

IN THE NAME OF ALLAH

ESTIMATION OF REFERENCE CROP POTENTIAL
EVAPOTRANSPIRATION AND ISO-ET₀ MAPS FOR IRAN

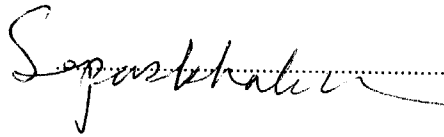
BY
AMINOLLAH SEYYED AZIZI

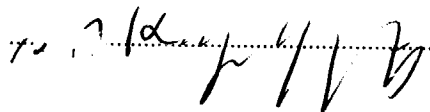
THESIS

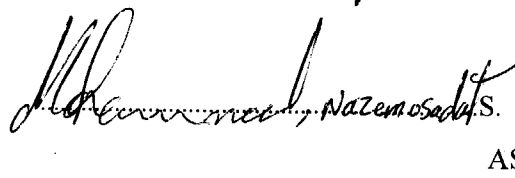
SUBMITTED TO THE SCHOOL OF GRADUATE STUDIES IN
PARTIAL FULLFILMENT OF THE REQUIREMENTS FOR THE
DEGREE OF MASTER OF SCIENCE (M.Sc.)

IN
IRRIGATION AND DRAINAGE
SHIRAZ UNIVERSITY
SHIRAZ, IRAN

EVALUATED AND APPROVED BY THE THESIS COMMITTEE AS: **EXCELLENT**

 A. R. SEPASKHAH, Ph. D., PROF. OF
IRRIGATION (CHAIRMAN)

 A. A. KAMGAR HAGHIGHI, Ph. D.,
ASSOCIATE PROF. OF IRRIGATION

 S. J. NAZEMOSADAT, Ph.D.,
ASSISTANT PROF. OF IRRIGATION

JANUARY 1999

۱۵/۱۵۲

To:

**My Kind Parents,
brothers and sisters.**

१०/०५

Acknowledgement

“The best and the most thanks is special for Allah ”

The author would most sincerely like to thank his major Professor Dr. A. R. Sepaskhah, Professor of Irrigation for his guidance and valuable suggestions throughout the course of this study, preparation of manuscript, and final editing of this thesis.

He also wishes to express his gratitude to the members of the graduate committee, Dr. A. A. Kamgar Haghighi, Associate Professor of Irrigation and Dr. S. J. Nazemosadat, Assistant Professor of Irrigation, for their useful suggestions in writing the manuscript.

Special thanks are expressed to my kind parents, sisters and brothers for their patience and encouragement during the study period.

Abstract

Estimation of Reference Crop Potential Evapotranspiration and Iso-ET₀ Maps for Iran

By

Aminollah Seyyed-Azizi

The increase in world population and the demand for greater food production have placed a heavy burden on arid countries where food production is limited because of climate, environment and technological factors. Management practices for water conservation have been increasingly emphasized because of sparse natural precipitation, high evapotranspiration and excessive depletion of limited groundwater resources. Thus, practical methods for determination of evapotranspiration are essential for optimal utilization of water, especially in irrigation which normally demands the largest share of the available water resources (Alshalan et al., 1987).

There are several empirical methods to estimate ET₀, but still measurement of ET₀ by different types of the lysimeter, gives the most accurate value for it. Several combination methods such as Penman and Penman-Monteith have been presented and are being used all over the world, but it should be noted that some empirical and local

coefficients are used in these equations, which should be calculated for each region (Jensen et al., 1990). Penman and Penman-Monteith methods consist of two major terms: radiation and aerodynamic. In different parts of the world, it has been tried to find the regional coefficients for these two terms.

In the present research, in order to find a relation between solar radiation (R_s) and sunshine duration (n), i.e., in solar radiation equation, values of R_s/R_a and n/N for each month and for 10 stations throughout Iran were calculated. Using a simple linear regression model, R_s/R_a as dependent variable and n/N as independent variable, coefficients "a" and "b" were found for each station. Finally, a unique equation was derived for Iran, using radiation data of 10 stations in the country, as follows :

$$R_s = (0.325 + 0.59n/N) R_a$$

$$R^2 = 0.59$$

$$\text{St. Err} = 0.06$$

$$\text{Obs.} = 490$$

To find the day-night wind speed ratio for 15 stations in different regions of Iran, firstly their average day time and night time wind speeds (U_d and U_n , respectively) were calculated and then U_d/U_n ratios were obtained for each day and station, using daily data. Finally, averaging these daily ratios for each station, the annual mean values of U_d/U_n for several regions of Iran were calculated. Results indicated that this ratio was higher for the coastal regions, comparing with the other regions. For example, this ratio for Ramsar, Bandar-Abbas and Oroomieh, which are coastal cities, was considerably more than for the

other inland regions. Also, these results showed that this ratio was less for the western regions, comparing with the eastern parts of Iran, and it may be a result of seasonal winds, higher difference between mean monthly maximum and minimum air temperatures, special climatic condition and airmass replacements in these regions.

The ET₀41 computer program, which was developed by Zand-parsa and Sepaskhah (1996) was used in this research and was modified for solar radiation and U_d/U_n ratio. Using ET₀41 computer program, it is possible to calculate ET₀ by FAO Blaney-Criddle, Hargreaves-Samani, Jensen-Haise, FAO corrected Penman and Penman-Monteith methods. In this program, using the information of mean monthly maximum relative humidity, mean monthly relative humidity, mean monthly temperature, mean monthly maximum temperature, wind speed at 2m height, sunshine hours, ratio of U_d/U_n and the elevation of the station from sea level, for each month of each year, the mean monthly and annual values of ET₀ by the five mentioned methods were calculated. In order to plot the iso-ET₀ line maps for Iran, the Surfer and Autocad 14 softwares were used, and the plots of iso-ET₀ lines for mean monthly and annual values were presented.

In the present research, the results of the FAO-Penman and Penman-Monteith methods were used to develop new equations, similar to the Hargreaves-Samani equation (HS) in two different forms. To modify the HS equation, non-linear multiple regression was used. In this regression the results of the FAO-Penman and Penman-Monteith methods, separately, were used as dependent variables and extra-terrestrial radiation, difference between mean monthly maximum and minimum air temperatures and mean monthly

air temperature as independent variables (form 1) and extra-terrestrial radiation, altitude of the station and mean monthly air temperature as independent variables (form 2). Therefore, four equations were developed, as follows:

$$ET_0 1_{FAO-Penman} = EXP(-6.47)Ra^{0.95}TD^{0.2}(T+25)^{1.36}$$

$$R^2=0.87$$

$$ET_0 2_{FAO-Penman} = EXP(-6.72)Ra^{0.88}(EL+25)^{0.04}(T+25)^{1.56}$$

$$R^2= 0.87$$

$$ET_0 1_{Penman-Monteith} = EXP(-7.53)Ra^{0.97}TD^{0.24}(T+25)^{1.6}$$

$$R^2=0.86$$

$$ET_0 2_{Penman-Monteith} = EXP(-7.88)Ra^{0.86}(EL+25)^{0.05}(T+25)^{1.82}$$

$$R^2=0.86$$

The mean annual ET_0 from the several mentioned methods of estimation was plotted and compared with Penman-FAO method. Results showed that in the regions with low annual ET_0 (<1400 mm/year), FAO Blaney-Criddle method has estimated the largest values and Jensen-Haise method has estimated the lowest values. In the regions with the intermediate ET_0 (1400-2000 mm/year), Jensen-Haise method estimated the largest ET_0 and the Hargreaves-Samani method estimated the least. Penman-Monteith method estimated the closest value to that of Penman-FAO, although less than it.

Table of Contents

Content	Page
List of Tables	XI
List of Figures	XVII
Chapter 1. Introduction	1
Chapter 2. Review of Literature	5
Chapter 3. Theory	16
3-1- FAO Blaney-Criddle Method	16
3-2- Penman Method	19
3-2-1 Recommended Relationships	21
3-2-2 Additional Considerations	22
3-2-3 Description of Variables and Their Method of Estimation	23
3-2-3-1 Vapor Pressure Deficit (ea-ed)	23
3-2-3-2 Wind Function f(U)	29
3-2-3-3 Weighting Factor (1-W)	31
3-2-3-4 Weighting Factor (W)	31
3-2-3-5 Net Radiation	33
3-2-3-6 Adjustment Factor (c)	38
3-3 Jensen-Hais Method	42
3-4 The FAO Penman-Monteith Method	43
3-5 Hargreaves-Samani Method	46

Content	Page
Chapter 4. Materials and Methods	48
4-1 Radiation	48
4-2 Wind	49
4-3 Vapor Pressure	52
4-4 ETo41 Computer Program	53
4-5 Meteorological Data	53
4-6 Mean ETo Based on Different Statistical Periods	56
4-7 ETo Estimation	57
4-8 Iso-ETo Line Maps for Iran	57
4-9 Modification of Hargreaves-Samani Equation for Mean Monthly ETo Estimation	58
Chapter 5. Results and Discussion	
5-1 Radiation	59
5-2 Wind	63
5-3 ETo Estimation	64
5-4 Mean ETo Based on Different Statistical Periods	66
5-5 ETo Estimation by Original and Local Solar Radiation Equation and Wind Ratio	66
5-6 Comparison of ETo from Different Methods	69
5-7 Modified Hargreaves-Samani Equation for Mean Monthly ETo Estimation	69
Chapter 6. Conclusions	164
Appendices	

Content

Page

References

Title Page and Persian Abstract

List of Tables

Table		Page
3-1	Mean daily percentage (p) of annual day-time hours for different latitudes.	20
3-2	Saturation vapor pressure (e_a) in mbar as function of mean air temperature (T) °C.	24
3-3	Vapor pressure (e_d) in mbar from dry and wet bulb temperature data in °C (Aspirated psychrometer).	25
3-4	Vapor pressure (e_d) in mbar from dry and wet bulb temperature data in °C (Aspirated psychrometer).	26
3-5	Vapor pressure (e_d) in mbar from dry and wet bulb temperature data in °C (Non-ventilated psychrometer).	27
3-6	Vapor pressure (e_d) in mbar from dry and wet bulb temperature data in °C (Non-ventilated psychrometer).	28
3-7	Values of wind function $f(U)$ for wind run at 2m height in km/day.	30
3-8	Values of weighting factor (W) for the effect of radiation at E_{To} at different temperatures and altitudes.	32

Table	Page
3-10 Mean daily duration of maximum possible sunshine hours (N) for different months and latitudes.	37
3-11 Effect of vapor pressure $f(e_a)$ on longwave radiation.	39
3-12 Effect of the ratio of actual and maximum bright sunshine hours $f(n/N)$ on longwave radiation.	39
3-13 Effect of temperature $f(T)$ on longwave radiation.	40
3-14 Adjustment factor (c) in presented Penman equation.	41
4-1 Stations which their solar radiation data are available.	48
4-2 Position and elevation of the meteorological stations, which are used to estimate U_d/U_n ratio.	49
4-3 Position, elevation and data years of the meteorological stations.	54
5-1 Results of linear regression of solar radiation for different stations.	59
5-2 Statistical comparison of the regional solar equation.	60
5-3 U_d/U_n ratio for 15 stations in Iran.	63
5-4 Annual mean ETo for several stations in Iran by different methods.	67
5-5 Mean monthly ETo by different methods for Abadan.	73
5-6 Mean monthly ETo by different methods for Ahwaz.	73
5-7 Mean monthly ETo by different methods for Arak.	74
5-8 Mean monthly ETo by different methods for Babolsar.	74

Table	Page
5-9 Mean monthly ETo by different methods for Badjgah.	75
5-10 Mean monthly ETo by different methods for Bam.	75
5-11 Mean monthly ETo by different methods for Bandar- Abbas.	76
5-12 Mean monthly ETo by different methods for Bandar- Anzali.	76
5-13 Mean monthly ETo by different methods for Birjand.	77
5-14 Mean monthly ETo by different methods for Bushehr.	77
5-15 Mean monthly ETo by different methods for Chahbahar.	78
5-16 Mean monthly ETo by different methods for Dezful.	78
5-17 Mean monthly ETo by different methods for Fassa.	79
5-18 Mean monthly ETo by different methods for Hamedan.	79
5-19 Mean monthly ETo by different methods for Iranshahr.	80
5-20 Mean monthly ETo by different methods for Isfahan.	80
5-21 Mean monthly ETo by different methods for Kashan.	81
5-22 Mean monthly ETo by different methods for Kerman.	81
5-23 Mean monthly ETo by different methods for Kermanshah.	82
5-24 Mean monthly ETo by different methods for Khorrarnabad.	82
5-25 Mean monthly ETo by different methods for Khoy.	83

Table	Page
5-26 Mean monthly ETo by different methods for Mashhad.	83
5-27 Mean monthly ETo by different methods for Oroomieh.	84
5-28 Mean monthly ETo by different methods for Ramsar.	84
5-29 Mean monthly ETo by different methods for Rasht.	85
5-30 Mean monthly ETo by different methods for Sabzevar.	85
5-31 Mean monthly ETo by different methods for Saghez.	86
5-32 Mean monthly ETo by different methods for Sanandag.	86
5-33 Mean monthly ETo by different methods for Semnan.	87
5-34 Mean monthly ETo by different methods for Shahrkord.	87
5-35 Mean monthly ETo by different methods for Shahrood.	88
5-36 Mean monthly ETo by different methods for Shiraz.	88
5-37 Mean monthly ETo by different methods for Tabas.	89
5-38 Mean monthly ETo by different methods for Tabriz.	89
5-39 Mean monthly ETo by different methods for Tehran.	90
5-40 Mean monthly ETo by different methods for Torbat Heydarieh.	90
5-41 Mean monthly ETo by different methods for Yazd.	91
5-42 Mean monthly ETo by different methods for Zabol.	91
5-43 Mean monthly ETo by different methods for Zahedan.	92

Table	Page
5-44 Mean monthly ETo by different methods for Zanjan.	92
5-45 Sensitivity analysisi of different statistical periods for calculating mean ETo (Bushehr).	132
5-46 Sensitivity analysisi of different statistical periods for calculating mean ETo (Isfahan).	135
5-47 Sensitivity analysisi of different statistical periods for calculating mean ETo (Kermanshah).	
5-48 Sensitivity analysisi of different statistical periods for calculating mean ETo (Mashhad).	141
5-49 Sensitivity analysisi of different statistical periods for calculating mean ETo (Ramsar).	144
5-50 Average of differences between corrected and not corrected ETo in each month in Ahwaz.	147
5-51 Average of differences between corrected and not corrected ETo in each month in Bandar Anzali.	147
5-52 Average of differences between corrected and not corrected ETo in each month in Babolsar.	148
5-53 Average of differences between corrected and not corrected ETo in each month in Bandar -Abbas.	148
5-54 Average of differences between corrected and not corrected ETo in each month in Bushehr.	149
5-55 Average of differences between corrected and not corrected ETo in each month in Chahbahar.	149
5-56 Average of differences between corrected and not corrected ETo in each month in Isfahan.	150