriculture, forestry and land use and to improve global circulation patterns (Yates, 1997).

Reference evapotranspiration is the amount of soil water that evaporates from a certain uniform vegetation cover (Walter *et al*., 2005). Possible calculate the reference evapotranspiration (ET_o) in Colorado with two reference crops; a cool season turf grass and alfalfa using an ASCE Standardized Penman-Monteith Equation (Walter *et al*., 2005). Using (ET_o) is a commonly used method for determining irrigation phenomena for turf grass landscapes and crops (St.Hilaire *et al*., 2008). For the cool season grass reference evapotranspiration crop(ET_{os}), this value is measured by the Northern Colorado water conservation district in Colorado at many field sites including four Ft. Collins sites (NCWCD, 2013). The reference evapotranspiration crop value is then multiplied by the crop coefficient (Kc) which products the particular crop evapotranspiration (ET_c) for a specific crop species (Grant and OM, 2013). Unfortunately, (Kc) values are unknown for most species of ornamental plants (Shaw and Pittenger, 2004). In addition, reference crops, such as the cool season turf grass and corn, usually have uniform surfaces; this does not apply to ornamental plantings of various heights and type of plants (St.Hilaire *et al*., 2008).

Evaluating the need for grass and alfalfa water as the (ET_o) fraction $(ET_o \times Kc \ \ or \ \ PF)$ is a very effective tool to estimate and irrigate water requirements as the grass nodes closely imitate the standard reference evaporation transpiration (ET_o) (Gibeault *et al*., 1985; Devitt *et al*., 1992; Richardson *et al*., 2012). The generally accepted research-based average (PFs) are 0.6 and 0.8, respectively, with the expectation of providing only adequate appearance when grown as average regular lawns for warm and cold season lawns (ASOABE, 2013).

Meteorological Factors Determining ET_0

Meteorological factors that determine ET_0 are weather parameters that provide energy for evaporation and remove water vapor from the evaporating surface. The main weather parameters for consideration are presented below (Allen *et al*., 2006) (Figure 2.3).

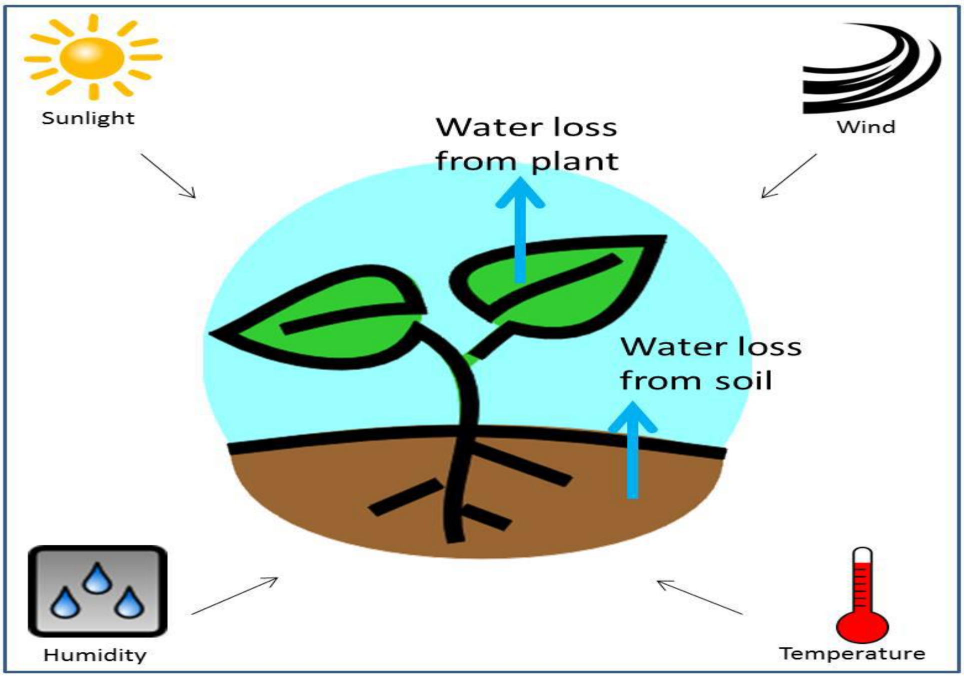

Figure 2.3. ET_0 concept diagram, showing the process of ET_0 (middle illustration) and the main drivers of ET_0 (far corners of the diagram) (Allen *et al*., 2006)

Solar radiation

The ET_0 process is determined by the amount of energy available to evaporate the water. Solar radiation is the largest source of energy and can convert large amounts of liquid water into water vapor. The amount of potential radiation that can reach an evaporating surface is determined by its location and time (Allen *et al*., 2006).

Temperature

The solar radiation absorbed by the atmosphere and the heat emitted by the earth increases the temperature of the air. The sensible heat of ambient air transfers the energy to the crop and thus has a controlling effect on the ET_0 ratio. Water loss as a result of ET_0 in sunny hot weather is greater than in cloudy and cold weather (Allen *et al*., 2006).

Air humidity

While the supply of energy from the sun and ambient air is the main driving force of water evaporation, the difference between the water vapor pressure on the ET_0 surface and the ambient air is the decisive factor for the removal of the vapor. In dry arid areas, well-watered areas consume large amounts of water due to excessive energy and drying capacity of the atmosphere (Allen *et al*., 2006).

Wind speed

The vapor removal process is largely dependent on the turbulence of the wind and air carrying a large amount of air from the evaporation surface. When water evaporates, the air above the evaporating surface is slowly saturated with water vapor. If this air is not constantly replaced by dry air, the driving force to remove water vapor and ET is reduced (Allen *et al*., 2006).

The aim of this research first based on the increasing awareness about climate change effects on environment and creating water crisis in Duhok province and surrounding areas. For this reason, the goal of this study is to determine ET_0. For this purpose, reference evapotranspiration in Duhok, Zakho, Akre, Amedi, Sumeel, Bardarash, Bamerne, Kanimase and Mangesh city in Duhok region. Hargreaves, Blaney-Criddle (FAO), Turc, Priestly-Taylor, Makkink, FAO-56 Penman-Monteith and Kimberly-Penman methods were used. Secondly a new model were obtained with Multiple regression analyses by using climate parameters.

3. MATERIALS AND METHODS

3.1. Materials

The Kurdistan Region consists of the three governorships of Duhok, Erbil and Sulaymaniyah under the authority of the Kurdistan Regional Government (KRG). Each of these three governorships is divided into districts with a total of 26 regions. Each region is divided into sub-regions. While each Governorate has a capital, there are district centers in districts and sub-districts (Ismael, 2015).

3.1.1. Duhok Province

The station location of the study area was Duhok province in the Kurdistan Region of Iraq; Meteorology and Seismology. This city is the center of Duhok, the smallest governor of the Kurdistan Region. Duhok is located in northwestern Iraq and in the western part of the Kurdistan Region, about 470 km north of Baghdad. There are two rivers crossing the city, the first is the Duhok River, the second is the smaller and seasonal river Heshkarow. The name of Duhok also consists of two words: (Du), in Kurdish language (two) and (Hok) means (lump). According to the most recent excavations in the city, some archaeological evidence and manuscripts have been created for the 3000 BC dates (DGDAT, 2013). The province of Duhok has seven districts such as (Duhok, Zakho, Sumeel, Akre, Amedi, Shekhan, and Bardarash), as shown in Figure 3.1. And the Duhok province has mutual borders with two countries such as Turkey and Syria, and also it has two locally mutual borders with Erbil province following with Kurdistan region government and Ninawah province following with central Iraqi government, as shown in (Figure 3.2).

Figure 3.1. Map is shown districts in Duhok province. URL (https://en.wikivoyage.org/wiki/Dahuk, 13.09.2019)

Figure 3.2. Map is shown the location of Duhok province. URL (https://link.springer.com. 13.09.2019)

The province of Duhok climate is characterized by wet season and the relative humidity at maximum and the temperature and probability evaporation are at minimum in winter. The weather in summer is hot and dry and the temperature and evaporation are maximum, while the relative humidity is minimum. The lowest point from selected study area in the Duhok province is Zakho, which has an elevation of 444 meters above sea level, and the highest point is Amediye, measuring 1,195 meters above sea level (Bayar A. Ragab, 2017). In this study we collected climate data from different station in various districts and sub-districts such as (Duhok, Zakho, Akre, Amedi, Sumeel (Agriculture College / University of Duhok), Bardarash, Bamerne, Kanimase, and Mangesh) as shown in (Figure 3.3.).

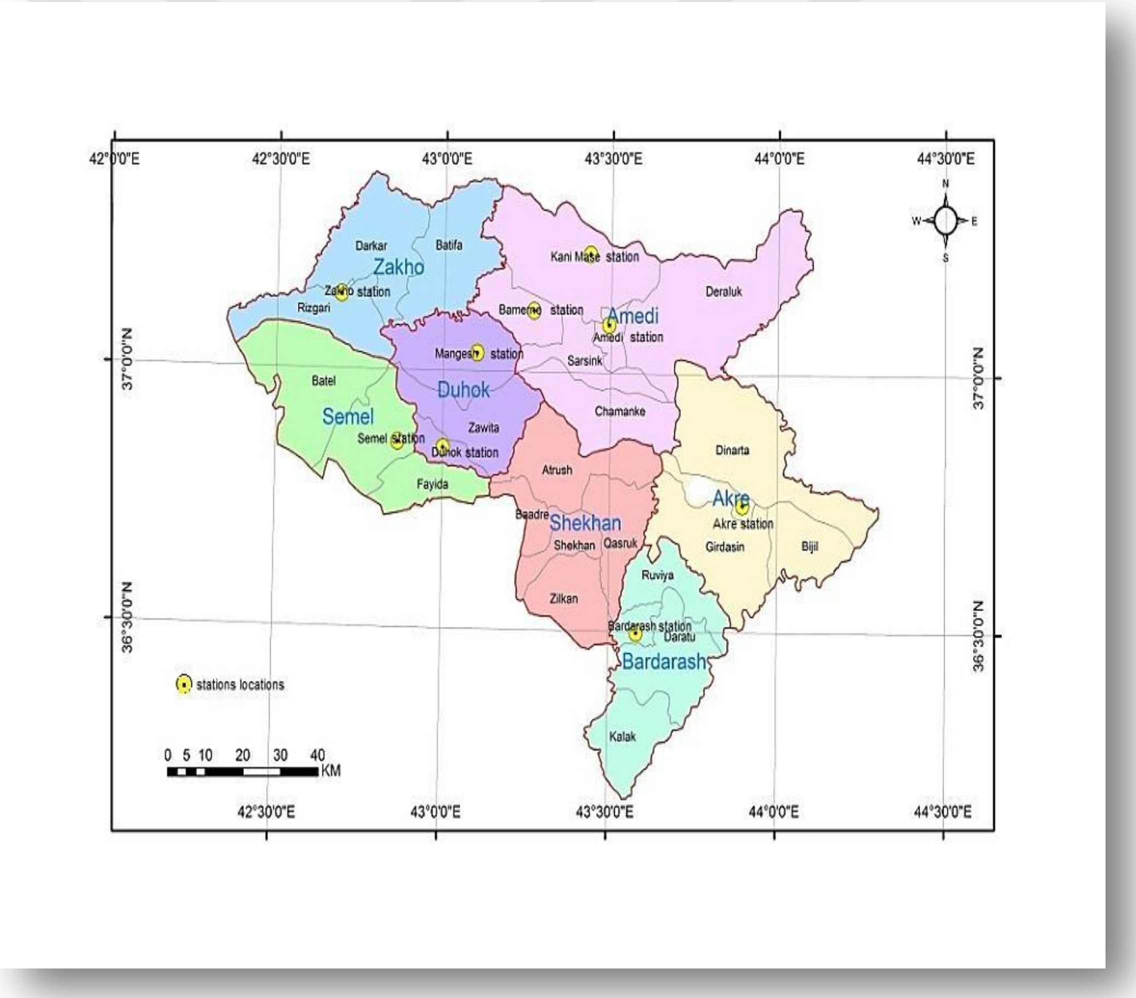

Figure 3.3. Map is shown location of station in Duhok province (DOMSD, 2019)

3.1.1.1. Duhok District

Duhok is the first largest district from seven districts in Duhok province, and is situated in a wide valley extended between two opposing mountain ranges, namely Bekher mountain in the north and Zawa mountain in the south, Duhok Dam was built over Duhok valley catchment to the north of the city during 1980-1988 for irrigating rain-fed agricultural lands, which are located to the west of the city center and extend up to neighboring Sumeel district (Brendan, John and Khaled, 2005; Chatty, 2010; Wikipedia, 2012; Mohammed, 2013).

3.1.1.2. Zakho District

Zakho is the second largest district in Duhok province. It lies between the latitude (N37.14°) and the longitude (E42.69°). The altitude is 444 m above sea level and is located only 50 km northwest of the district center of Duhok. The city is located 8 km west of the Turkish border crossing Ibrahim Khalil. The city has a population of 350,000. Zakho has a hot summer Mediterranean climate (Csa) with very hot and dry summers and cool winters with abundant winter rainfall (DOMSD, 2019).

3.1.1.3. Akre District

Aker district is one of the districts in Duhok province; it is located between latitude (N36.74°) and longitude (E43.89°), and altitude is 636m above sea level and located 100 km East of Duhok, 25 km from the Ruvea intersection (DOMSD, 2019).

3.1.1.4. Amedi District

The district of Amedi is one of the districts in the province of Duhok. It lies between latitude (N37.09^{o}) and longitude (E43.49^{o}) and 1195 m above sea level (DOMSD, 2019). Amadiya has a hot summer Mediterranean climate with long, hot summers and cool, wet winters. Climate classification according to Köppen: Csa is the northernmost city in Iraq and the country's mildest city (Goode's, 2000).

3.1.1.5. Sumeel District (Agriculture College / University of Duhok)

Sumeel district is one of the districts in Duhok province. It lies between the latitude (N36.51°) and the longitude (E42.52°), and the altitude is 473 m above sea level (DOMSD, 2019). The city is located on the main road connecting Iraq with neighboring Turkey. It is 14 km west of the city of Duhok (Sumeel city in history).

3.1.1.6. Bardarash District

Bardarash district is one of the districts in Duhok province. It is located between latitude (N36º30’03”) and longitude (E43º35’4”) and altitude is 379m above sea level (MDDOAS, 2019). Bardarach (Kurdish: Berdereş بەردەڕەش) is a district located of Iraqi Kurdistan Region in Duhok province and 70 km north of the city of Erbil province (the capital of Iraqi Kurdistan Region) and 32 km north-east of Mosul province(Yaseen; Wikipedia, 2019).

3.1.1.7. Bamerne Sub-District

Bamerne is one of the sub-districts in the province of Duhok. It lies between the latitude (N37.11^{o}) and the longitude (E43.26^{o}), and the altitude is 1211 m above sea level (DOMSD, 2019).

3.1.1.8. Kanimase Sub-District

Kanimase is one of the sub-districts in the province of Duhok. It lies between the latitude (N37.23^{o}) and the longitude (E43.43^{o}) and at an altitude of 1340 meters above sea level (DOMSD, 2019).

3.1.1.9. Mangesh Sub District

Mangesh is one of the sub-districts in the province of Duhok. It lies between latitude (N37.03^{o}) and longitude (E43.10^{o}) and 945 m above sea level (DOMSD, 2019). Mangesh (Syrian: ܡܲܢܓܹܫ) is a Chaldean city in the region of Duhok in northern Iraq. The city is located in the Sapna Valley between Amedi in the east and Zakho in the west (Ishtar, 2011).

3.2. Methods

3.2.1. Temperature-based method

3.2.1.1. Hargreaves Method

The Hargreaves method (Hargreaves and Samani, 1985; Hargreaves and Allen, 2003) allows the estimation of evapotranspiration (ET_o) from reference crops in areas where meteorological information is scarce. This is an empirical estimation method that uses the average daily air temperature T (℃) in combination with the extraterrestrial radiation Ra (MJ / m^2 / day) as an indicator of the incident global radiation. Hargreaves and Samani (1982, 1985) proposed several improvements to the Hargreaves (1975) equation to estimate the grass-related reference ET (mm d^{-1}). The Hargreaves equation is expressed as:

$$ET_o = aR_aTD\,0.5\,(T_a + 17.8) \tag{1}$$

Or

$$ET_o = 0.0023R_s\left(\frac{T_{max}+T_{min}}{2} + 17.8\right)\sqrt{T_{max} - T_{min}} \tag{2}$$

Where: parameter expressed as below

a = 0.0023 is a parameter

TD = The difference between maximum and minimum daily temperature in℃

R_a = The extraterrestrial radiation expressed in equivalent evaporation units. The only variables for a given location and time period is the daily mean, max and min air temperature. Therefore, the Hargreaves method has become a temperature-based method.

3.2.1.2. Blaney-Criddle Method

The Blaney-Criddle method for estimating ET is well known in the Western US (i.e., for a Mediterranean-type climate) and has been widely used elsewhere (Blaney-Criddle, 1950; Singh, 1989). The usual form of the Blaney-Criddle equation converted into metric units is:

$$ET = kp\,(0.46\,Ta\ + 8.13) \qquad (3)$$

Where: parameter expressed as below
ET = Potential evapotranspiration, mm
Ta = Average temperature in℃
p = Percentage of total daytime hours for the used period (daily or monthly) out of total daytime hours of the year (365×12)
k = Monthly consumptive use coefficient

According to the recommendation of Blaney and Criddle (1950) values of 0.85 and 0.45 were used in the first phase of the comparative study for the growing season (April to September) and the non-growing season (October to March).

3.2.2. Radiation-based method

3.2.2.1. Turc Method

The Turc developed an equation for potential ET under general climatic conditions of Western Europe (Turc, 1961). He proposed the following equations for two humidity conditions:

$When\ RH_{mean} > 50\%$,

$$ET_0 = 0.013\,\frac{T_{mean}}{(T_{mean}+15)}(R_s\ + 50\,)\frac{1}{\lambda} \qquad (4)$$

$When\ RH_{mean} \leq 50\%$,

$$ET_0 = 0.013\,\frac{T_{mean}}{(T_{mean}+15)}(R_s\ + 50\,)\frac{1}{\lambda}\left\{1 + \frac{(50- RH_{mean})}{70}\right\} \qquad (5)$$

Where: parameter expressed as below
T_{mean} = Mean air temperature (℃)
RH_{mean}= Mean relative humidity (%)

R's = Solar radiation ($cal/cm^2/day$)
R_s = ($MJ/m^2/day$) is known, it can be calculated as: $R's = R_s/0.041869$
λ = The latent heat of vaporization (MJ/kg). It can be estimated using mean air temperature as: $\lambda = 2.501 - 0.002361T_{mean}$

3.2.2.2. Priestly-Taylor Method

The Priestly and Taylor proposed an equation for the surface that is generally moist and a condition for possible evaporation (Priestley and Taylor, 1972). The equation can be expressed as:

$$E_p = a\,\frac{1}{\lambda}\,\frac{\Delta}{(\Delta+\lambda)}(R_n - G) \tag{6}$$

Where: parameter expressed as below
Δ Is slope of saturation vapor pressure-temperature curve (kPa/°C), it can be calculated if T_{mean} values are known using Teten's expression as:

$$\Delta = \frac{4098\, e^0_{mean}}{(T_{mean}+237.3)} \tag{7}$$

Where: parameter expressed as below
e^o_{mean} = Saturation vapor pressure at mean temperature (kPa)
γ = Psychometric constant (kPa/°C)
R_n = Net Radiation ($MJ/m^2/day$)
α = Short wave reflectance or albedo and its value is taken as 0.23
G = Heat flux density to the ground ($MJ/m^2/day$)

3.2.2.3. Makkink Method

The Makkink proposed an equation for estimating potential evapotranspiration ($mm\ d^{-1}$) from grass (Makkink, 1957). Proposed the equation:

$$ET = 0.61\frac{\Delta}{\Delta+\gamma}\,\frac{R_S}{\lambda} - 0.12 \tag{8}$$

Where: parameter expressed as below

R_s= The total solar radiation in cal (cm^{-2} day^{-1})

Δ = The slope of saturation vapour pressure curve (in mb/°C)

γ = The psychrometric constant (in mb/°C)

λ = Latent heat (in calories per gram)

P = Atmospheric pressure (in millibar)

3.2.3. Pan evaporation-based or combination-based method

3.2.3.1. FAO-56 Penman-Monteith Method

The United Nations International Irrigation and Drainage and Food and Agriculture Commission has proposed the FAO-Penman-Monteith method (Allen *et al.*, 1998) as the standard method for estimating reference evapotranspiration. The FAO-modified Penman-Monteith method is well known and the FAO-56-PM method is expressed as:

$$ET_o = \frac{0.408\Delta(R_n - G) + \gamma\frac{900}{T_{mean}+273}U_2(e_s - e_a)}{\Delta + \gamma(1 + 0.34\, U_2)} \tag{9}$$

Where: parameter expressed as below

ET_o = Reference evapotranspiration (mm day^{-1})

R_n= Net radiation at the crop surface (MJ m^{-2} day^{-1})

G = Soil heat flux density (MJ m^{-2} day^{-1})

T = Mean daily air temperature at 2 m height (°C)

U_2= Wind speed at 2 m height (m s^{-1})

e_s= Saturation vapour pressure (kPa)

e_a= Actual vapour pressure (kPa)

$e_s - e_a$= Saturation vapour pressure deficit (kPa)

Δ = Slope vapour pressure curve (kPa°C^{-1})

γ = Psychrometric constant (kPa°C^{-1})

The FAO-56 Penman-Monteith method (FAO-56 PM) requires observation of maximum and minimum air temperature, maximum and minimum relative humidity (or actual vapor pressure), and wind speed data for daily, weekly, ten-day, or monthly calculations in 2 m altitude and solar radiation for accurate estimation of ($ET_{\boldsymbol{o}}$).

Where radiation data is lacking or not reliable, solar radiation (Rn) can be estimated using records of hours of sun, as suggested by (Allen *et al*., 1998).

$$R_n = R_{ns} - R_{nl} \tag{10}$$

Where, R_{ns} is net shortwave radiation (MJ/m^2/day) and R_{nl} is net long wave radiation (MJ/m^2/day).

$$R_{ns} = (1 - a)R_s \tag{11}$$

Where, R_s is incoming solar or shortwave radiation (MJ/m^2/day) and $\boldsymbol{\alpha}$ albedo or canopy reflectance coefficient ($\boldsymbol{\alpha}$ = 0.23, for hypothetical grass reference surface).

$$R_s = a_s + b_s \frac{n}{N} R_a \tag{12}$$

Where, R_a is extraterrestrial radiation (MJ/m^2/day), n is actual duration of sunshine (hours), N is maximum possible duration of sunshine, as is regression constant expressing the fraction of extraterrestrial radiation that will reach the earth surface on overcast/cloudy days $(n = 0)$ and $a_s + b_s$ is fraction of extraterrestrial radiation that reaches earth surface on clear sky days *(n=N)*.

$$R_s = \frac{1440}{\pi} G_s d_r [\omega_s \sin(\emptyset) \sin(\delta) \sin(\omega_s) \cos(\emptyset) \cos(\delta)] \tag{13}$$

$$d_r = 1 + 0.033 \cos\left(\frac{2\pi}{365} J\right) \tag{14}$$

$$\delta = 0.409 \sin\left(\frac{2\pi}{365} J - 1.39\right) \tag{15}$$

$$\omega_s = arccos[-\tan(\emptyset) \tan(\delta)] \tag{16}$$

Where, G_s is solar constant (0.0820 MJ/m^2/day), d_r inverse relative Earth-Sun distance, ω_s is sunset hour angle (rad), δ is solar declination angle (rad) and $\emptyset$ is latitude of station (rad), J is the number of the day in calendar year.

$$R_{nl} = \sigma\left[\frac{T_{max},k^4 - T_{min},k^4}{2}\right]\left(0.34 - 0.14\sqrt{e_s}\right)\left(1.35\frac{R_s}{R_{so}} - 0.35\right) \tag{17}$$

Where, $\boldsymbol{\sigma}$ is Stefan-Boltzman constant (4.903 ×10^{-9} MJ/K^4/m^2/day), T_{max}, $K\&T_{min,K}$ are absolute maximum and minimum temperature values (^0K), ratio R_s/R_{so} is relative shortwave radiation (limited to ≤ 1.0) and R_{so} is clear sky radiation (MJ/m^2/day) estimated as;

$$R_{so} = (a_{s-}b_s)R_a \tag{18}$$

3.2.3.2. Kimberly-Penman Method

For the first time in 1948, H.L. Because it was derived by Penman, the original Penman equation was changed several times. The Kimberly-Penman equation, adapted by James L. from ARS in Wright Idaho. 1982 Kimberly-Penman uses alfalfa as the reference product for well-watered plants with 30 to 50 cm ball growth (Allen *et al.*, 1989).

$$\lambda_{ET_0} = \frac{\Delta}{\Delta-\gamma}(R_n - G) + \frac{\gamma}{\Delta+\gamma}6.43W_{\int}(e_s - e_a) \tag{19}$$

Where: parameter expressed as below
ET_0 = The reference evapotranspiration in mm day^{-1}
Δ = The slope of the sasturation vapor pressure and temperature curve in kPa/°C
γ = The psychrometric constant in kPa/°C
R_n = Net radiation in mm day^{-1}
G = Soil heat flux in mm day^{-1}, (G) was neglected since its value is insignificant as compared to other values)
λ = Latent heat of vaporization [MJ/m^{2}d]
$W_{\int}$ = Wind function
$e_s - e_a$= The mean daily saturation vapor-pressure deficit (kPa)

The wind function ($W_{\int}$) takes the form:

$$W_{\int} = (a_w + b_w u_2) \qquad (20)$$

u_2 = wind speed at 2 m [m/s] (21)

a_w = 0.4+1.4 exp. [− ((J − 173)/58)^2] (22)

b_w = (0.007 + 0.004 exp. [− ((J − 2432)/80)^2)] (86.4) (23)

Where: J is the Julian day of the year. In southern latitudes, J is incremented or decremented by 183, respectively (Allen *et al*., 1989).

The climate data that we collected from different station analyzed by this program, and through this program it is possible to select equation that will be used to determine reference evapotranspiration. Ref-ET is a software package that calculates reference evapotranspiration ET. Evaporation is the process whereby liquid water is converted to water vapour (vaporization) and removed from the evaporating surface (vapour removal). Transpiration consists of the vaporization of liquid water contained in plant tissues and the vapour removal to the atmosphere. ET is the sum of evaporation and plant transpiration from the Earth's land and ocean surface to the atmosphere. ET is important for determining the water requirements for the crops, climatic characterization, and for water management. The primary purpose of REF-ET are to provide standardized reference ET calculations that can be compared with other ET computer programs or spreadsheets. The Refet also contains supplementary weather site information including the temperature values, weather station elevation, the location latitude and longitude, default day/night wind ratio, etc. (RET-ET, 2016).

3.3. Statistical analyses

The comparison was made using the ANOVA test to see whether there is a difference between ET_0 results and The Duncan multiple t- test was used for grouping of methods. Multiple regression analyses to obtain new model for evapotranspiration. Average of ET_0 values were taken as input parameter and, the Average temperature, maximum temperature, minimum temperature, relative humidity, wind speed and sunshine duration were taken as input parameters for Multiple regression analyses. Long- term climate values were used to create model and 2018 climate data were used to test the model (Gomez and Gomez, 1984).

4. RESULT AND DISCUSSION

4.1. Climate data

The climatic data for 2018 year and long-term average, required ET equation, are obtained from meteorological station (name of station), diverted required form/units and summarized as (Table 4.1.- 4.9).

Table 4.1. Climate data of Duhok Station

The weather station name; Duhok station
The type of meteorological station; Classic measurement device
The anemometer height; 2m height on the earth surface
The temperature height; 1.5m height on the earth surface
The weather station elevation (altitude); 569m above sea level
The weather station latitude; (N 36º85’04”)
The weather longitude; (E 43º00’10”)

Month	Avg. Temp. (℃)	Avg. Min Temp. (℃)	Avg. Max Temp. (℃)	Avg. Humidity (%)	Avg. Wind Speed (m/s)	Sum. Rainfall (mm)	Avg. Sunshine (hours)
2018							
January	9	4.8	13.2	67	1.64	76	4.07
February	10.8	6.6	15	70	1.31	121.5	4.39
March	16.4	10.9	21.8	59.1	1.58	19.3	6.37
April	19.3	13.3	25.2	57	1.52	121.9	7.59
May	23.4	17.5	29.3	55.5	1.51	120.6	8.32
June	29.3	22.3	36.3	36	1.95	1.1	11.27
July	33.2	25.5	40.9	30	1.45	0	12.28
August	32.7	25.1	40.2	33	1.35	0	11.50
September	29.6	22.3	36.9	32	1.21	0	10.20
October	23.5	17.9	29.1	49.5	1.43	66	6.20
November	14.2	10.1	18.3	74.5	1.25	181.1	4.06
December	10.1	7.1	13.1	80	1.51	245.5	2.56
Long term (2013-2017)							
January	7.4	3.2	11.5	69.8	1.25	156.72	4.57
February	9.7	4.9	14.5	67.7	0.97	51.8	6.71
March	13.4	8.8	17.9	65.5	1.33	92.04	5.79
April	18.2	13	23.9	57.2	1.31	45.72	8.21
May	24.2	17.9	30.5	44.9	1.34	18.24	9.28
June	29.5	22.5	36.4	32	1.27	4.1	11.38
July	33.4	26	40.8	28	1.11	0	11.43
August	33.3	25.8	40.8	28.4	1.15	0.1	11.04
September	28.5	21.5	35.4	36.7	1.06	4.23	10.09
October	21.7	15.9	27.5	41.7	1.03	32.88	7.66
November	14.1	9.2	19.2	60	0.98	83.76	5.69
December	9.2	4.8	13.6	67.3	1.08	78.72	4.37

Table 4.2. Climate data of Zakho Station

The weather station name; Zakho station The type of meteorological station; Classic measurement device The anemometer height; 2m height on the earth surface The temperature height; 1.5m height on the earth surface The weather station elevation (altitude); 444m above sea level The weather station latitude; (N 37º14’47”) The weather longitude; (E 42º69’20”)							
Month	Avg. Temp. (℃)	Avg. Min Temp. (℃)	Avg. Max Temp. (℃)	Avg. Humidity (%)	Avg. Wind Speed (m/s)	Sum. Rainfall (mm)	Avg. Sunshine (hours)
2018							
January	9.3	5.6	13.7	65.5	0.73	71.6	4.07
February	11.9	7.4	16.3	66	0.61	106.2	4.39
March	17.6	12.2	22.9	57	0.77	29.1	6.37
April	20.1	13.9	26.2	58	0.68	103.5	7.59
May	24.1	18.2	30	55	0.75	109.7	8.01
June	30.9	23.6	38.2	29.5	0.71	2.4	11.52
July	34.8	27	42.6	22.5	0.66	0	12.16
August	34.4	26.7	42	22.5	0.62	0	11.25
September	31	23.6	38.4	23.5	0.54	0	10.28
October	24.4	18.6	30.1	42.5	0.61	79.5	6.10
November	14.8	10.8	18.7	69.5	0.49	164.2	4.33
December	10.4	7.5	13.3	76	0.72	289.6	3.08
Long term (2013-2017)							
January	8.1	3.8	12.4	65.4	0.89	133.9	3.63
February	10.7	5.7	15.7	60.2	0.87	50.5	6.46
March	14.2	9.2	19.1	59.5	1.00	108.6	5.87
April	19.1	12.9	25.2	52	1.04	55.7	8.39
May	24.8	17.9	31.6	39	1.02	26.6	9.30
June	30.6	23.2	37.9	23.8	0.98	4.7	11.58
July	34.9	27.2	42.6	19.3	0.90	0	11.98
August	34.7	26.9	42.4	21.3	0.83	0.2	10.78
September	29.8	22.5	37.1	27.4	0.75	6.8	9.94
October	22.6	16.5	28.7	41.7	0.76	64.7	7.32
November	15	9.8	20.1	58.5	0.67	87.6	5.82
December	9.8	5.4	14.2	64	0.75	86.7	4.07

Table 4.3. Climate data of Akre Station

The weather station name; Akre station
The type of meteorological station; Automatic measurement device
The anemometer height; 10m height on the earth surface
The temperature height; 1.5m height on the earth surface
The weather station elevation (altitude); 636m above sea level
The weather station latitude; (N 36º74’69”)
The weather longitude; (E 43º89’65”)

Month	Avg. Temp. (℃)	Avg. Min Temp. (℃)	Avg. Max Temp. (℃)	Avg. Humidity (%)	Avg. Wind Speed (m/s)	Sum. Rainfall (mm)	Avg. Sunshine (hours)
2018							
January	8.8	4.6	13	56	1.12	102.8	5.38
February	11.2	6.9	15.4	59	1.23	191.8	5.32
March	16.3	11.3	21.2	51	1.36	29.8	7.29
April	19.4	13.7	25.1	45	1.81	85.8	8.52
May	23.7	18.3	29.1	43.5	2.19	115.6	8.22
June	30.6	23.9	37.3	20.5	2.01	0	12.39
July	35	27.9	42.1	14.5	1.85	0	12.36
August	30.9	24	37.7	15.5	1.63	0	12.20
September	30.9	24	37.7	16	1.58	0	11.23
October	24.1	18.9	29.2	34	1.90	60.4	7.15
November	14.3	10.6	18	62	1.37	209.6	5.09
December	9.4	6.1	12.6	71	1.14	318.2	3.10
Long term (2013-2017)							
January	7.5	3.1	11.9	35.1	1.23	163.3	5.50
February	9.5	4.5	14.4	32.3	1.46	59.6	5.41
March	12.7	7.8	17.6	35.5	1.75	106.2	4.84
April	18	12	24	32.8	1.79	40.2	6.66
May	24.5	18.1	30.9	28	2.13	14.4	7.31
June	30.4	23.9	36.8	25.5	2.46	5.9	9.62
July	35	28	41.9	25.9	1.67	0	10.18
August	35.1	28.1	42	25.6	1.58	0.2	9.35
September	29.7	23	36.3	24	1.35	5.04	8.48
October	22.4	16.9	27.9	22.7	1.37	41.6	6.54
November	14.6	9.7	19.5	24.5	1.13	92.2	5.44
December	9.2	4.8	13.5	27.5	1.14	114.7	3.05

Table 4.4. Climate data of Amedi Station

The weather station name; Amedi station
The type of meteorological station; Automatic measurement device
The anemometer height; 10m height on the earth surface
The temperature height; 1.5m height on the earth surface
The weather station elevation (altitude); 1195m above sea level
The weather station latitude; (N 37º09’4”)
The weather longitude; (E 43º49’35”)

Month	Avg. Temp. (℃)	Avg. Min Temp. (℃)	Avg. Max Temp. (℃)	Avg. Humidity (%)	Avg. Wind Speed (m/s)	Sum. Rainfall (mm)	Avg. Sunshine (hours)
2018							
January	5.1	1.8	8.3	66.5	1.80	129.6	4.02
February	7.6	3.8	11.4	67	1.55	165.4	4.07
March	13.3	8.5	18.1	58	2.07	68.6	6.46
April	15.8	10.7	20.9	55	1.91	106.4	8.01
May	19.4	14.2	24.6	58	1.81	139	5.00
June	27.3	20.9	33.6	30.5	2.03	2.2	7.18
July	31.9	25.2	38.5	21	1.99	0	7.33
August	31.3	24.8	37.8	22	1.90	0	11.01
September	27.9	21.7	34	23	2.25	0	11.08
October	19.6	14.7	24.5	47	1.87	116	6.01
November	10.6	7.1	14	71.5	1.59	180	3.52
December	5.1	2.4	7.8	81.5	1.66	375.2	2.53
Long- term (2015-2017)							
January	2.2	-1.3	5.7	64.5	1.83	195.4	4.11
February	6.2	1.65	10.8	56.5	1.80	83.8	5.63
March	9.1	4.8	13.3	65.5	2.03	155.4	4.82
April	14.9	9.6	20.1	53.3	2.36	76.2	6.49
May	20.8	15.2	26.4	42.5	2.38	42.6	7.00
June	27.4	21.1	33.6	28.3	2.44	6.2	7.71
July	32.2	25.7	38.7	19.5	2.21	0.2	8.69
August	32.3	25.9	38.7	18	2.44	0.1	10.36
September	27.4	21.3	33.5	22.3	2.34	5.5	10.20
October	19.2	14	24.4	33	2.07	71.6	7.26
November	11.2	7	15.4	48	1.66	112.2	5.66
December	5.4	1.9	8.9	63.3	1.84	89.2	4.55

Table 4.5. Climate data of Sumeel Station

<table>
<tr><td colspan="8">The weather station name; Sumeel station
The type of meteorological station; Automatic measurement device
The anemometer height; 3m height on the earth surface
The temperature height; 2.5m height on the earth surface
The weather station elevation (altitude); 473m above sea level
The weather station latitude; (N 36º51’38”)
The weather longitude; (E 42º52’02”)</td></tr>
<tr><th>Month</th><th>Avg. Temp. (℃)</th><th>Avg. Min Temp. (℃)</th><th>Avg. Max Temp. (℃)</th><th>Avg. Humidity (%)</th><th>Avg. Wind Speed (m/s)</th><th>Sum. Rainfall (mm)</th><th>Avg. Sunshine (hours)</th></tr>
<tr><td colspan="8">2018</td></tr>
<tr><td>January</td><td>9</td><td>5.3</td><td>17.6</td><td>71</td><td>3.17</td><td>74.2</td><td>4.07</td></tr>
<tr><td>February</td><td>10.9</td><td>6.7</td><td>14.1</td><td>74</td><td>1.94</td><td>66.4</td><td>4.39</td></tr>
<tr><td>March</td><td>16.3</td><td>10.6</td><td>22.2</td><td>59</td><td>2.85</td><td>16</td><td>6.37</td></tr>
<tr><td>April</td><td>19.1</td><td>15.8</td><td>23.4</td><td>55</td><td>3.04</td><td>103.5</td><td>7.59</td></tr>
<tr><td>May</td><td>24.2</td><td>18</td><td>30</td><td>53</td><td>3.48</td><td>85.6</td><td>8.32</td></tr>
<tr><td>June</td><td>29.2</td><td>26.1</td><td>32.9</td><td>31.5</td><td>3.74</td><td>4</td><td>11.27</td></tr>
<tr><td>July</td><td>33</td><td>29.7</td><td>36.6</td><td>24</td><td>3.45</td><td>0</td><td>12.28</td></tr>
<tr><td>August</td><td>32</td><td>30.1</td><td>34.4</td><td>28</td><td>2.49</td><td>0</td><td>11.50</td></tr>
<tr><td>September</td><td>29.1</td><td>25.2</td><td>33.6</td><td>28</td><td>2.35</td><td>0.2</td><td>10.20</td></tr>
<tr><td>October</td><td>23.2</td><td>14.3</td><td>29</td><td>47</td><td>3.18</td><td>23.8</td><td>6.20</td></tr>
<tr><td>November</td><td>14</td><td>9.9</td><td>22.3</td><td>80</td><td>2.14</td><td>170.8</td><td>4.06</td></tr>
<tr><td>December</td><td>9.4</td><td>4.2</td><td>13.1</td><td>87</td><td>2.14</td><td>161</td><td>2.56</td></tr>
<tr><td colspan="8">Long- term (2013-2017)</td></tr>
<tr><td>January</td><td>6.8</td><td>1.1</td><td>11.6</td><td>77</td><td>1.61</td><td>109.7</td><td>4.57</td></tr>
<tr><td>February</td><td>9.2</td><td>3.9</td><td>14.4</td><td>70</td><td>1.71</td><td>39.1</td><td>6.71</td></tr>
<tr><td>March</td><td>12.8</td><td>6.9</td><td>18.2</td><td>69</td><td>2.00</td><td>80.6</td><td>5.79</td></tr>
<tr><td>April</td><td>17.6</td><td>10.7</td><td>25</td><td>58</td><td>1.92</td><td>37.9</td><td>8.21</td></tr>
<tr><td>May</td><td>23.9</td><td>19.2</td><td>29.3</td><td>40</td><td>2.33</td><td>11.4</td><td>9.28</td></tr>
<tr><td>June</td><td>29</td><td>23.9</td><td>35</td><td>26</td><td>2.55</td><td>1.7</td><td>11.38</td></tr>
<tr><td>July</td><td>32.5</td><td>29.1</td><td>37.3</td><td>22</td><td>2.08</td><td>0</td><td>11.43</td></tr>
<tr><td>August</td><td>32.4</td><td>28.6</td><td>35.3</td><td>22</td><td>2.11</td><td>0.04</td><td>11.04</td></tr>
<tr><td>September</td><td>27.6</td><td>21.7</td><td>32.8</td><td>27</td><td>1.68</td><td>4</td><td>10.09</td></tr>
<tr><td>October</td><td>20.6</td><td>15.5</td><td>26.1</td><td>38</td><td>1.72</td><td>27.2</td><td>7.66</td></tr>
<tr><td>November</td><td>12.6</td><td>6.5</td><td>19.9</td><td>62</td><td>1.54</td><td>53.2</td><td>5.69</td></tr>
<tr><td>December</td><td>8.4</td><td>3.4</td><td>14.1</td><td>74</td><td>1.50</td><td>60.2</td><td>4.37</td></tr>
</table>

Table 4.6. Climate data of Bardarash Station

The weather station name; Bardarash station
The type of meteorological station; Automatic measurement device
The anemometer height; 2m height on the earth surface
The temperature height; 2m height on the earth surface
The weather station elevation (altitude); 379m above sea level
The weather station latitude; (N 36º30’03”)
The weather longitude; (E 43º35’4”)

Month	Avg. Temp. (℃)	Avg. Min Temp. (℃)	Avg. Max Temp. (℃)	Avg. Humidity (%)	Avg. Wind Speed (m/s)	Sum. Rainfall (mm)	Avg. Sunshine (hours)
2018							
January	9.06	4.86	13.3	34.7	1.27	56.4	4.05
February	11.6	7.43	14.1	34.4	1.35	123.9	4.37
March	17.8	12.6	22.7	34.5	1.40	7.7	6.35
April	21.4	16.8	25.3	35	1.48	60.4	7.57
May	26.3	15.9	34.9	35.9	1.91	85.6	8.30
June	35.3	32.3	42.2	38.8	1.85	3	11.25
July	39.2	36.1	45.5	40.3	2.13	0	12.26
August	37.6	34.2	40.2	31.1	1.55	0	11.48
September	33.3	29.8	37.9	16.2	1.23	0	10.18
October	25.7	15.9	32	39.2	1.42	27	6.18
November	15.3	11.1	21.8	82.8	1.42	112.5	4.04
December	10.7	7.2	14.8	88.8	1.44	205.9	2.54
Long- term (2015-2017)							
January	7.2	2.1	10.6	54.8	1.07	43	4.55
February	10.1	3.8	15.9	51	1.38	28	6.69
March	14.3	8.3	18	48.9	1.49	31.2	5.77
April	19.8	11.5	26.5	42.6	1.49	32.9	8.19
May	28.1	18.7	34.4	32.1	1.65	3.5	9.26
June	34.7	25.5	40.3	27.2	1.99	1.6	11.36
July	39.6	36.2	43.1	23.3	2.12	0	11.41
August	38.8	31.7	42.9	28.9	1.73	0	11.02
September	32.6	22.4	39.2	35	1.34	6	10.07
October	24.4	19.7	30	42.1	1.29	9.2	7.64
November	14.9	8.1	21.5	46.4	1.14	46.1	5.67
December	9.3	4.9	14.8	44.9	1.25	50.6	4.35

Table 4.7. Climate data of Bamerne Station

The weather station name; Bamerne station
The type of meteorological station; Automatic measurement device
The anemometer height; 10m height on the earth surface
The temperature height; 1.5m height on the earth surface
The weather station elevation (altitude); 1211m above sea level
The weather station latitude; (N 37º11’91”)
The weather longitude; (E 43º26’87”)

Month	Avg. Temp. (℃)	Avg. Min Temp. (℃)	Avg. Max Temp. (℃)	Avg. Humidity (%)	Avg. Wind Speed (m/s)	Sum. Rainfall (mm)	Avg. Sunshine (hours)
2018							
January	5.7	2.1	9.2	64	2.75	119	4.40
February	8.2	4.2	12.2	64	2.36	158	5.04
March	12.9	8.1	17.7	58.5	2.45	81.2	6.48
April	15.8	10.8	20.8	55	2.71	107.2	7.41
May	19.3	14.4	24.1	58.5	2.52	146.6	7.32
June	25.3	20.1	30.4	33.5	2.38	2.4	8.36
July	30.2	23.3	37.1	24	2.30	0	10.52
August	30.8	24	37.6	22	2.51	0	11.09
September	27.5	21.2	33.7	23.5	2.47	0	10.22
October	21.2	15.8	26.5	40.5	2.62	88	8.04
November	11.2	7.4	14.9	69.5	2.56	218.5	4.40
December	6.5	2.9	9.2	77	2.41	340.1	3.43
Long- term (2013-2017)							
January	5.3	1.3	9.2	63.3	2.23	182.9	5.32
February	6.8	2.2	11.3	56.4	27.62	73.92	6.70
March	9.7	5.5	13.9	62.3	2.76	156.7	5.70
April	14.7	9.4	20	53.7	2.58	75.4	7.76
May	20.9	15.4	26.3	45.1	2.67	39.4	6.71
June	26.4	20.4	32.4	27.4	2.77	4.4	6.66
July	31.1	24.8	37.4	20.4	2.72	0	10.34
August	31.3	25	37.6	19.9	2.72	0.1	8.74
September	25.8	19.8	31.8	25.6	2.58	3.1	10.30
October	19	13.9	24	41.1	2.53	61.9	7.74
November	11.8	7.4	16.2	53.4	2.29	96.7	5.36
December	6.5	2.7	10.2	62.5	2.37	90.3	5.20

Table 4.8. Climate data of Kanimase Station

The weather station name; Kanimase station
The type of meteorological station; Automatic measurement device
The anemometer height; 10m height on the earth surface
The temperature height; 1.5m height on the earth surface
The weather station elevation (altitude); 1340m above sea level
The weather station latitude; (N 37º23’04”)
The weather longitude; (E 43º43’62”)

Month	Avg. Temp. (℃)	Avg. Min Temp. (℃)	Avg. Max Temp. (℃)	Avg. Humidity (%)	Avg. Wind Speed (m/s)	Sum. Rainfall (mm)	Avg. Sunshine (hours)
2018							
January	8.8	4.6	13	46	1.12	112.8	5.38
February	11.15	6.9	15.4	54	1.23	146.2	5.32
March	16.25	11.3	21.2	53	1.36	95.8	7.29
April	19.4	13.7	25.1	45.5	1.81	89.6	8.52
May	17.5	10.6	24.4	35	2.19	130.6	8.22
June	23.8	14.8	32.8	31.5	2.01	34.6	12.39
July	35	27.9	42.1	27.5	1.85	0	12.36
August	34.15	27	41.3	30	1.63	0	12.20
September	25.05	15.7	34.4	34.5	2.14	0	10.16
October	18.6	11.1	26.1	33	1.81	126	6.19
November	9.35	4.4	14.3	52	1.63	175	3.57
December	3.85	0.1	7.6	63	1.30	381	2.37
Long- term (2015-2017)							
January	1.2	-3.5	5.8	50.8	1.16	175.4	4.61
February	3.9	-1.3	9.1	59	1.63	69.9	5.43
March	7.6	2.8	12.3	56.6	1.93	183.4	4.98
April	12.3	6.4	18.1	61.6	2.53	73.3	4.09
May	17.4	10.7	24	48.3	2.12	51.3	8.65
June	23.2	15.3	31	27.6	2.39	5.1	11.32
July	28.3	20.2	36.3	27.6	2.40	0.6	11.96
August	28.4	20	36.7	26	2.29	3.2	11.05
September	24.1	16	32.2	31	2.20	8.2	10.15
October	16.3	9.9	22.7	41.6	1.81	80.24	7.05
November	9.5	3.8	15.1	50.3	1.48	107.9	5.57
December	3.6	-1.2	8.3	53	1.20	97.6	2.9

Table 4.9. Climate data of Mangesh Station

The weather station name; Mangesh station
The type of meteorological station; Automatic measurement device
The anemometer height; 10m height on the earth surface
The temperature height; 1.5m height on the earth surface
The weather station elevation (altitude); 945m above sea level
The weather station latitude; (N 37º03’52”)
The weather longitude; (E 43º10’01”)

Month	Avg. Temp. (℃)	Avg. Min Temp. (℃)	Avg. Max Temp. (℃)	Avg. Humidity (%)	Avg. Wind Speed (m/s)	Sum. Rainfall (mm)	Avg. Sunshine (hours)
2018							
January	6.2	2.2	10.2	73	2.69	93.6	4.27
February	8.5	4	13	65.5	1.44	110	4.37
March	13.3	7.8	18.8	67	1.31	49.2	7.17
April	16	10.2	21.8	54.5	1.27	76.6	8.14
May	19.7	13.8	25.6	47.5	1.00	124.4	8.13
June	26.05	18.9	33.2	32	1.19	5.4	11.20
July	30.6	22.7	38.5	23.5	0.84	0	12.49
August	30.25	22.4	38.1	20.5	0.77	0	12.15
September	27.15	19.7	34.6	27	0.55	0	11.34
October	21.15	15.4	26.9	56.5	0.51	90	7.18
November	11.4	7.3	15.5	64	0.61	258	4.13
December	6.75	3.5	10	64	2.31	406	3.00
Long- term (2013-2017)							
January	5.4	0.8	10	63.2	2.52	170.8	4.54
February	7.2	2.3	12	61.2	25.70	69.2	5.50
March	10.8	6.5	15	64.7	2.34	118.1	6.11
April	15.3	9.3	21.2	55.5	2.32	55.2	7.33
May	20.7	13.9	27.4	47.8	2.28	33	7.78
June	26.4	18.9	33.8	29.9	2.17	2.4	9.65
July	30.1	23.1	38.2	22.6	2.05	0.6	12.44
August	30.9	23.2	38.5	22.1	2.00	0.2	11.48
September	26	19	33	30	1.79	11.4	10.24
October	18.8	13	24.6	48.33	2.09	44.5	7.73
November	11.8	6.7	16.8	62.3	1.52	90.4	6.08
December	6.7	2.3	11	65.8	2.50	82.7	4.78

Temperature properties of the station were shown as figure to compare and general view (Figure 4.1. and 4.2).

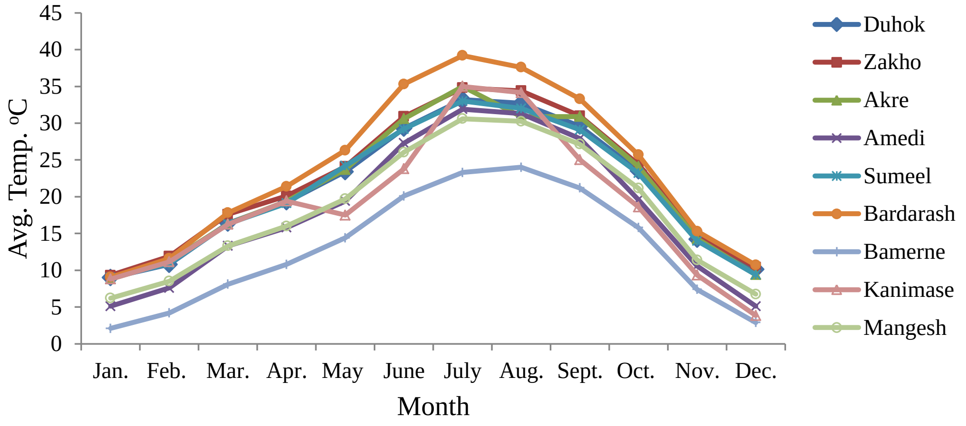

Figure 4.1. Average temperature values for 2018 year

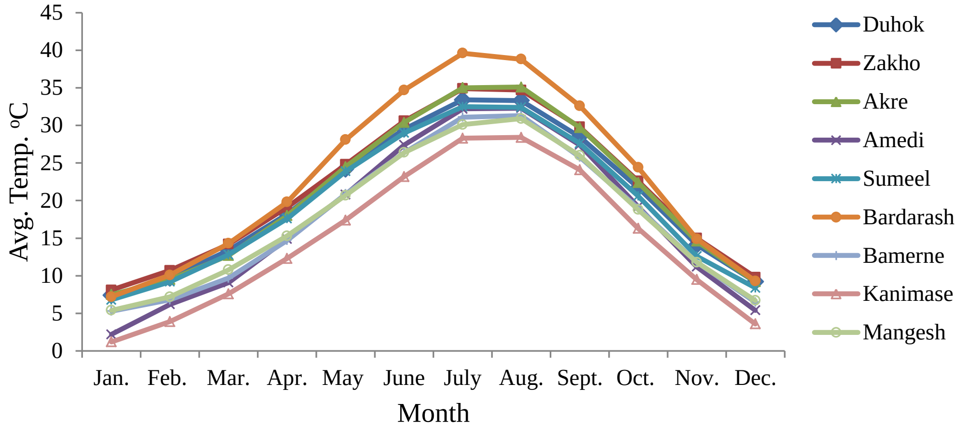

Figure 4.2. Average temperature values for long term

As seen in the Figure 4.1 and 4.2, Bardarash was the hottest province in 2018 and Bamerne had the lowest temperature. However, when the long-term data are considered, Bardarash is the hottest province and the lowest temperature is mixed. In this case, it can be said that extraordinary temperature values were observed in Bamarne city for 2018.

Average humidity values (%) of the station were given in figures to compare and general view (Figure 4.3. and 4.4).

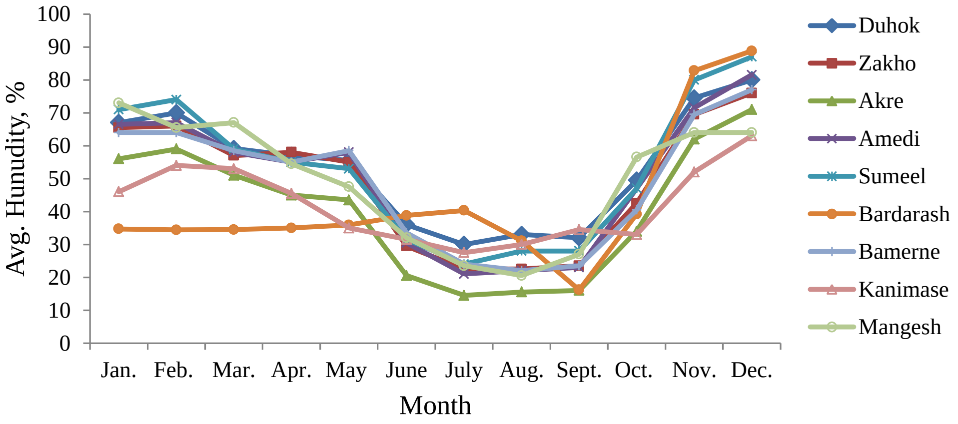

Figure 4.3. Average humidity values for 2018 year

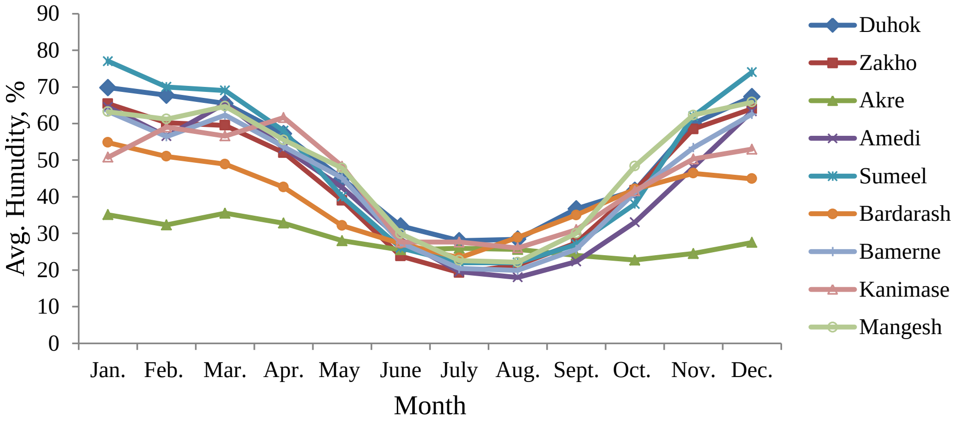

Figure 4.4. Average humidity values for long term

As can be seen in the Figure 4.3 and 4.4 in 2018, especially in May-September period all provinces have similar humidity values. However, in January-April period, the lowest humidity values were observed in the Bardarash city. Similar results are observed in the long - term data, but in January - April period the Akre city has lower humidity than Bardarash.

4.2. Reference evapotranspiration results

The computed Evapotranspiration values with using of long-term average and annual values for each city are given in the tables below (Table 4.10.-4.18).

Table 4.10. The computed Evapotranspiration values of Duhok Station

Months	Methods						
	FAO 56 Penman Monteith	Kimberly Penman	Blaney Criddle	Hargreaves	Priestly-Taylor	Makkink	Turc
	2018						
1	1,33	1,04	1,19	1,26	0,85	0,98	2,01
2	1,56	1,37	1,52	1,74	1,37	1,37	1,61
3	2,81	2,53	3,17	3,05	2,35	2,34	2,79
4	3,91	3,69	4,33	4,27	3,71	3,2	3,75
5	4,82	4,8	5,6	5,32	4,7	3,88	4,55
6	7,13	7,37	9,09	6,95	5,8	5,11	5,91
7	7,32	7,98	10,2	7,76	6,24	5,55	7,37
8	6,7	7,36	9,11	6,95	5,79	5,03	7,25
9	5,28	5,66	7,35	5,39	4,28	4,01	5,68
10	3,51	3,45	4,1	3,2	2,66	2,27	3,48
11	1,68	1,61	1,58	1,6	1,6	1,2	1,59
12	1,07	0,9	0,84	1,02	0,94	0,76	1,03
Long – term (2013-2017)							
1	1,1	0,93	0,96	1,17	0,83	0,99	1,84
2	1,55	1,44	1,64	1,79	1,47	1,67	1,81
3	2,31	2,18	2,39	2,54	2,22	2,08	2,41
4	3,71	3,58	4,19	3,99	3,67	3,3	3,82
5	5,12	5,08	6,32	5,61	4,77	4,18	4,87
6	6,41	6,86	8,83	6,95	5,76	5,15	6,08
7	6,61	7,29	9,72	7,64	5,93	5,31	7,48
8	6,36	6,98	9,13	7,03	5,51	4,92	7,33
9	4,98	5,39	6,78	5,13	4,42	3,93	5,91
10	3,24	3,23	4,22	3,11	2,63	2,5	3,51
11	1,8	1,67	2,03	1,76	1,5	1,43	1,96
12	1,19	1,05	1,09	1,19	0,92	0,95	1,15

Table 4.11. The computed Evapotranspiration values of Zakho Station

Months	Methods						
	FAO 56 Penman Monteith	Kimberly Penman	Blaney Criddle	Hargreaves	Priestly-Taylor	Makkink	Turc
	2018						
1	0,99	0,88	1,08	1,22	0,79	0,96	2,05
2	1,35	1,27	1,54	1,81	1,31	1,36	1,66
3	2,4	2,35	3,09	3,09	2,32	2,35	2,84
4	3,45	3,49	4,08	4,41	3,74	3,2	3,78
5	4,29	4,47	5,28	5,41	4,64	3,81	4,5
6	5,69	6,47	8,88	7,36	5,71	5,24	6,08
7	6	6,89	10,2	8,07	5,93	5,55	8,05
8	5,44	6,12	9,2	7,22	5,31	4,98	7,92
9	4,18	4,73	7,42	5,54	3,97	4,03	6,53
10	2,77	2,95	3,99	3,25	2,53	2,22	3,82
11	1,46	1,5	1,54	1,54	1,54	1,21	1,73
12	0,93	0,84	0,81	0,97	0,88	0,79	1,08
Long – term (2013-2017)							
1	1,01	0,83	0,93	1,18	0,75	0,86	1,76
2	1,56	1,41	1,83	1,84	1,36	1,63	1,85
3	2,3	2,17	2,55	2,67	2,18	2,09	2,47
4	3,7	3,59	4,42	4,28	3,64	3,33	3,89
5	4,94	5,01	6,52	5,92	4,67	4,18	4,9
6	6,11	6,76	9,35	7,33	5,53	5,24	6,7
7	6,36	7,19	10,6	8,04	5,68	5,5	8,56
8	5,77	6,42	9,38	7,31	5,15	4,86	8,05
9	4,55	5	7,12	5,36	4,08	3,89	6,41
10	2,96	3,04	4,14	3,2	2,57	2,4	3,86
11	1,62	1,59	2,05	1,77	1,44	1,42	1,98
12	1,07	0,97	1,07	1,17	0,86	0,88	1,14

Table 4.12. The computed Evapotranspiration values of Akre Station

Months	Methods						
	FAO 56 Penman Monteith	Kimberly Penman	Blaney Criddle	Hargreaves	Priestly-Taylor	Makkink	Turc
	2018						
1	1,3	1,08	1,34	1,25	0,83	1,14	2,21
2	1,76	1,52	1,83	1,77	1,39	1,53	1,77
3	2,92	2,58	3,4	2,9	2,44	2,53	2,96
4	4,49	4,05	5,02	4,19	3,78	3,44	3,98
5	5,61	5,24	6,35	5,13	4,54	3,89	4,66
6	7,81	7,94	10,7	7	5,59	5,52	6,69
7	8,16	8,76	11,9	7,73	5,53	5,67	9,12
8	7,16	7,83	10	6,38	5,19	5,15	8,86
9	5,96	6,25	8,92	5,37	3,65	4,34	7,52
10	4,43	4,04	5,05	3,11	2,59	2,49	4,54
11	1,99	1,85	1,94	1,52	1,61	1,36	2,09
12	1,14	0,96	0,89	1,03	0,94	0,81	1,04
Long – term (2013-2017)							
1	2,23	1,66	2,15	1,8	1,2	1,48	1,92
2	3,01	2,33	2,88	2,58	1,91	1,89	2,67
3	4,31	3,66	4,69	4,13	3,07	2,93	4,02
4	5,99	5,4	6,89	5,69	3,99	3,69	5,25
5	7,84	7,76	9,57	6,83	5,14	4,71	7,03
6	7,39	7,96	10,2	7,64	5,62	5,02	7,73
7	6,91	7,48	9,32	7,01	5,13	4,52	6,99
8	5,37	5,58	7,16	5,15	3,86	3,59	5,67
9	3,85	3,47	4,72	3,09	2,26	2,31	3,88
10	2,36	1,95	2,71	1,77	1,22	1,42	2,48
11	1,76	1,21	1,42	1,18	0,79	0,8	1,37
12	2,23	1,66	2,15	1,8	1,2	1,48	1,92

Table 4.13. The computed Evapotranspiration values of Amedi Station

Months	Methods						
	FAO 56 Penman Monteith	Kimberly Penman	Blaney Criddle	Hargreaves	Priestly-Taylor	Makkink	Turc
	2018						
1	1,14	0,88	0,74	0,91	0,74	0,86	1,31
2	1,45	1,21	1,2	1,43	1,2	1,22	1,23
3	2,75	2,42	2,86	2,56	2,21	2,24	2,49
4	3,82	3,59	3,97	3,55	3,59	3,15	3,49
5	3,92	3,81	4,16	4,48	3,66	2,89	3,36
6	6,16	6,3	7,53	6,33	4,41	3,92	4,58
7	6,98	7,52	8,85	7,02	4,56	4,1	5,98
8	7,19	7,77	9,56	6,25	5,18	4,86	7,78
9	6,53	6,82	8,28	4,71	4,04	4,17	6,65
10	3,53	3,37	3,66	2,65	2,51	2,1	3,52
11	1,58	1,43	1,22	1,25	1,4	1,02	1,27
12	0,89	0,76	0,41	0,76	0,85	0,64	0,63
Long – term (2015-2017)							
1	1,09	0,84	0,51	0,85	0,72	0,82	0,69
2	1,72	1,4	1,43	1,52	1,21	1,42	1,25
3	2,15	1,94	1,85	2,1	1,97	1,76	1,79
4	3,68	3,34	3,72	3,52	3,09	2,78	3,08
5	5,15	4,82	5,6	4,84	4	3,48	3,99
6	6,84	6,9	8,02	6,28	4,58	4,08	5,06
7	7,61	7,98	9,67	6,99	4,86	4,52	6,71
8	8,07	8,7	10,1	6,36	4,91	4,75	7,77
9	6,61	6,86	7,96	4,69	4,01	3,98	6,66
10	4,13	3,77	4,37	2,75	2,5	2,37	3,91
11	2,17	1,86	1,99	1,46	1,4	1,37	1,94
12	1,32	1,08	0,84	0,91	0,89	0,89	0,82

Table 4.14. The computed Evapotranspiration values of Sumeel Station

Months	Methods						
	FAO 56 Penman Monteith	Kimberly Penman	Blaney Criddle	Hargreaves	Priestly-Taylor	Makkink	Turc
	2018						
1	1,93	1,41	1,77	1,66	0,93	1,04	2,32
2	1,67	1,49	1,5	1,61	1,48	1,34	1,57
3	3,41	2,85	3,57	3,15	2,32	2,33	2,79
4	4,59	4,11	4,74	3,44	3,68	3,21	3,77
5	6,15	5,73	6,64	5,44	4,69	3,9	4,59
6	8,9	8,87	10	4,87	5,68	5,11	5,93
7	9,87	10,6	11,7	5,19	5,95	5,53	8,03
8	7,96	8,81	9,61	3,68	5,55	5	7,95
9	6,64	6,98	7,99	4,07	4,09	3,99	6,23
10	4,97	4,65	4,64	3,5	2,59	2,2	3,62
11	1,89	1,74	2,02	2,08	1,53	1,24	1,69
12	1,07	0,96	0,81	1,18	1,03	0,72	0,94
Long – term (2013-2017)							
1	1,07	0,91	0,9	1,26	0,81	0,95	1,66
2	1,7	1,5	1,74	1,83	1,42	1,64	1,74
3	2,44	2,25	2,48	2,75	2,18	2,04	2,33
4	4,03	3,75	4,47	4,49	3,59	3,25	3,77
5	5,99	5,56	6,94	5,03	4,63	4,17	4,87
6	8,07	8,1	10	6,21	5,53	5,14	6,63
7	7,96	8,54	10,6	5,66	5,63	5,29	8,11
8	7,53	8,24	9,63	4,57	5,16	4,85	7,89
9	5,67	5,98	7,24	4,46	3,99	3,87	6,41
10	3,86	3,63	4,46	2,9	2,49	2,45	3,95
11	2,08	1,81	2,13	1,98	1,46	1,39	1,99
12	1,22	1,05	1,09	1,29	0,9	0,93	1,12

Table 4.15. The computed Evapotranspiration values of Bardarash Station

Months	Methods						
	FAO 56 Penman Monteith	Kimberly Penman	Blaney Criddle	Hargreaves	Priestly-Taylor	Makkink	Turc
	2018						
1	1.39	0.87	1.37	0.95	0.26	0.73	1.66
2	1.86	1.3	1.94	1.27	0.77	1.11	1.66
3	2.9	2.3	3.83	2.71	1.65	2.11	3.16
4	4.18	3.62	5.25	3.59	3.19	3.06	4.38
5	6.09	5.53	7.44	7	4.33	3.82	5.42
6	7.59	7.82	10.8	6.92	6.25	5.33	6.88
7	8.96	9.63	12	7.01	7.48	5.67	7.51
8	7.22	7.93	10.2	4.64	5.97	4.92	6.48
9	5.08	5.43	8.79	4.02	3.22	3.78	5.77
10	3.63	3.38	4.46	3.3	2.13	1.93	3.75
11	1.34	1.33	1.63	1.51	1.16	0.96	1.54
12	0.72	0.65	0.69	0.87	0.65	0.54	0.88
Long – term (2015-2017)							
1	0.89	0.66	0.84	0.86	0.31	0.71	1.37
2	1.64	1.24	1.99	1.66	0.81	1.37	1.57
3	2.43	2.04	2.73	2.31	1.71	1.82	2.16
4	4.01	3.54	5.03	4.51	3.14	3.09	3.65
5	5.86	5.45	7.85	6.54	4.38	4.13	5.01
6	7.86	8	10.9	7.76	5.67	5.17	7.23
7	8.64	9.21	12.5	5.88	5.88	5.38	8.09
8	7.51	8.23	10.6	6.35	5.66	4.8	7.79
9	5.37	5.78	7.63	5.43	4.05	3.65	5.64
10	3.25	3.2	4.65	2.69	2.12	2.22	3.27
11	1.86	1.58	2.27	1.61	0.94	1.12	1.67
12	1.31	0.94	1.29	0.95	0.34	0.69	0.97

Table 4.16. The computed Evapotranspiration values of Bamerne Station

Months	Methods						
	FAO 56 Penman Monteith	Kimberly Penman	Blaney Criddle	Hargreaves	Priestly-Taylor	Makkink	Turc
	2018						
1	1,46	1,07	1,01	0,97	0,76	0,93	1,47
2	1,8	1,48	1,56	1,5	1,28	1,38	1,41
3	2,86	2,5	2,88	2,53	2,24	2,23	2,46
4	4,03	3,76	4,1	3,51	3,46	3,02	3,35
5	4,55	4,54	4,85	4,31	4,25	3,46	3,93
6	6,36	6,55	7,48	5,44	4,74	4,16	4,78
7	7,7	8,18	9,81	6,9	5,34	4,95	6,86
8	7,97	8,68	9,9	6,32	5,1	4,87	7,5
9	6,66	6,9	8,01	4,7	3,9	3,94	6,31
10	4,52	4,2	4,87	2,88	2,61	2,56	4,16
11	1,94	1,76	1,58	1,33	1,49	1,16	1,54
12	1,12	0,94	0,69	0,85	0,86	0,76	0,78
Long – term (2013-2017)							
1	1,35	1,05	0,99	1,01	0,76	1,02	1,5
2	3,83	6,13	2,33	1,51	1,33	1,56	1,4
3	2,49	2,23	2,24	2,11	2,05	1,93	1,97
4	3,89	3,54	4,01	3,49	3,33	3,03	3,31
5	5,18	4,8	5,57	4,78	3,95	3,39	3,91
6	6,93	6,88	7,69	6,03	4,29	3,74	4,5
7	8,41	8,88	10,4	6,72	5,23	4,94	7,34
8	8,01	8,62	9,33	6,15	4,56	4,23	6,92
9	6,57	6,88	7,62	4,43	4	3,89	6,36
10	4,15	3,88	4,34	2,64	2,5	2,41	3,8
11	2,33	1,94	2,07	1,48	1,34	1,31	1,72
12	1,5	1,2	1,08	0,95	0,83	0,96	0,95

Table 4.17. The computed Evapotranspiration values of Kanimase Station

Months	Methods						
	FAO 56 Penman Monteith	Kimberly Penman	Blaney Criddle	Hargreaves	Priestly-Taylor	Makkink	Turc
	2018						
1	1,51	1,2	1,53	1,33	0,87	1,19	2,32
2	1,9	1,61	1,94	1,86	1,44	1,57	1,88
3	2,95	2,63	3,35	2,98	2,51	2,56	3,03
4	4,51	4,09	4,98	4,24	3,77	3,44	4,04
5	5,33	5,02	5,47	4,91	4,13	3,48	4,09
6	6,89	7,24	8,44	6,9	5,32	5,05	6,74
7	7,91	8,56	11	7,72	5,84	5,65	7,8
8	7,53	8,31	10	7,03	6,02	5,32	7,99
9	6,44	6,86	7,03	5,61	4,37	3,84	5,69
10	4,02	3,7	4,06	3,38	2,28	2,15	3,04
11	2,03	1,68	1,51	1,58	1,35	1,04	1,49
12	1,13	0,87	0,52	0,95	0,84	0,63	0,54
Long – term (2015-2017)							
1	1,1	0,86	0,51	0,99	0,7	0,83	0,42
2	1,55	1,3	1,1	1,53	1,16	1,27	0,9
3	2,21	1,92	1,84	2,16	1,79	1,68	1,65
4	2,99	2,66	2,77	3,45	2,44	2,05	2,35
5	4,7	4,57	5,09	4,8	4,03	3,57	4,11
6	7,02	7,26	8,27	6,34	4,94	4,72	5,46
7	7,96	8,68	9,69	7,12	5,46	5,17	7,63
8	7,62	8,45	8,99	6,71	4,98	4,7	7,01
9	6,14	6,52	6,9	5,1	3,95	3,79	5,81
10	3,58	3,37	3,63	2,92	2,41	2,21	3,25
11	2,01	1,75	1,79	1,69	1,32	1,31	1,59
12	1,25	0,95	0,62	1,05	0,83	0,68	0,53

Table 4.18. The computed Evapotranspiration values of Mangesh Station

Months	Methods						
	FAO 56 Penman Monteith	Kimberly Penman	Blaney Criddle	Hargreaves	Priestly-Taylor	Makkink	Turc
	2018						
1	1,26	0,99	0,96	1,06	0,78	0,91	1,56
2	1,53	1,28	1,37	1,61	1,23	1,28	1,36
3	2,4	2,27	2,62	2,74	2,37	2,35	2,62
4	3,58	3,45	3,87	3,81	3,57	3,16	3,53
5	4,21	4,27	4,92	4,82	4,3	3,66	4,17
6	5,86	6,29	8	6,53	5,42	4,95	5,64
7	6,04	6,75	9,47	7,45	5,8	5,5	7,6
8	5,52	6,12	8,87	6,71	5,21	5,11	7,85
9	4,15	4,65	6,87	5,1	4,11	4,18	6,74
10	2,56	2,73	3,42	2,99	2,7	2,37	3,73
11	1,43	1,4	1,31	1,41	1,43	1,11	1,39
12	1,43	1,05	0,88	0,89	0,8	0,72	0,81
Long - term (2013-2017)							
1	1,45	1,06	1,03	1,09	0,73	0,92	1,44
2	3,55	5,48	2,16	1,58	1,25	1,38	1,33
3	2,42	2,22	2,31	2,21	2,11	2,02	2,16
4	3,8	3,54	3,95	3,77	3,28	2,93	3,28
5	5,12	4,92	5,69	5,29	4,21	3,62	4,17
6	6,85	6,94	8,37	6,71	5,03	4,54	5,22
7	7,9	8,49	10,6	7,29	5,76	5,49	7,77
8	7,45	8,11	9,77	6,71	5,15	4,95	7,74
9	5,67	5,97	7,08	4,81	4,05	3,85	6,15
10	3,7	3,55	4,02	2,81	2,56	2,38	3,56
11	1,84	1,64	1,87	1,58	1,38	1,39	1,65
12	1,48	1,17	1,08	1,03	0,82	0,91	0,94

As seen in Table 4.10 - 4.18 monthly ET_0 values ranged from 0,26 to 12,5 mm for all stations. In general, Blaney-Criddle method gave the highest values, while Priestly-Taylor and Makking methods gave lower values. For Duhok station Both the long-term data and the Blaney-Criddle FAO method for 2018 gave higher values than the other methods and formed a different group. The lowest values were obtained by Makkink method. In Zakho station, the highest values were obtained by BC method and the lowest values were obtained by Makkink and Priestley-Taylor methods. At the Amedi station, the lowest values were obtained by Makkink method. The highest values were obtained by BC method but they were in the same group with other methods. Similar results were obtained at other stations respectively.

Gupta (2016) found that Priestly-Taylor method gives lower values compared to FAO PM method and regression equation R value is 0.723 in his study in Delhi region. Orta *et al* (2000) in their study conducted in Tekirdağ, the water consumption of apple trees irrigated by drip and surface irrigation methods was measured in ten days period and these values were measured; using the climatic parameters, Penman (FAO) method, Blaney-Criddle (FAO) method, pan evaporation (FAO) method, Christiansen-Hargreaves modification of pan evaporation method, Jensen-Haise method and Penman – Monteith methods were compared with the reference plant water consumption calculated. As a result of the study, seasonal plant water consumption values; drip irrigation method, surface irrigation method is 62.7% less than the average stated. They found that FAO Penman method yields healthier results in estimating water consumption of apple trees.

Allen *et al* (1996) have defined the reference evapotranspiration as the evaporation rate of a comparative plant (grass) with certain conditions and developed the Penman-Monteith method for calculating it. FAO (World Agriculture Organization) stated that FAO-56 PM equation can be a reference model because it gives more consistent results in the calculation of reference evapotranspiration value than other methods.

Considering this situation, Makkink and Blaney-Criddle (FAO) methods which gave different results in general. Kimberly PM, Hargreaves and Turc and Priestly- Taylor methods gave about similar result with FAO-56 PM.

4.3. Statistical analyses of reference evapotranspiration results

The comparison was made using the ANOVA test to see whether there is a difference between (ET_o) results in using the 2018 and long - term data averages of climate data. For these tests, the period between May and September, which represents the generally high temperature and represents the irrigation season, was preferred (Table 4.19).

Table 4.19. The ANOVA test

Station		Groups	Sum of Squares	df	Mean Square	F	Sig.
Duhok	2018	Between Groups	35,611	6	5,935	5,946	,000
		Within Groups	27,947	28	0,998		
		Total	63,558	34			
	2013-2017	Between Groups	37,138	6	6,190	4,287	,003
		Within Groups	40,431	28	1,444		
		Total	77,569	34			
Zakho	2018	Between Groups	44,896	6	7,483	5,104	,001
		Within Groups	41,048	28	1,466		
		Total	85,943	34			
	2013-2017	Between Groups	52,870	6	8,812	7,034	,000
		Within Groups	35,077	28	1,253		
		Total	87,947	34			
Akre	2018	Between Groups	77,890	6	12,982	6,765	,000
		Within Groups	53,733	28	1,919		
		Total	131,623	34			
	2013-2017	Between Groups	61,657	6	10,276	9,068	,000
		Within Groups	31,732	28	1,133		
		Total	93,388	34			
Amedi	2018	Between Groups	46,832	6	7,805	3,986	,005
		Within Groups	54,829	28	1,958		
		Total	101,661	34			
	2015-2017	Between Groups	63,343	6	10,557	7,193	,000
		Within Groups	41,096	28	1,468		
		Total	104,439	34			

Bardarash	2018	Between Groups	82,649	6	13,775	6,456	,000
		Within Groups	59,746	28	2,134		
		Total	142,395	34			
	2015-2017	Between Groups	87,984	6	14,664	7,992	,000
		Within Groups	51,377	28	1,835		
		Total	139,361	34			
Bamerne	2018	Between Groups	51,926	6	8,654	4,717	,002
		Within Groups	51,368	28	1,835		
		Total	103,293	34			
	2013-2017	Between Groups	67,879	6	11,313	6,832	,000
		Within Groups	46,363	28	1,656		
		Total	114,242	34			
Kanimase	2018	Between Groups	46,772	6	7,795	4,043	,005
		Within Groups	53,990	28	1,928		
		Total	100,762	34			
	2015-2017	Between Groups	45,833	6	7,639	4,594	,002
		Within Groups	46,560	28	1,663		
		Total	92,394	34			
Mangesh	2018	Between Groups	30,965	6	5,161	3,647	,008
		Within Groups	39,620	28	1,415		
		Total	70,585	34			
	2013-2017	Between Groups	49,108	6	8,185	4,694	,002
		Within Groups	48,826	28	1,744		
		Total	97,934	34			

ANOVA test results were statistically significant for each station. The Duncan multiple t-test results of the prediction methods for each station were given in the (Table 4.20 - 4.28).

Table 4.20. The Duncan multiple t- test results for Duhok station

2018				
Methods	N	Subset for alpha = 0.05		
		1	2	3
Makkink	5	4,716		
Priestley-Taylor	5	5,362	5,362	
Turc	5	6,152	6,152	
FAO56 PM	5	6,250	6,250	
Hargreaves	5		6,474	
Kimberly PM	5		6,634	
Blaney-Criddle FAO	5			8,270
Sig.		0,074	0,145	1,000
2013-2017				
Methods	N	Subset for alpha = 0.05		
		1	2	3
Makkink	5	4,698		
Priestley-Taylor	5	5,278	5,278	
FAO56 PM	5	5,896	5,896	
Kimberly PM	5		6,320	
Turc	5		6,334	
Hargreaves	5		6,472	
Blaney-Criddle FAO	5			8,156
Sig.		0,083	0,101	1,000

Table 4.21. The Duncan multiple t- test results for Zakho station

2018				
Methods	N	Subset for alpha = 0.05		
		1	2	3
Makkink	5	4,722		
Priestley-Taylor	5	5,112	5,112	
FAO56 PM	5	5,120	5,120	
Kimberly PM	5	5,736	5,736	
Turc	5		6,616	6,616
Hargreaves	5		6,720	6,720
Blaney-Criddle FAO	5			8,196
Sig.		0,237	0,069	0,060
2013-2017				
Methods	N	Subset for alpha = 0.05		
		1	2	3
Makkink	5	4,734		
Priestley-Taylor	5	5,022		
FAO56 PM	5	5,546	5,546	
Kimberly PM	5	6,076	6,076	
Hargreaves	5		6,792	
Turc	5		6,924	
Blaney-Criddle FAO	5			8,594
Sig.		0,093	0,084	1,000

Table 4.22.The Duncan multiple t- test results for Akre station

2018				
Methods	N	Subset for alpha = 0.05		
		1	2	3
Priestley-Taylor	5	4,900		
Makkink	5	4,914		
Hargreaves	5	6,322	6,322	
FAO56 PM	5		6,940	
Kimberly PM	5		7,204	
Turc	5		7,370	
Blaney-Criddle FAO	5			9,5740
Sig.		0,136	0,285	1,000
2013-2017				
Methods	N	Subset for alpha = 0.05		
		1	2	3
Makkink	5	4,306		
Priestley-Taylor	5	4,748		
Hargreaves	5		6,464	
Turc	5		6,534	
FAO56 PM	5		6,700	
Kimberly PM	5		6,836	
Blaney-Criddle FAO	5			8,6280
Sig.		0,517	0,620	1,000

Table 4.23. The Duncan multiple t- test results for Amedi station

2018					
Methods	N	Subset for alpha = 0.05			
		1	2	3	
Makkink	5	3,988			
Priestley-Taylor	5	4,370	4,370		
Turc	5	5,670	5,670	5,670	
Hargreaves	5	5,758	5,758	5,758	
FAO56 PM	5		6,156	6,156	
Kimberly PM	5			6,444	
Blaney-Criddle FAO	5			7,676	
Sig.		,076	,074	,050	
2015-2017					
Methods	N	Subset for alpha = 0.05			
		1	2	3	4
Makkink	5	4,162			
Priestley-Taylor	5	4,472	4,472		
Hargreaves	5		5,832	5,832	
Turc	5		6,038	6,038	
FAO56 PM	5			6,856	6,856
Kimberly PM	5			7,052	7,052
Blaney-Criddle FAO	5				8,270
Sig.		0,689	0,062	0,156	0,091

Table 4.24. The Duncan multiple t- test results for Sumeel station

2018				
		Subset for alpha = 0.05		
Methods	N	1	2	3
Hargreaves	5	4,650		
Makkink	5	4,706		
Priestley-Taylor	5	5,192		
Turc	5	6,546	6,546	
FAO56 PM	5		7,904	7,904
Kimberly PM	5		8,198	8,198
Blaney-Criddle FAO	5			9,188
Sig.		0,056	0,085	0,178
2013-2017				
		Subset for alpha = 0.05		
Methods	N	1	2	3
Makkink	5	4,664		
Priestley-Taylor	5	4,988		
Hargreaves	5	5,186		
Turc	5		6,782	
FAO56 PM	5		7,044	
Kimberly PM	5		7,284	
Blaney-Criddle FAO	5			8,882
Sig.		0,503	0,519	1,000

Table 4.25. The Duncan multiple t- test results for Bardarash station

2018					
		Subset for alpha = 0.05			
Methods	N	1	2	3	
Makkink	5	4,704			
Priestley-Taylor	5	5,450	5,450		
Hargreaves	5	5,918	5,918		
Turc	5	6,412	6,412		
FAO56 PM	5		6,988		
Kimberly PM	5		7,268		
Blaney-Criddle FAO	5			9,846	
Sig.		,101	,088	1,000	
2015-2017					
		Subset for alpha = 0.05			
Methods	N	1	2	3	4
Makkink	5	4,626			
Priestley-Taylor	5	5,128	5,128		
Hargreaves	5	6,392	6,392	6,392	
Turc	5		6,752	6,752	
FAO56 PM	5			7,048	
Kimberly PM	5			7,334	
Blaney-Criddle FAO	5				9,896
Sig.		0,060	0,083	0,325	1,000

Table 4.26. The Duncan multiple t- test results for Bamerne station

2018				
Methods	N	Subset for alpha = 0.05		
		1	2	3
Makkink	5	4,276		
Priestley-Taylor	5	4,666		
Hargreaves	5	5,534	5,534	
Turc	5	5,876	5,876	
FAO56 PM	5		6,648	6,648
Kimberly PM	5		6,970	6,970
Blaney-Criddle FAO	5			8,010
Sig.		0,097	0,136	0,144
2013-2018				
Methods	N	Subset for alpha = 0.05		
		1	2	3
Makkink	5	4,038		
Priestley-Taylor	5	4,406		
Hargreaves	5	5,622	5,622	
Turc	5	5,806	5,806	
FAO56 PM	5		7,020	7,020
Kimberly PM	5		7,212	7,212
Blaney-Criddle FAO	5			8,122
Sig.		0,055	0,083	0,211

Table 4.27. The Duncan multiple t- test results for Kanimase station

2018				
Methods	N	Subset for alpha = 0.05		
		1	2	3
Makkink	5	4,668		
Priestley-Taylor	5	5,136	5,136	
Hargreaves	5	6,434	6,434	6,434
Turc	5	6,462	6,462	6,462
FAO56 PM	5		6,820	6,820
Kimberly PM	5			7,198
Blaney-Criddle FAO	5			8,388
Sig.		,070	,089	,054

2015-2017			
Methods	N	Subset for alpha = 0.05	
		1	2
Makkink	5	4,390	
Priestley-Taylor	5	4,672	
Turc	5	6,004	6,004
Hargreaves	5	6,014	6,014
FAO56 PM	5		6,688
Kimberly PM	5		7,096
Blaney-Criddle FAO	5		7,788
Sig.		0,078	0,058

Table 4.28. The Duncan multiple t- test results for Mangesh station

2018			
Methods	N	Subset for alpha = 0.05	
		1	2
Makkink	5	4,680	
Priestley-Taylor	5	4,968	
FAO56 PM	5	5,156	
Kimberly PM	5	5,616	
Hargreaves	5	6,122	6,122
Turc	5	6,400	6,400
Blaney-Criddle FAO	5		7,626
Sig.		0,052	0,068

2013-2017					
Methods	N	Subset for alpha = 0.05			
		1	2	3	4
Makkink	5	4,490			
Priestley-Taylor	5	4,840	4,840		
Hargreaves	5	6,162	6,162	6,162	
Turc	5	6,210	6,210	6,210	
FAO56 PM	5		6,598	6,598	6,598
Kimberly PM	5			6,886	6,886
Blaney-Criddle FAO	5				8,302
Sig.		0,068	0,063	0,437	0,063

As seen in the Tables 4.20 - 4.28, it is seen that Blaney Ciddle (FAO) method generally created a different group by giving the highest values at each station. In the lowest value group was the Makking method. The second low value was Priestly-Taylor, but this was not observed at all stations. As a result, if a generalization is made; it can be said that Kimberly PM, Hargreaves, Turc and Priestly-Taylor methods are in the same group with FAO-56 PM Method.

4.4. Multiple regression analyses to obtain reference evapotranspiration

Considering the literature and the results obtained in this study; The FAO-54 method and the other four methods (Kimberly PM, Hargreaves, Turc and Priestly-Taylor methods) were used for further analyses. Blaney Ciddle (FAO) and Makking methods were not evaluated. Average of ET values obtained by these 5 methods were taken as input parameter and, the mean temperature, maximum temperature, minimum temperature, relative humidity, wind speed and sunshine duration were taken as input parameters for Multiple regression analyses. Long- term climate values were used to create model and 2018 climate data were used to test the model.

All climatic factors and their different combinations were tested respectively. Statistically significant inputs to improve the model and, highest R^2 value were considered and best model results were given in (Table 4.29).

Table 4. 29. Multiple regression analyses results

Model	Constant	Standard Error	P	R^2
Intercept	1,365	0,690	0.050	0,932
Avg. Temp. (°C)	0,089	0.018	$3{,}70 \times 10^{-6}$	
Avg. Sunshine (hours)	0,308	0.062	$4{,}02 \times 10^{-6}$	
Avg. Humidity, (%)	-0,035	0,008	$6{,}56 \times 10^{-5}$	

Regression model can be expressed in the following form

$$ET_0 = 1{,}365 + 0{,}089.T + 0{,}308.S - 0{,}035.H$$

Where;

T: Avg. Temperature (°C)

S: Avg. Sunshine (hours)

H: Avg. Humidity, (%)

Annual climate data were used to test the model and regression model results and ET_0 models (5 models) results were given in (Figure 4.5).

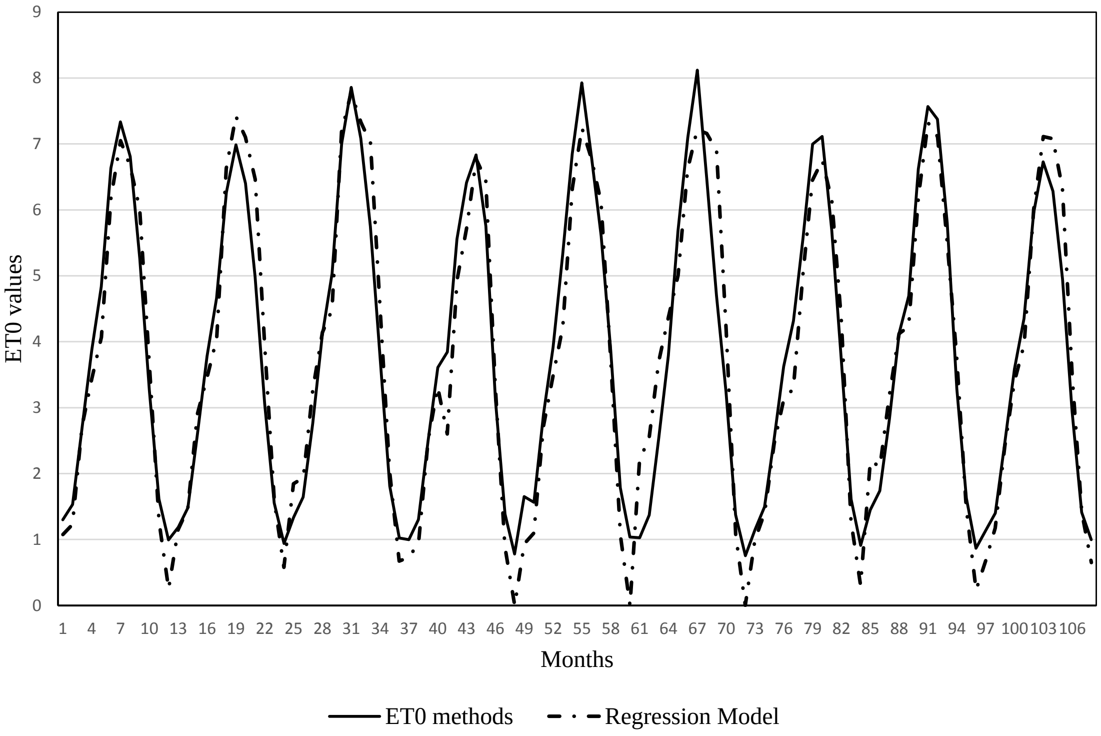

Figure 4.5.Testing of ET_0 multiple regression models

As it can be seen in Figure 4.5, the regression model yielded very consistent results with other methods. In some stations, the model for winter has yielded low results. However, this can be neglected as it is insignificant for the irrigation season. In addition, a deviation was observed in the two stations in the summer months. However, this difference seen in extreme values is acceptable.

In addition to this, this model, which has been developed specially for the region, is presented as a model that can be used both by farmers and researchers because of its ease of use and high accuracy.

5. CONCLUSION AND RECOMMENDATIONS

In order to prepare the irrigation projects, it is necessary to know the amount of water that will be used by the plants planned to be grown for monthly or shorter periods. The basis for calculating the irrigation water requirement is to determine the evapotranspiration. In the calculation of plant water consumption, the realistic estimation of the evaporation from the field where the plant is located and the sweating of the plant is very important. Evapotranspiration refers to the amount of water reaching the atmosphere as a result of evaporation of water from the soil and perspiration of the plant. Devices that provide direct measurement of the amount of evapotranspiration are called lysimeters and the use of these devices is also possible for our country. However, because the farmland is very large, placing a lysimeter everywhere and measuring it requires large amounts of cost. Considering the conditions of our country, it is not possible to use such devices in the whole land. Therefore, many different empirical equations have been developed for the direct calculation of evapotranspiration values.

Especially for the Duhok province, this study is of great importance both in terms of agricultural productivity and efficient use of limited water resources. In this study, ET_0 values were calculated for 9 different stations in the Duhok province with 7 different models used for this purpose and the results were compared statistically. The FAO-54 method proposed in the literature reviewed and the other 4 methods (Kimberly PM, Hargreaves, Turc and Priestly-Taylor methods) compatible with this method were taken as basis. First of all, it may be recommended to use any or all of these methods average for the region. However, a new model has been produced with multiple regression analyses for easier use.

Average of ET_0 values obtained by these 5 methods were taken as input parameter and, the mean temperature, maximum temperature, minimum temperature, relative humidity, wind speed and sunshine duration were taken as input parameters for Multiple regression analyses. All climatic factors and their different combinations were tested respectively. Statistically significant inputs to improve the model and, highest R^2 value were considered and best model results were obtained. As a result; The model obtained by average temperature, humidity and sunshine times (R^2: 0,932) was determined as the best model. The model, which was tested with annual data, was presented by both farmers and researchers as an easy and highly accurate model.

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