A Computer Program for Simultaneous Calculation of Reference and Crop Evapotranspiration by Three Methods

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Received on: 29/2/2010 ***Accepted: 28/3/2010***

ABSTRACT

A computer program is developed for computing reference evaporation (ETo), crop coefficient (kc) and crop evapotranspiration (ETc) under various regional and climatic conditions. The program requires for input basic climatological data (temperature, humidity, wind speed and sunshine duration data) that are routinely available at most weather and agricultural research stations. The program calculates ETo simultaneously by three different methods (Blaney-Criddle, radiation and modified Penman methods) and generates results on screen and in output files that can be easily converted into graphs. The program has a large built-in database for essential global parameters needed for calculations such as distribution of extra-terrestrial radiation, maximum possible daily sunshine hours and other information and mathematical relations. The database also covers crop information needed for calculation of kc and ETc such as seasonal and stage lengths for a variety of field crops. The program is designed such that most required data are input in a single file and line inputs are very limited for convenient usage. Extensive testing of the program under various conditions showed very stable performance, consistency and reproducibility, and revealed that the program is capable of providing accurate estimates of reference evapotranspiration, crop coefficient and crop evapotranspiration for many crops. The program is believed to provide a convenient tool for use both by growers and in pertinent scientific applications.

Key words: reference evapotranspriration, crop evapotranspriration, crop coefficient, irrigation.

INTRODUCTION

The ability to estimate crop evapotranspiration (ETc) represents one of the basic elements required for successful planning and management of irrigation systems. Irrigation scheduling is based in principal on data of daily ETc and soil characteristics Kovda *et al.*, (1973); Hansen *et al.*, (1980); (Withers and Vipond, 1980). It has long been acknowledged that actual evapotranspiration (ET) is a function of both the weather and the soil's physical properties and that prevailing environmental conditions significantly determine the limitation of crop production (Pruitt, 1960); (Penman, 1963); Pruitt *et al.*, (1972); (Slatyer, 1967); (Kramer, 1983). The amount of water available for ETc is strongly correlated with the amount of dry matter production (Taylor, 1965); Pruitt *et al.*, (1972); (Black, 1981). When designing water management or irrigation projects, the use of climatological and meteorological data, soil characteristics information and crop parameters becomes particularly valuable. In many cases, justification for supplemental irrigation depends on crop production-evapotranspiration relations (USDA-SCS, 1967); (Withers and Vipond, 1980); Hansen *et al.*, (1980).

Throughout the past 60-70 years, numerous studies on parameters influencing ET were conducted and attempts were made to materialize these parameters into mathematical functions that allow for quantitative estimation of ETc (e.g. Blaney and Criddle, 1947); (Blaney and Criddle, 1962); (Olivier, 1961); (Stanhill, 1965); (Jensen, 1966) among many others). Several of these attempts were successful and resulted in the formulation of equations or the development of techniques for ET determinations and measurements.

Among the earliest developed formulas were those of (Blaney and Criddle 1947), Penman (1948), (Thornthwaite 1948), and (Olivier 1961). Several years later, new methodologies were developed involving the use of evaporation pan data and measurements (Hargreaves, 1968) or field lysimetry.

The methods of Blaney-Criddle (Blaney and Criddle, 1947); (Blaney and Criddle, 1962), Thornthwaite (Thornthwaite, 1948) and Olivier (Olivier, 1961) are empirical methods based essentially on temperature, which implies the advantage of requiring only the more commonly measured data- and hence usability in most areas- and the simplicity of calculation. The empirical nature of these equations, however, may markedly limit the scope of their applicability and usefulness

. Evapotranspiration is a function of the effect of the total energy environment on the plant. Obviously, neither temperature nor humidity alone is a measure of the total energy, although they are significantly influenced by it. Empirical equations are therefore most appropriate if applied to climatic zones similar in general to those for which they were originally derived. One approach to resolve the limitation problem is done by calibration of these equations for locations where they are applied against other, more sophisticated equations, or against field measurements (e.g. evaporation pans or lysimeters).

If local evapotranspiration variations are induced mainly by temperature, with other elements (e.g. humidity, or wind speed) remaining fairly constant, a method based on temperature will be more appropriate. On the other hand, if temperature fluctuations throughout the season are minimal, a method based on humidity will give more realistic results. Due to this often-encountered uncertainty, it is commonly resorted to using all available methods and choosing the one method that gives the most likely results (Withers and Vipond, 1980).

The Blaney-Criddle (B-C) original formula is written as:

$$U = K\Sigma pT = KF \qquad [1]$$

where U is consumptive use of crop in inches during growing season

F = sum of the monthly consumptive use factors for the period (ΣpT)

T = monthly mean temperature in °F

P = percentage of daytime hours of the year occurring during each month of the growing period

K = an empirical coefficient (annual, seasonal, monthly).

Values of seasonal coefficient for different crops are given in tables in various literature (e.g. Withers and Vipond, 1980).

Among other –non empirical methods- are the radiation method (Jensen, 1966; Doorenbos and Pruitt, 1977) and Penman method.

The radiation method is suggested to predict the effect of climate on crop water requirements for areas where available climatic data include measured air temperature and sunshine but not wind or humidity (Doorenbos and Pruitt, 1977). For the radiation method, only general or approximate levels of humidity or wind speed are required and such information may be accessed from published weather descriptions or from local sources. Potential evapotranspiration results obtained from the radiation method are usually more reliable than empirical methods in areas of high radiation such as equatorial zones or small islands or at high elevations. Radiation equation usually takes a form where potential evaporation is a linear function of net solar radiation, with other factors involving temperature, relative humidity and wind speed.

The Penman equation was created by combining the energy balance equation (Tanner and Pelton, 1960; Withers and Vipond, 1980) with Dalton's equation (Marshall and Holmes, 1988). The energy balance equation states that:

$$R_I = \alpha R_I + R_B + H + E \qquad [2]$$

where R_I is the radiation reaching the earth's surface, cal cm^{-2} min^{-1}

α is the reflectance (albedo) of the surface (dimensionless-fraction)

R_B is the long-wave back radiation, cal cm^{-2} min^{-1}

H is the increase in sensible heat of the atmosphere, cal cm^{-2} min^{-1}

E is the energy available for evaporation from the surface, cal cm^{-2} min^{-1}

The combined Penman formula calculates evaporation energy (E) as:

$$E = ((\Delta/\gamma)\, R_n + E_a) / (\Delta/\gamma + 1) \qquad [3]$$

where R_n is the net radiation (i.e. $R_I\,(1-\alpha)-R_B$)

Δ is the slope of the saturation vapor pressure-temperature curve

γ is the psychrometric constant, mbar °C^{-1}

$E_a = f(u)\,(e_a - e_d)$, e_a is the saturated vapor pressure at air temperature (mbar) and e_d is the vapor pressure of the atmosphere above.

Penman method has undergone several modifications and adaptations (Doorenbos and Pruitt, 1977), (Smith, 1992); Allen *et al.*, (1998) in order to improve its applicability and to account for variables not included adequately in the original equation.

Newer approaches in evapotranspiration measurements take advantage of technology advances and utilize computer programming and models (e.g. Smith, 1992); (Droogers, 2000), (Mahmood and Hubbard, 2003); Mo *et al.*, 2004) for faster and more accurate calculations, or even the use of satellite images and information (Kite and Droogers, 2000). Computer modeling facilitates the inclusion of numerous parameters and complex mathematical expressions that should bring predictions and estimates to higher levels of precision and reliability.

MATERIALS AND METHODS

The program

The computer program presented in this article was developed to provide a fast and accurate method of calculating reference and crop evapotranspiration. The program is based on recognized formulas and methods widely reported (e.g. Doorenbos and Pruitt, 1977); (Smith, 1992); Allen *et al.*, (1998) and executes calculations by three different methods. These methods are: Blaney-Criddle (B-C), radiation method, and the modified Penmen equation. The program was compiled in Basic language using Turbo Basic software (Borland International, Inc, Turbo Basic V. 1.0, 1987) and was completed in 2002.

The data required for the program are tabulated such that each set of information occupies on line and represents a "run". A run can therefore represent a single day, a week, a decade (10-day interval), a month or any other number of days. The data include: month of the year (m), number of days per run, temperature (maximum, T_{max}, and minimum, T_{min}, or averages, T_{avg}), relative humidity (maximum, RH_{max}, and minimum, RH_{min}), wind speed (u), height of wind speed measurements, h_u (or else height is assumed to have the standard value of 2.0 meters), and sunshine duration in hours (n).

Other required input data are provided to the program as line-input and include: name of region or location, location latitude (degrees) and altitude (meters), inquiries regarding the requested calculations (ETo or both ETo and ETc), number of runs, and input file name (file containing the data). File types accepted by the program include virtually all non-formatted, plain text types such as: *dat*, *txt*, *prn* and *doc* files. Values in each line of the data input file can be written in space- or comma-delimited format.

In case the user chooses to have the program calculate both ETo and ETc, the program will ask for additional information concerning the crop, namely: crop name (selected from a list), length of each of the 4 growth stages (expressed as runs), and run number representing the start of the growing season. For example, if the crop in question is corn (maize), and if the input data are set-up such that a whole year is covered in 10-day intervals (i.e. 36 runs) and taking growth stage lengths of 20-25-25-10 days for initial, crop-development, mid-season and late stage, respectively Allen *et al.*, (1998), then number of runs covering the 4 stages would be approximately 2, 3, 3 and 1. The program will ask for the number of starting run, here we take the planting date of early June Allen *et al.*, (1998), say June 1st, and the starting run for the growing season will thus be run number 16 (preceded by 5 months, 3 runs each). A detailed explanation of data preparation and input method and format, as well as comprehensive agronomic information on growing season lengths, lengths of different growing stages, and planting dates for different crops in different geographic zones and under different climates are shown in an overview section of the program. This section is provided within the program database and includes all source information required for calculations as well as a complete background of each of the calculation methods along with pertinent information and equations.

Although the program is intended to be valid for global application, local conditions were given special consideration in the selection of the calculation methods. Blaney-Criddle formula was originally developed for the Western USA and therefore most suitable for arid regions, particularly under coastal climates which are the prevalent conditions in the Middle East- North Africa region. Also, the radiation method is most applicable to areas where solar radiation is significantly effective, which is also the case in the arid climate region of the Middle East and North Africa. The modified Penman method was included in the program as it is acknowledged to be the most comprehensive and inclusive of all methods.

The program displays the results immediately after completing the inputs. Displayed results include a first screen with input location information, then it displays consecutively 3 result screens for each run (one for each of the three calculation methods), then a screen of a summary table listing the results of all runs, all methods and their averages. Upon user's request generated output result tables can be obtained in hard copies by a regular printer. An example of program-generated ETo result table is shown in a following section on program validation.

If the program is instructed to calculate ETc in addition to ETo, a second summary table is created and displayed, containing calculated crop coefficient (kc) and ETc for each run within the growing season in addition to average ETo values of all input runs.

A statistics summary follows with information on seasonal crop water use, and peak and seasonal average ETo, among other useful information. An example of program-generated ETc result table is shown in the program validation section.

In each of the three result screens displayed for each run, details of intermediate calculations of the run are shown. This is intended to provide a convenient tool for tracking the calculations and monitoring detailed steps for different cases.

Program validation and testing were carried out through comparing results with results calculated by FAO's *Cropwat* program, which is based on adapted Penman-Monteith approach (Smith, 1992), or with field measured results such as those obtained from evaporation pans (Hargreaves, 1968).

1. Blaney-Criddle method

For Blaney-Criddle (B-C) equation, calculations are based on the determination of f factor (Blaney and Criddle, 1962); Doorenbos and Pruitt, 1977) where:

$$f = p\,(0.46\,T_{avg} + 8.13) \qquad [4]$$

where T_{avg} is mean temperature (°C) and p is the mean daily percentage of annual daytime hours. The parameter p is a function of the time of the year (month) and latitude. Tabulated values of p were provided to the program's database; therefore a p-value is supplied to the program automatically based on location (latitude) and time of the year.

One of the important parameters required for calculation by the B-C method as well as by the other methods is the ratio between actual and maximum possible sunshine hours (n and N, respectively). Data of actual sunshine hours (n) are provided in input file, while N is obtained from the program's database. Since N is a function of latitude and time of the year, it was possible to provide it in the program's database so that it is available for calculations automatically. Tabulated N data were converted into equations to provide continuous N functions with time of the year. For a given latitude, the relationship between N and the of the month number (m, where January =1 and December = 12) was found by regression to take the linear form:

$$N = a\,\mathrm{m} + b \qquad [5]$$

Where a and b are latitude-dependant coefficients, with a having positive values for the months of January through June and negative values through the rest of the year in the northern hemisphere. In the southern hemisphere, the sign of a is reversed.

According to the approach utilized by (Doorenbos and Pruitt 1977), the ratio n/N is grouped into 3 categories: low (<0.6), medium (0.6-0.8), and high (>0.8), and RH_{min}, is grouped into 3 categories: low (<20%), medium (20-50%) and high (>50%). As a result, there are 9 possible combinations between n/N and RH_{min}. Within each of these nine groups, two new parameters, a and b, are determined based on wind speed, where in each group three ranges of average daytime wind speed are possible; namely, light (0-2 ms^{-1}), moderate (2-5 ms^{-1}) and strong (>5 ms^{-1}). After parameter f is calculated and after the program determines the appropriate values of parameters a and b, ETo is calculated according to the Equation:

$$ETo = a + bf \qquad [6]$$

An example showing a part of the input table and the program's output calculation screen is shown in Tables 1 and 2. In Table (1) input data of the first 10-day run of the month of January, 1998 for Alexandria is shown. This run represents the first of 36 runs covering the entire year.

Table (2) shows, as an example, the calculation screen generated by the program for this run as calculated by the B-C method. In total, 36 screens are generated for the 36 runs. Similarly, for each of the other two methods (radiation and modified Penman), 36 calculation screens are also generated covering the 36 runs of the year.

2. Radiation method

Essential input data required for the radiation method include temperature and sunshine duration or cloudiness and radiation information. Since temperature measurements and sunshine duration data are included in the input data file, calculations based on the radiation method are readily possible. The basic equation for calculating ETo from temperature and radiation data is:

$$ETo = a + b\,W R_s \qquad [7]$$

where R_s is the solar radiation received at the earth's surface, expressed in equivalent evaporation (mm d^{-1}), W is a weighing factor which depends on temperature and altitude, and a and b are coefficients determined by the prevailing mean RH and wind speed.

The weighing factor W is defined as:

$$W = \frac{\Delta}{\Delta + \gamma} \qquad [8]$$

where Δ is the rate of change of the saturation vapor pressure with temperature and γ is the psychrometric constant (Penman, 1963).

For different altitudes ranging between 0 and 4000 m, the correction factor W was converted from tabulations (Doorenbos and Pruitt, 1977) into a continuous function by a power equation of the form:

$$W = a + bT^c \qquad [9]$$

Table 1: A section of the data input table showing the first line representing the first run with data of January 1 through January 10, 1998 in Alexandria, Egypt

Month no.	No. of days	T_{max}	T_{min}	T_{avg}	RH_{max}	RH_{min}	U	h_u	n
1	10	18.6	8.9	--	93.6	53.6	3.14	2	4

Table 2: Example of program output screen, showing results of run number 1 (Alexandria data, 1998) and intermediate calculations (Blaney-Criddle method)

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Summary of Entries and Intermediate Calculations For Run Number For / During The Month of January
1. Blaney-Criddle Method

Mean temperature                                          =   13.750
Relative humidity (min) input                             =   0.536
Relative humidity (max) input                             =   0.936
Wind speed input                                          =   3.140     m/s
                                                          =   271.296   km/day
Height of wind speed measurements                         =   2.00      m
Wind speed adjusted for elevation (u2)                    =   3.140     m/s
                                                          =   271.296   km/day
Mean actual sunshine hours                                =   4.000     h
Mean max. possible daily sunshine hrs.                    =   10.448    h
n/N ratio (calculated)                                    =   0.383
Mean relative humidity (calculated)                       =   73.600    %
p-value {Blaney-Criddle}                                  =   0.240
f-value {for charts- Blaney-Criddle}                      =   3.469
Parameter a (intercept) { Blaney-Criddle}                 =   -1.550
Parameter b (slope) {Blaney-Criddle}                      =   0.880
1. Calculated reference evapotranspiration (ETo) {B-C}    =   1.503     mm/day
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where l is the altitude, and a, b, and c are constants. In Eq. [7], R_s is only a fraction of the radiation received at the top of the atmosphere which is termed extra-terrestrial radiation (R_a). This extra-terrestrial radiation is independent of weather conditions and depends strictly on the latitude and time of the year. Tables of R_a for various latitudes of both hemispheres and for different months Allen *et al.*, (1998) were converted into mathematical functions through regression, and the equations were fed to the program's database so the values of R_a are calculated automatically from information of hemisphere, latitude and time of the year. For a given latitude, R_a was found to correlate to the month of the year by the power equation:

$$R_a = a\,m^b \qquad [10]$$

where m is the month number (January =1 through December = 12), and a and b are coefficients depending on latitude. The coefficient a assumes positive values for the months of January through June and negative values through the rest of the year in the northern hemisphere. For the southern hemisphere, the sign of coefficient a is reversed. The amount of solar radiation R_s is related to extraterrestrial radiation by the equation (Withers and Vipond, 1980):

$$R_s = (\alpha + \beta\, n/N)\, R_a \qquad [11]$$

where α and β are often given the empirical values of 0.25 and 0.50, respectively.

As mentioned above, coefficients a and b in Eq. [7] are controlled by prevailing mean relative humidity RH_{mean} and wind speed. In the program, RH_{mean} is divided into four classes: 1) $RH_{mean}<40\%$, 2) RH_{mean} = 40-55%, 3) RH_{mean} = 55-70%, and 4) $RH_{mean}>70\%$. Within each of the 4 classes, coefficients a and b are determined based on average prevailing daytime wind speed, which is in turn divided into 4 levels: light (0-2 ms^{-1}), moderate (2-5 $m\ s^{-1}$), strong (5-8 $m\ s^{-1}$), and very strong (>8 $m\ s^{-1}$). After parameters a and b are determined, the program calculates ETo according to Eq. [7]. A printout of the program output result table of the radiation method for run 1 (shown in Table 1) and its intermediate calculations is displayed in Table 3 as an example.

3. Modified Penman method

The modified penman method is appropriate where available data include temperature, humidity, wind and bright sunshine hours or radiation. With as many parameters involved, the modified Penman method is believed to provide reliable results in predicting ETo under a given set of climatic conditions. In the modified Penman method, difference from the original Penman method involves a revised wind function term and an additional correction for day and night-time weather conditions not representative of climate for which the wind function was determined (Doorenbos and Pruitt, 1977), Allen *et al.*, (1998).

The equation used by the program takes the form:

$$ETo\ (unadjusted) = W R_n + (1-W) f(u)\,(e_a - e_d) \qquad [12]$$

where W is the temperature-related weighing factor, equaling $\frac{\Delta}{\Delta+\gamma}$ as defined before (Eq. [8])

R_n is net radiation in equivalent evaporation, in mm d^{-1}

f(u) is wind-related function

$(e_a - e_d)$ is the difference between the saturation vapor pressure at given mean air temperature and the mean actual vapor pressure of the air (mbar). Saturation vapor pressure (e_a) is a direct function of air temperature, T_{mean}. For program use, tabulated relation between e_a and T_{mean} was converted into the exponential equation:

$$e_a = exp\,(1.873 + 0.062\ T_{mean}) \quad (r^2 = 0.998) \qquad [13]$$

The mean actual vapor pressure of the air, e_d, is calculated by the equation:

$$e_d = e_a \frac{RH_{mean}}{100} \qquad [14]$$

and the wind function f(u) is calculated as:

$$f(u) = 0.27\,(1 + \frac{U_2}{100}) \qquad [15]$$

where U_2 is total wind run (km d^{-1}) at 2 m height. Height of wind speed measurement is corrected to the corresponding speed at 2 m height by means of the equation:

$$c.f. = 1.1552\, h_u^{-0.187} \qquad [16]$$

where $c.f$ is the correction factor and h_u is measurement height (m).

The net radiation (R_n) in Eq. [12] is defined as the difference between net shortwave radiation (R_{ns}) and net long-wave radiation (R_{nl}), i.e.:

$$R_n = R_{ns} - R_{nl} \qquad [17]$$

and R_{ns} is calculated by the program by the equation (Withers and Vipond, 1980):

$$R_{ns} = (1-\alpha)\,(0.25 + 0.50\, n/N)\, R_a \qquad [18]$$

where α is the crop surface reflectivity, or albedo, given the average approximate value of 0.25. Typical α values are approximately 0.05-0.10 for water and 0.20-0.25 for most crops and farmlands (Henderson-Sellers and Richardson, 1988). Other terms are defined as before.

Net long-wave radiation (R_{nl}) is determined from temperature (T), vapor pressure (e_d) and ratio n/N data, and is defined (Doorenbos and Pruitt, 1977) as:

$$R_{nl} = f(T)\, f(e_d)\, f(n/N) \qquad [19]$$

Temperature function is calculated based on the following equation (Henderson-Sellers and Richardson, 1988):

$$f(T) = \sigma T_k^4 \qquad [20]$$

where σ is the Stefan-Boltzmann constant ($\sigma = 5.67\times10^{-8}$ W m^{-2} K^{-4}, where T_k is absolute temperature, *Kelvin*).

Correction function for effects of vapor pressure $f(e_d)$ and actual-to-maximum sunshine ratio f(n/N) on long wave radiation (R_{nl}) are calculated

Table 3: Example of program output table of the radiation method, showing the results of run number 1 (Alexandria data, 1998) and its intermediate calculations

Summary Of Entries And Intermediate Calculations For Run Number 1 For/During The Month Of January
2. Radiation Method

Extra terrestrial radiation (in equivalent evaporation)	=	8.052	mm/day
Solar radiation- total shortwave (in equivalent evaporation)	=	3.554	mm/day
Calculated *a* factor (intercept) {radiation}	=	-0.300	
Calculated *b* factor (slope) {radiation}	=	0.810	
Weighing *W* factor {radiation}	=	0.609	
2. Calculated reference ETo {radiation}	=	**1.453**	**mm/day**

according to Doorenbos and Pruitt (1977), where

$f(e_d) = 0.56 - 0.079\sqrt{e_d}$ (for humid climates) [21]

and

$f(e_d) = 0.34 - 0.044\sqrt{e_d}$ (for dry climates) [22]

where the vapor pressure (e_d) is in mbar, and $f(n/N) = 0.10 + 0.9\ (n/N)$

After uncorrected Penman ETo is calculated, modification is executed based on four weather parameters; namely: average prevailing daytime wind speed, wind day-night ratio, maximum relative humidity, and solar radiation.

Seven cases are automatically assessed by the program and the appropriate combination of the above 4 elements is selected. For each selection a regression function is generated to calculate the corrected Penman ETo value. Table (4) lists the various combinations of the four parameters and the associated correcting equations as employed by the program.

**y* = Corrected ETo (modified Penman method) and *x* = uncorrected Penman ETo.

A computer-generated table of ETo results as calculated by modified Penman method for the run shown in Table (1) (Alexandria, 1998), along with intermediate calculations is presented as an example in Table (5).

A printout example of ETo as calculated by the three methods is shown in the validation section Table (6) for 36 runs of weather data.

Crop coefficient, kc

Actual crop evapotranspiration (ETc) is related to reference evapotranspiration (ETo) by the crop coefficient, kc Hansen *et al.*, (1980) such that

ETc = ETo × kc [24]

Crop coefficient is determined by the program for each of 4 growth stages, namely the initial stage (kc1), the crop development stage (kc2), the mid-season stage (kc3) and the late stage (kc4). The program covers 27 field crops. Values of kc for initial stage (kc1) are calculated based on the frequency of significant rain (obtained from meteorological records for a given interval) or irrigation. Mid-season stage (kc3) values were provided to the program's database for each crop and are thus automatically accessed. Crop development stage values (kc2) increases progressively with the advancement of crop growth and are determined through interpolation between kc1 and kc3. Calculated value at any given date of this stage can hence be determined. Late stage crop coefficient (kc4) is also calculated by the program through interpolation between kc3 and kc value at harvest, obtained from the program's database. Value of kc4 can thus be estimated also at any given date over this stage. ETc is then calculated by the program as the product of kc and ETo. Results of kc for different runs over the growing season as well as reference and crop evapotranspiration are displayed in a program-created ETc results table. For each run throughout the growing season, the displayed values of ETo, kc and ETc are those determined at mid-points of successive run lengths, each expressed in

Table 4: Correction equations of the modified Penman method for different conditions of daytime wind speed, day-night wind ratio, maximum relative humidity, and solar radiation

Daytime av. wind	Day-night wind ratio	RH_{max} %	Radiation mm d^{-1}	Penman modification equation*
≥ 4	≥ 3	$\rightarrow 100$	Moderate/high (>8, summer)	$y = 1.608\,x^{0.892}$
≤ 4	≥ 3	≥ 75	All conditions	$y = 1.167\,x^{0.959}$
0-5	≈ 2	≥ 60	All conditions	$y = x$ (no correction)
< 4	≤ 1.5	≥ 60	All conditions	$y = 0.704\,x^{1.116}$
5-8	≤ 1.5	≤ 40	Moderate/high (summer)	$y = 0.405\,x^{1.260}$
> 8	≤ 1.5	≤ 40	Moderate/high (summer)	$y = 0.346\,x^{1.215}$
> 8	≤ 1.5	≤ 40	Low (winter)	$y = 0.119\,x^{1.471}$

Table 5. An example of program-generated modified Penman output table, showing results of run 1 (Alexandria data, 1998) and its intermediate calculations. (The run's 3- method average is also shown)

Summary of Entries and Intermediate Calculations For Run Number 1 for/During The Month of January

3. Modified Penman Method

Saturation vapor pressure (*ea*) in mbar		15.321	
Vapor pressure (*ed*) in mbar	=	11.276	
Wind function f(u)	=	1.0025	
Weighing factor (W) {Penman}	=	0.6101	
Net solar radiation (Rns)	=	2.6657	mm/day
Correction for temp on long wave radiation Rnl : f(T):	=	13.326	
Correction for vapor pressure on Rnl: f(*ed*)	=	0.1922	
Correction for n/N on Rnl: f(n/N)	=	0.4446	
Net long wave radiation Rnl	=	1.139	mm/day
Net radiation Rn	=	1.5267	mm/day
ETo-Penman has been modified.	=		
Estimated day/night ratio:			
Modification equation:		1.5	
Eqn. 4. Y (corrected) = 0.7044 * X(uncorrected)^1.1164	≤		
3. Estimated ETo: Penman (unadjusted)	=		
Estimated ETo: Penman (adjusted)	=	**2.5124**	mm/day
		1.9701	mm/day
Average of three methods	=	**1.6419**	**mm/day**

number of days from the start of the growing season. An example printout of results table for average ETo, kc, and ETc is shown in Table (7) in the program validation section.

For the initial stage, the dependence of the crop coefficient kc1 on soil wetness is accounted for by adjusting the values according to the frequency of significant rain or irrigation. Five equations representing five different rain/irrigation frequencies are employed by the program. Each of these equations estimates kc1 as a function of combined weather conditions represented by calculated ETo. Empirical data presented by Doorenbos and Pruitt (1977) were used to generate these equations, which had the power form:

$$y = a + bx^{c} \qquad [25]$$

where y represents estimated kc1, x represents ETo associated with given conditions, and a, b and c are frequency-dependant coefficients.

The graphs representing the relationship between frequency of rain or irrigation, ETo during the initial stage and estimated kc1, along with associated regression equations are shown in Figure (1)

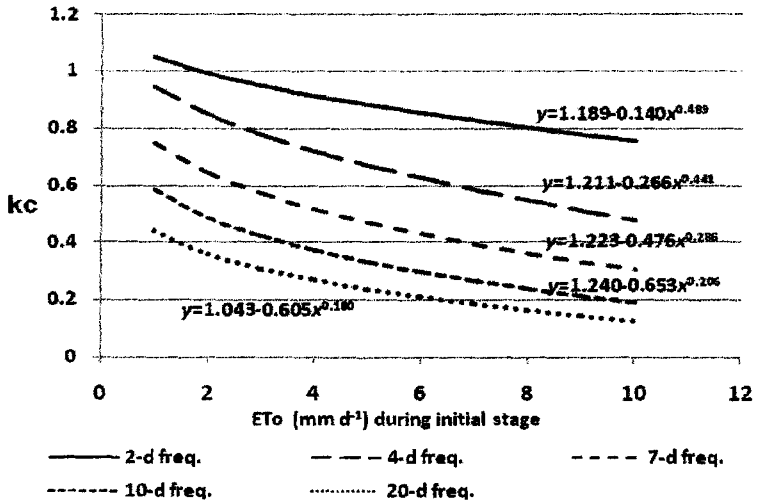


Fig. 1: Relationship between frequency of rain or irrigation, reference evapotranspiration (ETo) during the initial stage, and the initial stage crop coefficient (kcl)

Program validation

In order to test the program for correctness and accuracy, extensive validation trials were performed. Validation was directed at examining the precession of data processing, consistency of performance, functionality under different conditions and over different regions of the world, and result agreement or differences with other evaluation methods. Evaluation methods used to compare program results with included the FAO's *Cropwat* program (smith, 1992) as well as results obtained from actual field measurements (e.g. by evaporation pan).

Validation involved applying the program to a vast number of locations and weather conditions in many parts of the world, covering eastern and western longitudes in both northern and southern hemispheres. Results reported here are only a few of obtained results and are shown as typical examples of different regional conditions. Validation locations, their climatic characteristics, coordinates (longitudes and latitudes) and altitudes are listed in Table (6).

An example of program-generated table of ETo calculations is shown in Table (7) for the city of Alexandria, Egypt (data of the year 1998). In Figure (2), results of average ETo in agricultural research stations (ARS) in Alexandria, Cairo and Aswan are shown and compared for data of the same year, 1998 (36 10-day runs covering entire year). Differences in ETo imposed by climatic differences (different latitudes) between the three regions are clear. Also, a consistent pattern of dependence of ETo on the time of the year can be seen, with ETo peaking in midsummer and tapering off towards winter months.

Detailed program results of ETo as obtained by each of the three calculation methods are displayed for Ismailia, Egypt in Figure (3). The data used here are extended yearly normals (records of CLAC, 2006). In addition to results of the three methods, the graph displays results obtained for the same agricultural station by local measurements as well as results calculated by the FAO's *Cropwat* program. Results reflect good agreement between program calculations and other calculations and measurements. It is notable that the closest results obtained to measured results and to *Cropwat* calculations are those representing the 3-method averages. This trend was seen in many cases and over a large number of stations. Another comparison between program-calculated ETo and ET determined from evaporation pan is displayed in Figure. (4) for El-Bustan area, Egypt. Reasonable

Table 6: List of program validation locations, their climates, coordinates and altitude

Country	Location and data source	Climate	Coordinates		Altitude
			Longitude	Latitude	m
Egypt	Agricultural research and weather stations in:	Arid, Mediterranean, desert, subtropical climate			
	Alexandria		29.95° E	31.20° N	6
	Cairo		31.40° E	30.13° N	65
	Aswan		32.55° E	23.97° N	199
	Ismailia		32.18° E	30.58° N	13
	El-Bustan		30.21° E	30.40° N	60
	Menya		30.46° E	28.00° N	42
	Arish		33.48° E	31.00° N	18
	Siwa		25.31° E	29.00° N	10
Syria	Agricultural research stations in:	Mediterranean to arid, temperate climate			
	Latakia		35.48° E	35.50° N	30
	Tartous		35.54° E	35.00° N	157
France	Montpellier (meteorological station)	Marine w. coast, temperate climate	3.96° E	43.58° N	6
Italy	Rome (meteorological station)	Mediterranean to temperate climate	12.48° E	41.90° N	17
Greece	Souda, Crete (meteorological station)	Mediterranean to temperate climate	24.10° E	35.48° N	151
United States: California	Sacramento, California (meteorological station at Sacramento Executive AP)	Marine, coastal, temperate climate	121.60° W	38.51° N	8
Argentina	Santa Isabel (meteorological station)	semiarid, temperate, subtropical, highlands climate	66.90° W	36.26° S	320

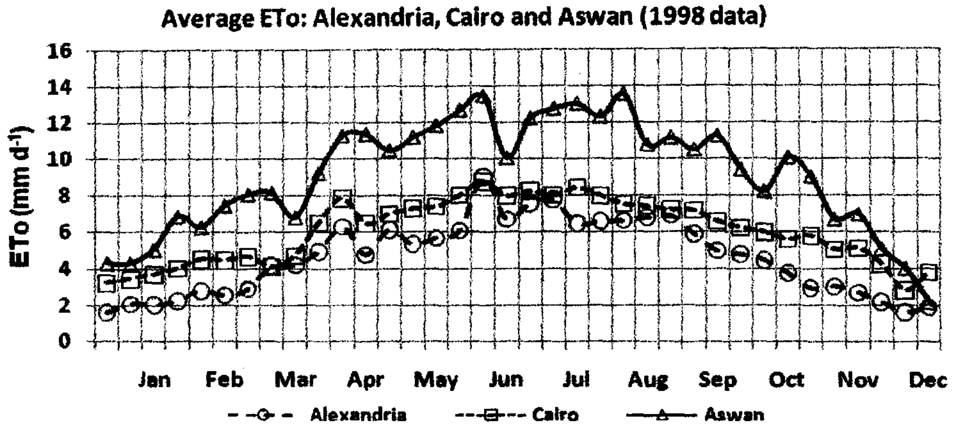


Fig.2: Yearly patterns of reference evaporation (ETo) as calculated by the program for stations in Alexandria, Cairo and Aswan (1998 data)

Table 7:An example of the program–generated result table for ETo as calculated by the three methods for the city of Alexandria, Egypt over 36 runs covering the year of 1998

Calculated reference (potential) evapotranspiration (ETo) for Alexandria (Nuzha) for 36 runs By Blaney-Criddle, Radiation, and modified Penman methods Calculation Summary

Run	Month	Blaney- Criddle	Radiation	Penman	Modified-Penman	Average*
1	Jan 1-10	1.503	1.453	2.512	1.97	1.642
2	Jan 11-20	1.547	1.622	3.177	3.177	2.115
3	Jan 21-31	1.488	1.713	3.025	3.025	2.075
4	Feb 1-10	1.716	2.465	3.277	2.65	2.277
5	Feb 11-20	2.117	2.347	4.066	4.066	2.843
6	Feb 21-28	2.286	2.619	3.507	2.858	2.588
7	Mar 1-10	2.016	3.178	4.262	3.554	2.916
8	Mar 11-20	3.334	3.709	5.529	5.529	4.191
9	Mar 21-31	3.364	3.738	5.613	5.613	4.239
10	Apr 1-10	4.807	5.11	5.792	5.005	4.974
11	Apr 11-20	6.193	5.663	7.075	7.075	6.31
12	Apr 21-30	3.807	4.363	6.243	6.243	4.804
13	May 1-10	5.55	4.976	7.926	7.926	6.151
14	May 11-20	4.517	4.866	6.7	6.7	5.361
15	May 21-31	5.648	5.552	6.69	5.879	5.693
16	Jun 1-10	4.667	6.212	7.449	7.449	6.109
17	Jun 11-20	9.231	8.189	9.705	9.705	9.042
18	Jun 21-30	6.072	6.329	7.773	7.773	6.724
19	Jul 1-10	7.63	7.439	8.482	7.663	7.578
20	Jul 11-20	7.527	7.354	8.438	8.438	7.773
21	Jul 21-31	5.025	6.437	8.006	8.006	6.489
22	Aug 1-10	5.925	6.122	7.766	7.766	6.604
23	Aug 11-20	6.539	5.728	7.643	7.643	6.636
24	Aug 21-31	6.634	5.882	7.93	7.93	6.815
25	Sep 1-10	7.106	5.677	7.954	7.954	6.912
26	Sep 11-20	6.691	5.424	6.434	5.629	5.915
27	Sep 21-30	4.471	4.402	6.906	6.091	4.988
28	Oct 1-10	4.86	4.426	5.951	5.159	4.815
29	Oct 11-20	4.786	3.864	5.601	4.822	4.491
30	Oct 21-31	3.579	3.535	4.963	4.212	3.775
31	Nov 1-10	3.009	2.821	3.715	3.049	2.96
32	Nov 11-20	3.323	2.96	3.515	2.866	3.05
33	Nov 21-30	2.755	2.492	3.575	2.921	2.723
34	Dec 1-10	2.509	1.667	3.065	2.46	2.212
35	Dec 11-20	1.492	1.392	2.646	2.087	1.657
36	Dec 21-31	1.418	1.385	3.023	3.023	1.942
Avg.		**4.309**	**4.253**	**5.72**	**5.387**	**4.65**

*Averages are based on Blaney-Criddle, radiation and modified penman methods. If Penman is modified, averages exclude uncorrected values.

Average of all runs (three methods per run) = 4.650 mm/day

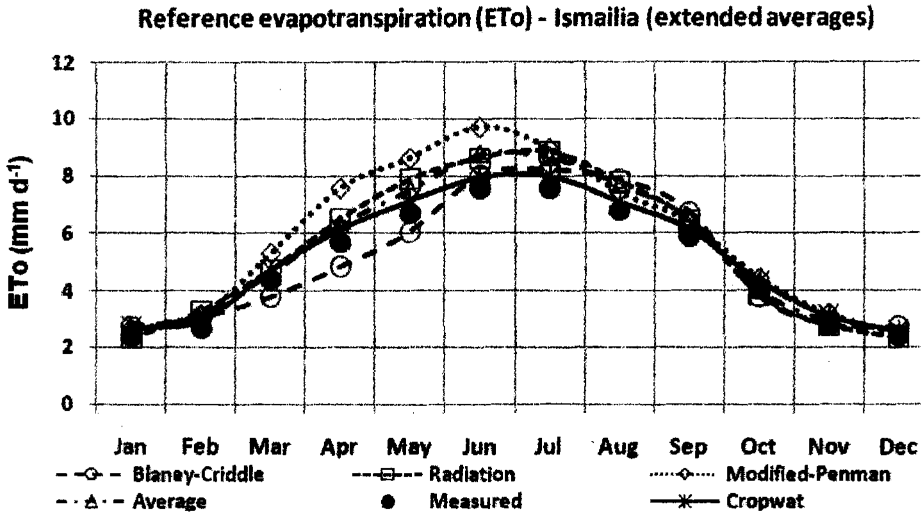


Fig. 3: Calculated reference ETo as compared with measured values and values determined by *Cropwat* for Ismailia, Egypt (extended averages)

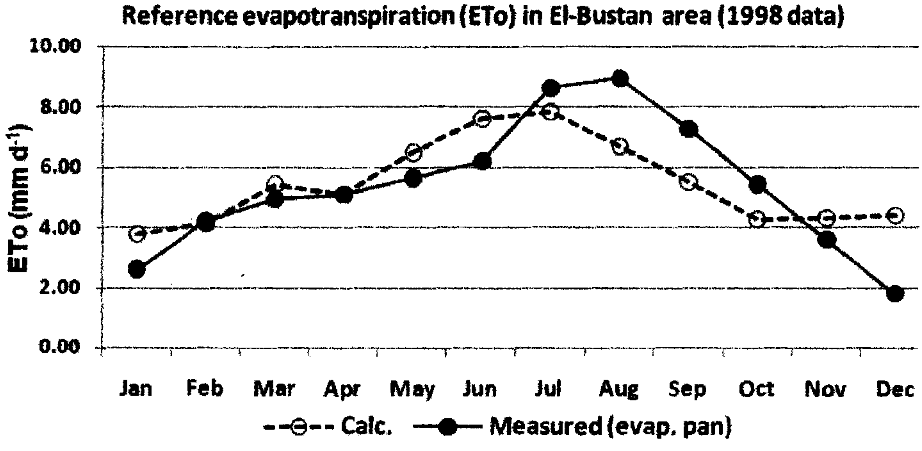


Fig. 4: Calculated and pan-measured monthly average ETo in El-Bustan, Egypt (1998 data)

calculated results and pan-based ET. In spite of some discrepancies between program calculated and pan-measured ETo values, which are manifested in slight under-prediction of ETo by the program for the months of August and September and over-prediction for the month of December, the overall agreement in trend and values over the rest of the year is fairly good.

Program validation involved application to two locations in Syria, Latakia and Tartous Table (6). Examples of obtained results are shown in Figure (5) and 6. In Figure (5), data of the year 1984 were used and results were compared with field pan-measured values. Good agreement between program results and measured values is seen, with the radiation method and the all-method average showing the closest agreement with measured results. Other methods showed reasonable agreement as well. In Figure. (6), calculated and measured values of ETo are shown for the Agricultural Research Station in Tartous, Syria for the month of November (taken as an example) over an extended period of 11 years (1980-1990). Despite some deviation in the first three years of records, calculated and measured values reflect a very good agreement, where radiation method and the 3-method average were the closest to field-measured values.

Three testing cases for three locations in Europe are shown in Figure (7) through 9.

These include Montpellier, France; Rome, Italy; and Souda, Greece Table (6). The data used for these three locations are extended yearly averages obtained from climatological stations, reported in

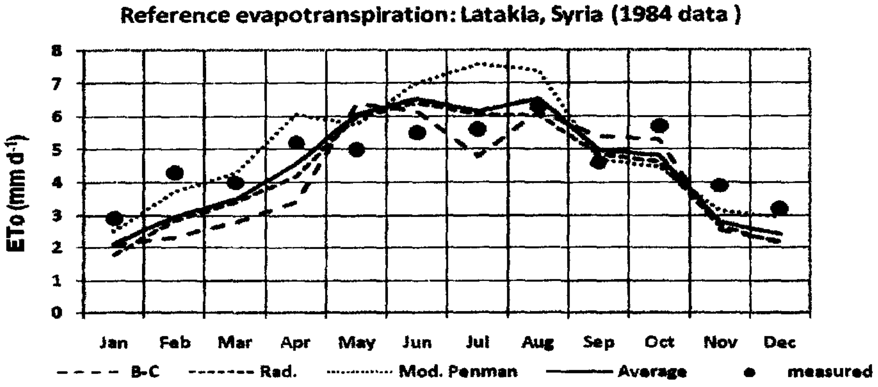


Fig. 5: Calculated reference evapotranspiration (ETo) in Latakia, Syria, compared with pan-measured values (data of 1984)

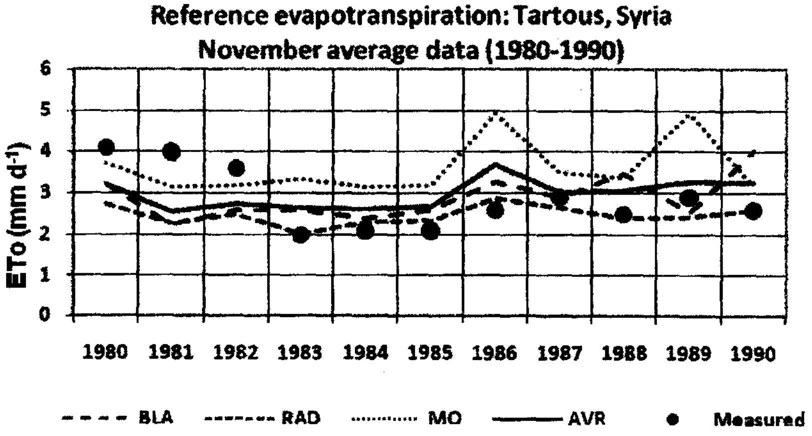


Fig. 6: Calculated and measured average reference evapotranspiration (ETo) for the month of November in Tartous, Syria over an extended period of 11-years (1980-1990)

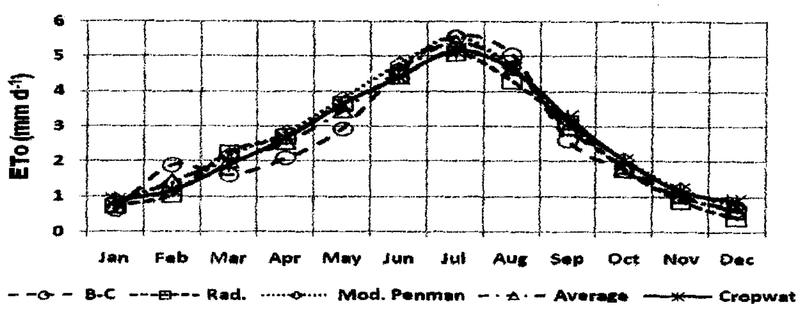


Fig. 7:Program results of ETo as compared with *Cropwat* results for Montpellier, France (extended yearly averages, *Climwat*, 2006)

the international climate database of *Climwat*, FAO (Gieser, 2006).

As seen in Figure.(7) through 9, results consistently showed very good agreement between program results and *Cropwat* calculations, indicating reasonable capability of the program to provide reliable estimates of reference evapotranspiration. It is notable that, here also, the best agreement with results produced by the *Cropwat* program were those of the all-method averages.

Similar performance consistency was seen when the program was applied to weather data obtained for the Americas. Results obtained by the program for many stations in North and South America were quite consistent and reflected reasonably good agreement with results calculated by the FAO's *Cropwat* or results of measured ETo. Two examples are shown in Figure (10) and 11 for locations of Sacramento, California, USA and Santa Isabel, Argentina (data of *Climwat*, Gieser, 2006). In Figure(10), program results for the weather Station in Sacramento executive airport, Sacramento, California Table (6) are compared with *Cropwat* calculations. Program results showed slightly higher values than those determined by *Cropwat*, however, a fairly good agreement with B-C and radiation methods is observed. It is important to note here that the B-C equation was originally developed for California climate, which may explain its relatively better performance for Sacramento area.

In Figure (11), data of the weather station in Santa Isabel, Argentina Table (6) were used and ETo was calculated and compared also with *Cropwat* results. Results were in very good agreement with *Cropwat* calculations, with slight divergence at the end of the year for the B-C and modified Penman methods. The radiation method as well as ETo averages showed, however, excellent convergence to *Cropwat* results over the entire year. The enhanced performance of the radiation method meets expectations for this region. It has been reported (Withers and Vipond, 1980) that the radiation equation provides more accurate estimates

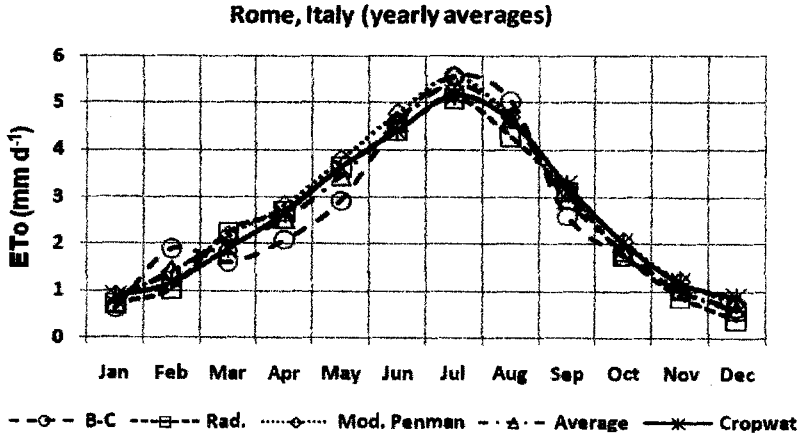


Fig. 8: Program results of ETo as compared with *Cropwat* results for Rome, Italy (extended yearly averages, *Climwat*, 2006)

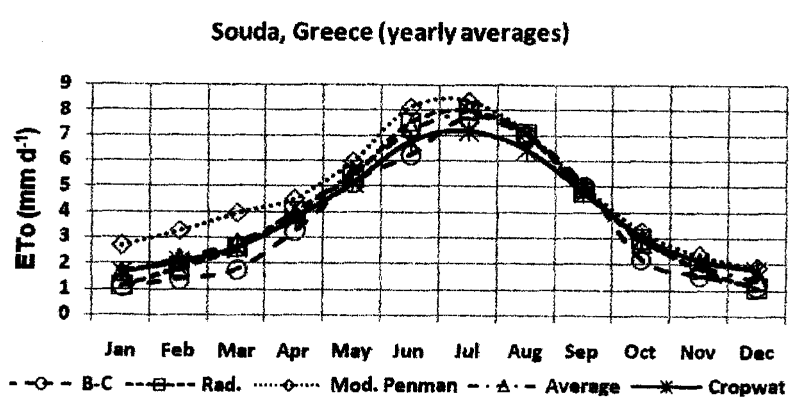


Fig. 9: Program results of ETo as compared with *Cropwat* results for Souda, Crete (Greece), (extended yearly averages, *Climwat*, 2006)

of evapotranspiration in zones of semiarid climates and higher altitudes. The location of Santa Isabel,. Argentina was selected as an example of regions in the southern hemisphere

Program validation for crop coefficient (kc) and actual crop evapotranspiration (ETc)

Extensive program testing was also performed to evaluate performance and result consistency of kc and ETc calculations. Most of the testing performed on kc and ETc was on crops grown in Egypt. Table 8 displays- as an example- the computer output file of ETo, kc and ETc for one of the test locations, ARS, Menya, Egypt, where the grown crop is cotton. In Fig. 12 through 14, results of calculated ETo, kc and ETc obtained for ARSs in Menya, Arish, and Siwa, Egypt are displayed. Climate and coordinate information of these locations are shown in Table (6)

Figure (12a) Shows results of ETo calculated by the program by the three methods for the research station in Menya (extended yearly averages) while Figure (12b) displays values of the crop coefficient (kc) of cotton grown in the area as calculated both by the program and by FAO's *Cropwat*. Figure (12c) displays the values of F ETo and ETc over the growing season (May through September). Only very slight discrepancies are seen between the three calculation methods as well as between each of the methods and their average (Fig. 12a). Crop coefficient (kc) showed typical trend over the four growth stages and the program determined values were in fairly good agreement with those calculated by *Cropwat* except for minor differences in the initial stage (kc1) and to a lesser extend during the crop development stage (kc2). Mid-season and late stage coefficients (kc3 and kc4, respectively) showed very good agreement with those estimated by *Cropwat*. Figure (12c) shows calculated values of ETo and ETc by the program and by *Cropwat* over the growing season. Excellent agreement can be seen both for ETo and ETc between the two programs. Figures (13 and 14) show kc, ETo, and ETc calculated by the program for Arish and Siwa, Egypt. A well defined kc curve is shown in both cases with distinct growth stages. Also, the relation between ETo, kc and ETc can easily be identified from the obtained results, where

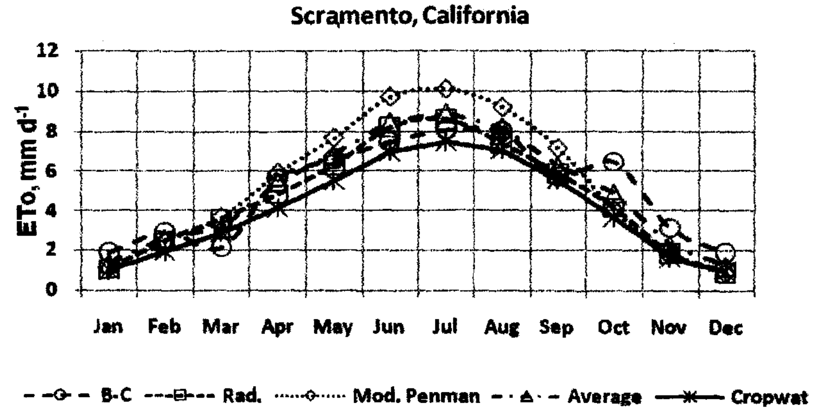


Fig. 10: Program results of ETo as compared with *Cropwat* results for Sacramento, California (extended yearly averages, *Climwat*, 2006)

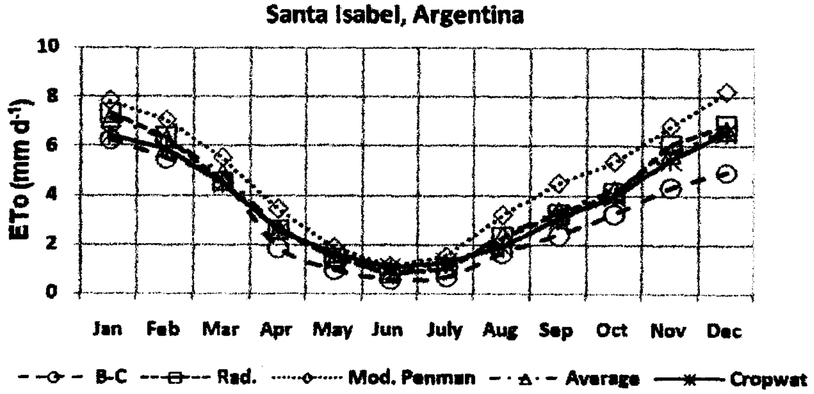


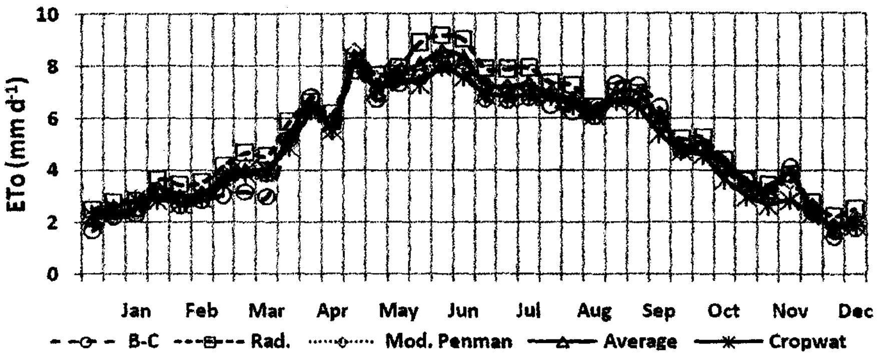
Fig. 11: Program results of ETo as compared with *Cropwat* results for Santa Isabel, Argentina, (extended yearly averages, *Climwat*, 2006)

Table 8: Result table generated by the program, including average reference evapotranspiration (ETo), crop coefficient (kc) and crop evapotranspiration (ETc) for cotton grown in Menya, Egypt (data of 1998)

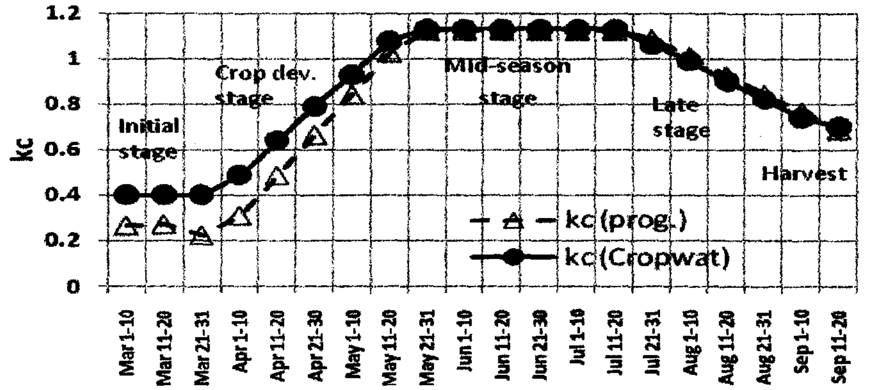
Run	Month	length	Mid-point	Avg. ETo	kc	ETc	Remarks
1	Jan 1-10	10	-	2.102	-	-	Pre season
2	Jan 11-20	10	-	2.408	-	-	Pre season
3	Jan 21-31	11	-	2.508	-	-	Pre season
4	Feb 1-10	10	-	3.306	-	-	Pre season
5	Feb 11-20	10	-	3.005	-	-	Pre season
6	Feb 21-28	8	-	3.132	-	-	Pre season
7	Mar 1-10	10	-	3.685	-	-	Pre season
8	Mar 11-20	10	5	4.001	0.267	1.067	Initial stage
9	Mar 21-31	11	15.5	3.843	0.272	1.046	Initial stage
10	Apr 1-10	10	26	5.379	0.224	1.206	Initial stage
11	Apr 11-20	10	36	6.607	0.312	2.064	Crop develop. st.
12	Apr 21-30	10	46	5.857	0.489	2.864	Crop develop. st.
13	May 1-10	10	56	8.197	0.666	5.457	Crop develop. st.
14	May 11-20	10	66	7.307	0.842	6.156	Crop develop. st.
15	May 21-31	11	76.5	7.754	1.028	7.969	Crop develop. st.
16	Jun 1-10	10	87	8.119	1.125	9.134	Mid-season stage
17	Jun 11-20	10	97	8.586	1.125	9.659	Mid-season stage
18	Jun 21-30	10	107	8.338	1.125	9.38	Mid-season stage
19	Jul 1-10	10	117	7.324	1.125	8.24	Mid-season stage
20	Jul 11-20	10	127	7.253	1.125	8.16	Mid-season stage
21	Jul 21-31	11	137.5	7.324	1.125	8.24	Mid-season stage
22	Aug 1-10	10	148	6.959	1.086	7.558	Late stage
23	Aug 11-20	10	158	6.758	1.008	6.813	Late stage
24	Aug 21-31	11	168.5	6.31	0.926	5.846	Late stage
25	Sep 1-10	10	179	7.033	0.845	5.941	Late stage
26	Sep 11-20	10	189	7.002	0.767	5.369	Late stage
27	Sep 21-30	10	199	6.075	0.689	4.185	Late stage
28	Oct 1-10	10	-	4.933	-	-	Post season
29	Oct 11-20	10	-	5.041	-	-	Post season
30	Oct 21-31	11	-	4.232	-	-	Post season
31	Nov 1-10	10	-	3.513	-	-	Post season
32	Nov 11-20	10	-	3.193	-	-	Post season
33	Nov 21-30	10	-	3.853	-	-	Post season
34	Dec 1-10	10	-	2.579	-	-	Post season
35	Dec 11-20	10	-	1.833	-	-	Post season
36	Dec 21-31	11	-	2.13	-	-	Post season

Length of initial stage = 31 days
Length of crop development stage = 51 days
Length of mid-season stage = 61 days
Length of late stage = 61 days
Total length of the growing season = 204 days
Cumulative seasonal ETc = 1186.647 mm
Mean daily water consumptive use = 5.817 mm/day
Peak ETc value during the growing season = 9.659 mm/day
measured for run no.: 17
during the month of : June
at days from planting = 97 days
or at approximately 47.55 % of total growing season length

a- Reference evapotranspiration (ETo): Menya (1998 data)



b. Crop coefficient (kc) for cotton grown in Menya (1998 data)



c. Reference and crop evapotranspiration over growing season (Menya, Cotton 1998 data)

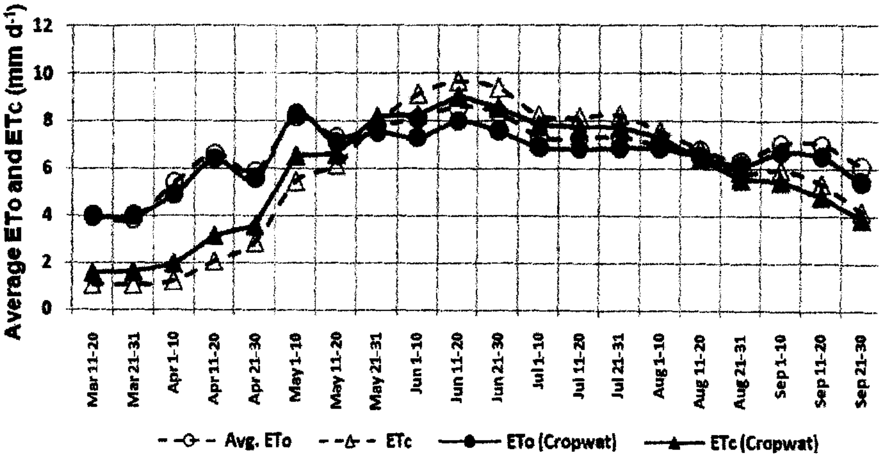


Fig. 12: Results calculated by the program for: a) reference evapotranspiration (ETo) in Menya, Egypt, b) crop coefficient (kc) for cotton grown in the area and c) reference evapotranspiration (ETo) and crop evapotranspiration (ETc) of the crop during the growing season (March through September)

in early growth stage (the initial stage) differences between ETo and ETc are greatest due to small kc values (smallest kc value of the season). During the crop development stage and as kc increases gradually towards its maximum seasonal value, actual crop evapotranspiration approaches the reference evapotranspiration until they become nearly equal during the mid–season stage. At the end of the mid-season stage the two curves split once again and their differences increase during the late stage as the crop coefficient kc decreases gradually again approaching its harvest value. These trends are clearly seen in results of both regions as with Menya results discussed above Figures (13 and 14) show kc, ETo, and ETc calculated by the program for Arish and Siwa, Egypt. A well defined kc curve is shown in both cases with distinct growth stages. Also, the relation between ETo, kc and ETc can easily be identified from the obtained results, where in early growth stage (the initial stage) differences between ETo and ETc are greatest due to small kc values (smallest kc value of the season). During the crop development stage and as kc increases gradually towards its maximum seasonal value, actual crop evapotranspiration approaches the reference evapotranspiration until they become nearly equal during the mid–season stage. At the end of the mid-season stage the two curves split.once again and their differences increase during the late stage as the crop coefficient kc decreases gradually again approaching its harvest value. These trends are clearly seen in results of both regions as with Menya results discussed above

The above discussion of program validation and testing indicates that the program functions appropriately and consistently and that it is capable of providing fairly reliable estimates of reference and crop evapotranspiration under different conditions and in various locations. As discussed earlier, the program requires a rather limited number of routinely determined weather parameters, and yet is capable of providing accurate results that are quite comparable with those determined through other globally accepted– often more complex- programs as well as with field measured values. This represents a principal advantage and renders the program handy and versatile and makes it suitable for use by scientists as well as by growers.

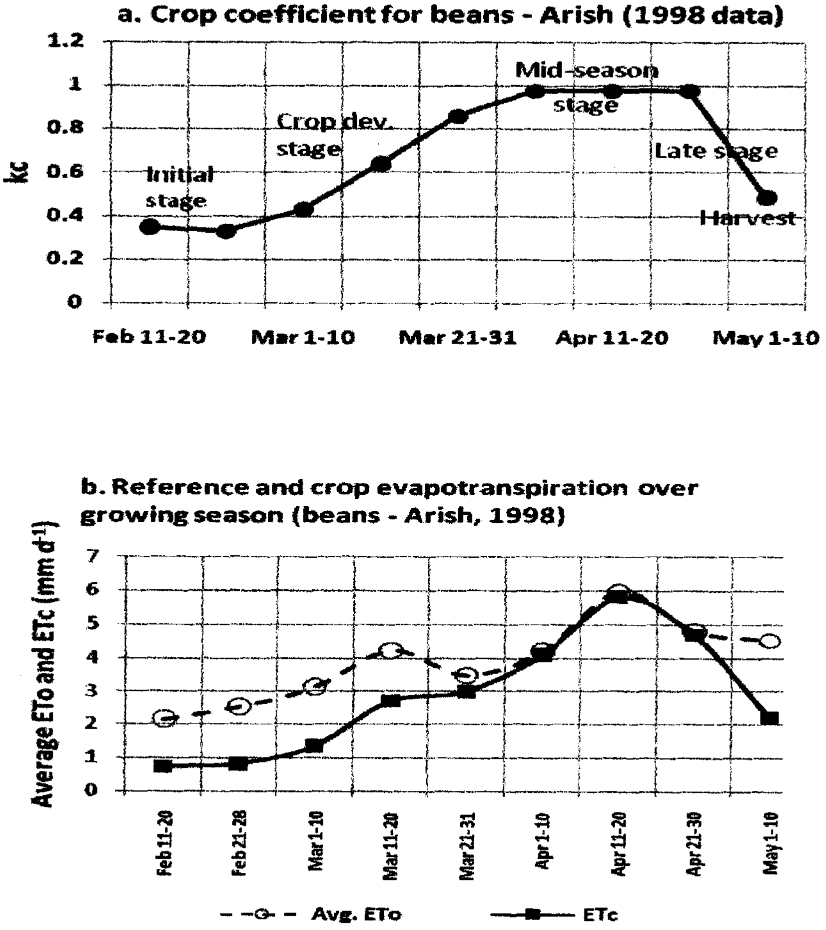


Fig. 13: Program results for beans grown in Arish, Egypt showing: a) crop coefficient (kc) and b) the relation between reference evapotranspiration (ETo) and crop evapotranspiration (ETc) over the growing season

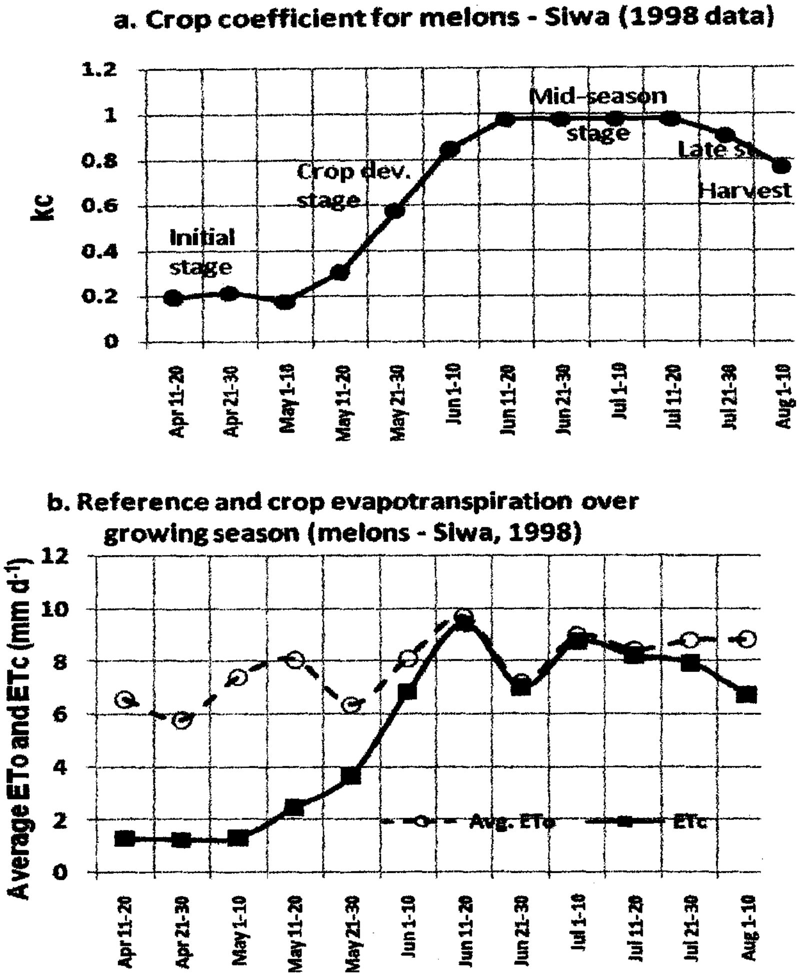


Fig. 14: Program results for melons grown in Siwa, Egypt showing: a) crop coefficient (kc) and b) the relation between reference evapotranspiration (ETo) and crop evapotranspiration (ETc) over the growing season

SUMMARY AND CONCLUSION

The compiled program was intended to provide a suitable tool for prediction of reference evapotranspiration (ETo), crop coefficient (kc) and actual crop evapotranspiration (ETc) for many crops by three methods, using basic, routinely available weather data. The program showed good overall consistency, reproducibility, and accuracy. Validation through extensive testing, using data of different locations over various parts of the world and through matching results with those obtained by the FAO's *Cropwat* or field measurements indicated reasonable dependability. Tests proved that the program is capable of predicting reliable values of ETo, kc and ETc, where very comparable results were consistently obtained. Due to its simplicity, it is believed that this program could represent a very convenient tool for regular use by growers as well as in scientific applications.

ACKNOWLEDGEMENTS

The author wishes to express his appreciation to Prof. A. El-Khudr, Tishreen University, Latakia, Syria and Eng. Y. Hanafy, Ministry of Agriculture, Egypt, for providing data of local measurements for Latakia and Tartous (Syria), and Bustan (Egypt). Providing these data was quite helpful in the process of program testing
g and validation.

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الملخص العربي

برنامج حاسب آلي للحساب المتزامن للبخر- نتح القياسي وبخر- نتح المحصول بثلاث طرق

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تمت صياغة برنامج حاسب آلي software لحساب البخر-نتح القياسي (ETo)، ومعامل المحصول (kc)، وبخر-نتح المحصول (ETc) تحت ظروف المناطق والمناخ المختلفة. يتطلب البرنامج، كمدخلات، بيانات مناخية أساسية (درجة الحرارة، الرطوبة النسبية، سرعة الرياح، وبيانات ساعات السطوع الشمسي) وهي بيانات تتاح عادة بشكل روتيني في أغلب المحطات البحثية الزراعية والمحطات المناخية. يقوم البرنامج بإجراء حساب متزامن للبخر-نتح القياسي بثلاث طرق مختلفة (معادلة بلاني-كريدل Blaney-Criddle، طريقة الإشعاع radiation، ومعادلة بنمان المعدلة modified Penman method). يقوم البرنامج بعرض النتائج على الشاشة وكذلك إرسالها إلى ملفات مستقلة بحيث يمكن تحويلها بسهولة إلى منحنيات ورسوم بيانية. ويتضمن البرنامج قاعدة بيانات كبيرة تشمل المتغيرات المناخية على مستوى الكرة الأرضية التي يحتاجها البرنامج لإجراء الحسابات مثل توزيع الإشعاع الشمسي الخارجي، وعدد ساعات السطوع القصوى الممكنة للمناطق الجغرافية المختلفة، إضافة لمعلومات أخرى كثيرة وكذلك كل العلاقات الرياضية والمعادلات اللازمة. تحتوي قاعدة البيانات كذلك على البيانات المحصولية اللازمة لحساب معامل المحصول (kc) وبخر-نتح المحصول (ETc) كأطوال مواسم النمو، وأطوال مراحل النمو المختلفة لعدد كبير من المحاصيل. وقد تم تصميم البرنامج بحيث يتم إدخال معظم البيانات المطلوبة في جدول واحد لسهولة الاستخدام وبحيث تكون المدخلات الأخرى line-inputs محدودة للغاية. وقد أوضحت عمليات الاختبار والتقييم المكثفة للبرنامج تحت ظروف مختلفة أداء ثابتا جدا، ودقيقا، وبينت أن البرنامج يمكنه إعطاء تقديرات دقيقة لكل من البخر-نتح القياسي (ETo)، ومعامل المحصول (kc)، وبخر-نتح المحصول (ETc) للعديدمن المحاصيل. ويمثل هذا البرنامج أداة عملية مناسبة للاستخدام سواء بواسطة القائمين علي عمليات الزراعة والري أو في التطبيقات العلمية ذات الصلة.