Reference Crop Evapotranspiration From Temperature

Article · January 1985

DOI: 10.13031/2013.26773

Zohrab Samani
New Mexico State University

PAPER NO. 85-2517

REFERENCE CROP EVAPOTRANSPIRATION FROM AMBIENT AIR TEMPERATURE

by

George H. Hargreaves and Zohrab A. Samani
Research Engineers
International Irrigation Center
Logan, UT USA

For presentation at the 1985 Winter Meeting
AMERICAN SOCIETY OF AGRICULTURAL ENGINEERS

Hyatt Regency, Chicago IL
December 17-20, 1985

SUMMARY:

Measured lysimeter evapotranspiration of cool season grass is taken as an index of reference crop evapotranspiration (ETP). An equation is presented that estimates ETP from values of maximum and minimum temperature.

The equation is further simplified for special cases of El Salvador and Sri Lanka such that for El Salvador, by using only elevation and latitude and for Sri Lanka by using only the latitude the ETP can be estimated.

American Society of Agricultural Engineers

St. Joseph, MI 49085-9659

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George H. Hargreaves[1], Zohrab A. Samani[2]

Introduction

The crop water requirements are usually estimated by calculating a potential evapotranspiration (ETP) of a reference crop which can be either grass or alfalfa and then multiplying by a crop coefficient (K_c). Many equations have been developed to estimate the potential evapotranspiration of the reference crop. The main problems associated with most of these methods are the availability of the climatological data and the necessity for local calibration. In many developing countries, the climatological data are often incomplete and inaccurate. The objective at the International Irrigation Center is to develop simple and practical methods to estimate crop water requirement with minimum climatological data. A procedure based on almost universally available data is presented here and is recommended for general use. This procedure requires little or no local calibration and uses only measurements of maximum and minimum temperature.

Development of the Method

The method is based on the original Hargreaves equation (1975, 1982) which can be described as:

$$ETP = K_g \times R_s (T_c + 17.8) \quad (1)$$

in which ETP (potential evapotranspiration of grass) and R_s (solar radiation), are in the same units and TC° is mean temperature in degrees Celcius, and K_g is the calibration coefficient. Hargreaves

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[1]Director of Research, International Irrigation Center, Department of Agricultural and Irrigation Engineering, Utah State University, Logan, Utah, 84322.

[2]Research Engineer, International Irrigation Center.

and Samani (1982) presented an equation for estimating R_S from extraterrestrial radiation, R_A, and the measured temperature range. The equation is:

$$R_S = K_{RS} \times R_A \times TD^{0.5} \quad (2)$$

in which R_S and R_A are in the same units. K_{RS} is a calibration coefficient and TD is mean maximum minus mean minimum temperature. Combining equations (1) and (2) results in:

$$ETP = K_{ET} \times R_A \times TD^{0.5} (TC° + 17.8) \quad (3)$$

Eight years of data for Alta fescue grass evapotranspiration from the 29 m^2 weighing lysimeters at Davis, California were used to calibrate the values of K_{Et} in equation (3) giving:

$$ETP = 0.0023 \times R_A \times TD^{0.5} (TC° + 17.8) \quad (4)$$

in which ET_O and R_A are in the same units of equivalent water evaporation and TD is in C°.

Testing the Method

In order to evaluate the applicability of the new method for different parts of the world, the method was compared with other methods in Haiti, Bangladesh, Australia and the United States. In Haiti, equation (4) was compared with seven other methods (Hargreaves and Samani, 1985). The ratio of the estimated values of ETP to actual lysimeter measured data was equal to 0.94 with a standard deviation of 3.6 percent compared to an average ratio of 0.91 and standard deviation of 6.9 for all other methods. In Bangladesh, the average ratio of estimated values from equation (4) to the Penman equation for sixteen stations was equal to 1.02 with a standard deviation of 10.4 percent.

Figures 1,2, and 3 compare measured lysimeter data with

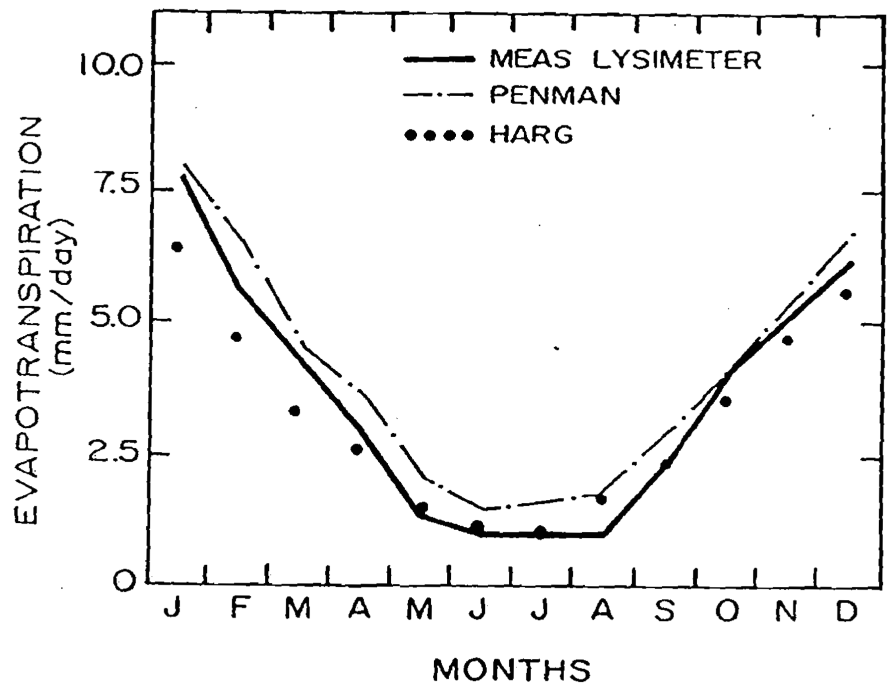

Figure 1. Measured and estimated potential evapotranspiration at Aspendale, Australia. (Fig. 7.1, Jensen)

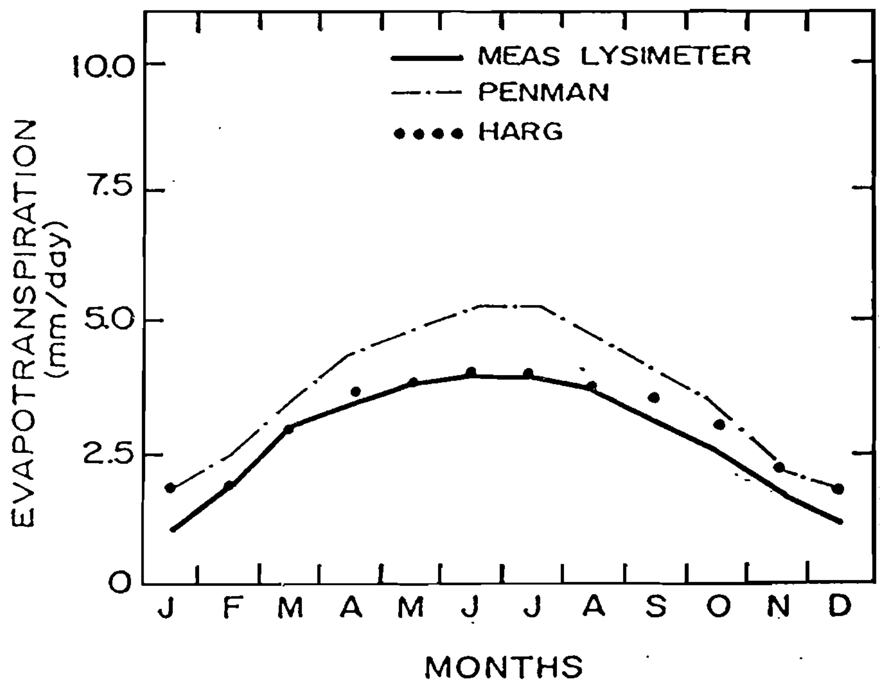

Figure 2. Measured and estimated potential evapotranspiration at Lompoc, California. (Fig. 7.31, Jensen)

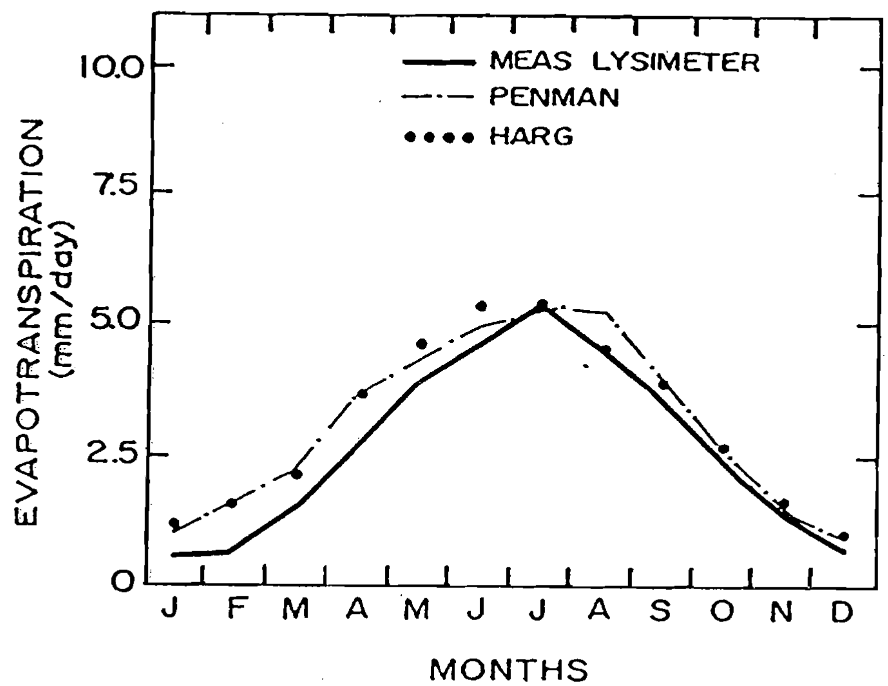

Figure 3. Measured and estimated potential evapotranspiration at Seabrook, New Jersey. (Fig. 7.31, Jensen)

estimated values from equation (4), and the modified Penman method (Jensen, 1974). The comparisons show that equation (4) can be used with reasonable accuracy to estimate the reference crop evapotranspiration. Considering the paucity of the climatological data in most parts of the world and the lack of knowledge and facilities to use more sophisticated methods in estimating ETP, the temperature method is recommended as a simple and practical method for estimating the reference crop evapotranspiration.

Further Simplification

In areas in which the values of maximum and minimum temperatures are relatively constant, equation (4) can be further simplified and shown as:

$$ETP = K_R \times R_A \qquad (5)$$

in which K_R is a coefficient that varies somewhat with rainfall and altitude. Hargreaves (1985) calculated the average weekly values of K_R for Mahaweli Project in Sri Lanka as follows:

K_R = 0.36 for weeks without rainfall
K_R = 0.33 for weeks with rainfall less than 50 mm
K_R = 0.29 for weeks with rainfall greater than 50 mm

The results from equation (5) were close enough to those from equation (4) such that equation (5) was quite satisfactory for irrigation scheduling and for evaluating the potential for rainfed agriculture.

A unique condition exists for the country of El Salvador in which maximum and minimum temperatures are strongly correlated to elevation (Figure 4). Combining equations described in figure (4) with equation (4) the resulting equation for ETP would be:

$$ETP = R_A \times [0.348 - 5 \times 10^{-5} \times Elev] \times (1 - 0.0002 \times Elev)^{0.5} \qquad (6)$$

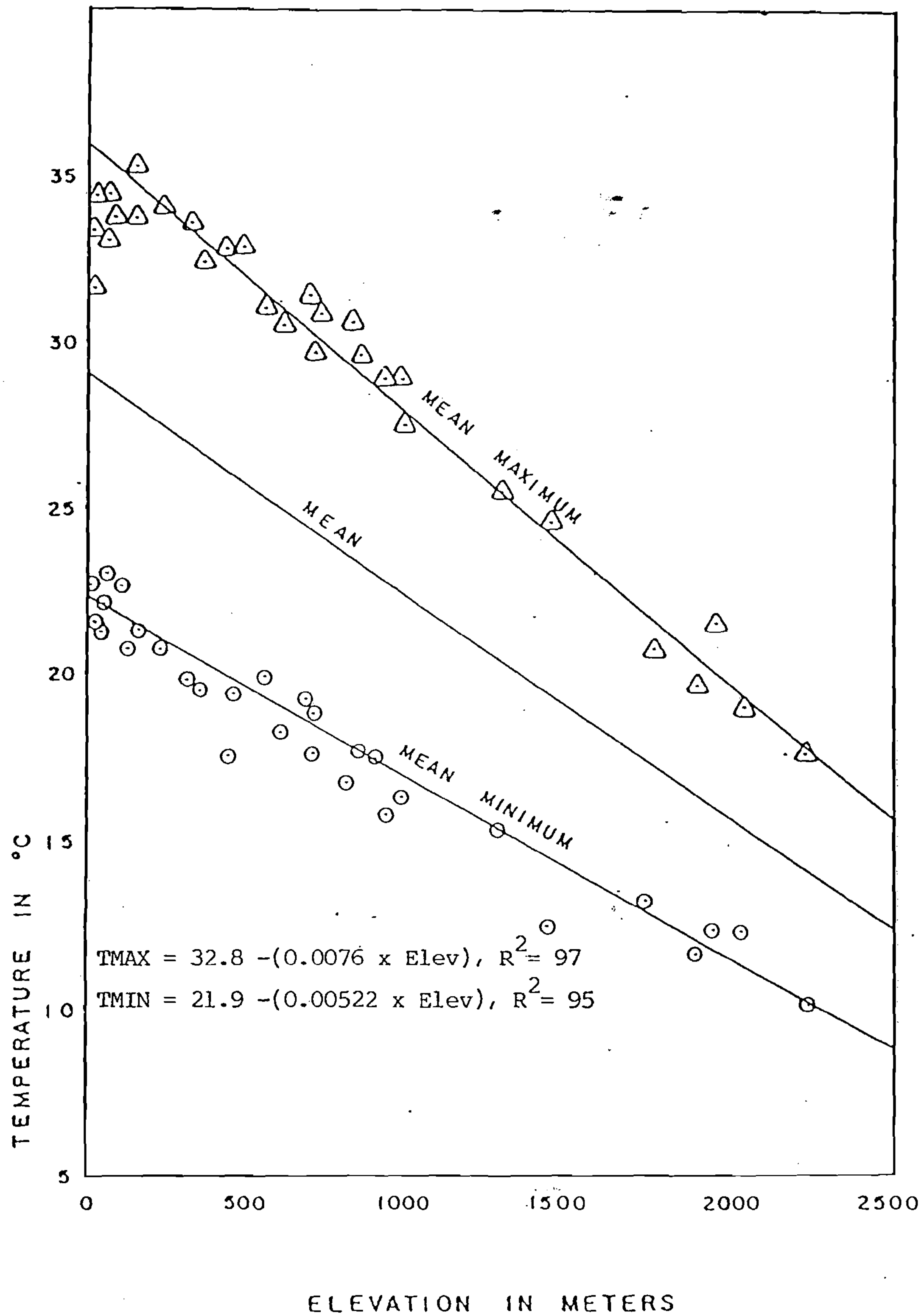

FIGURE I RELATIONSHIP BETWEEN ELEVATION AND TEMPERATURE FOR EL SALVADOR in which by knowing only the elevation, the crop water requirement can be estimated. For elevations close to zero, equation (6) can be simplified to:

$$ETP = 0.348 \times R_A \tag{7}$$

which is similar to the calibrated eqation for Sri Lanka.

Calculating R_A

The daily and monthly values of extraterrestrial radiation can be calculated by knowing the latitude of the station. The attached computer programs (Program I and Program II) describe the methods to calculate daily and monthly values of R_A.

Summary and Conclusion

A method for estimating reference crop evapotranspiration, ET_O from measured temperature alone is presented and compared with other methods of estimating ETP and with actual measured data. The estimated values of ETP from equation (4) presented herein compared favorably with those of other methods or lysimeter data.

A more simplified form of equation (4) is presented for areas of El Salvador and Sri Lanka. Considering the problems associated with the availability and reliability of climatological data in the world and the possible errors in the more sophisticated methods for estimating crop water requirements, the temperature method presented herein is recommended as the most simple and practical method for estimating reference crop evapotranspiration.

PROGRAM I

```
10 REM BASIC COMPUTER PROGRAM FOR ESTIMATING  DAILY RA VALUES
20 REM D=JULIAN DAY (JANUARY 1=1)
21 REM DEC=DECLINATION OF THE SUN IN RADIANS
30 REM ES=MEAN MONTHLY DISTANCE OF THE SUN TO THE EARTH DIVIDED BY THE MEAN ANNU
AL DISTANCE
40 REM LD=LATITUDES IN DEGREES
50 REM LDM=MINUTES OF LATITUDES
60 REM RA=MEAN MONTHLY EXTRATERRESTRIAL RADIATION IN MM/DAY
70 REM RAL=MEAN MONTHLY EXTRATERRESTRIAL RADIATION IN LANGLEYS/DAY
80 REM=MEAN DAILY TEMPERATURE IN DEGREE CELSIUS
100 REM PRINT THE HEADLINE
110 LPRINT "DAY","RA,MM/DAY"
120 INPUT "LATITUDE OF THE STATION IN DEGREE AND MINUTE ";LD,LDM
130 D=0
140 FOR I=1 TO 365
150 D=D+1
160 Y=COS(.0172142*(D+192))
170 DEC=.40876*Y
180 ES=1.00028+.03269*Y
190 XLR=(LDM/60+LD)/57.2958
200 Z=-TAN(XLR)*TAN(DEC)
230 OM=-ATN(Z/SQR(-Z*Z+1))+3.14159/2
250 REM CALCULATE THE DAILY EXTRATERRESTRIAL RADIATION IN LANGLEYS/DAY
255 DL=OM/.1309
260 RAL=120*(DL*SIN(XLR)*SIN(DEC)+7.639*COS(XLR)*COS(DEC)*SIN(OM))/ES
270 REM CALCULATE THE EXTRATERRESTRIAL RADIATION IN MM/DAY
280 RA=RAL*10/(595.9-.55*TC)
290 LPRINT I,RA
300 NEXT I
310 END
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PROGRAM II

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10 REM BASIC COMPUTER PROGRAM FOR ESTIMATING MONTHLY RA VALUES
20 REM DEC=DECLINATION OF THE SUN IN RADIANS
30 REM ES=MEAN MONTHLY DISTANCE OF THE SUN TO THE EARTH DIVIDED BY THE MEAN ANNU
AL DISTANCE
40 REM LD=LATITUDES IN DEGREES
50 REM LDM=MINUTES OF LATITUDES
60 REM RA=MEAN MONTHLY EXTRATERRESTRIAL RADIATION IN MM/DAY
70 REM RAL=MEAN MONTHLY EXTRATERRESTRIAL RADIATION IN LANGLEYS/DAY
80 REM TC=MEAN MONTHLY TEMPERATURE IN DEGREE CELSIUS
90 DIM DEC(12),ES(12)
100 REM PRINT THE HEADLINE
110 LPRINT "MONTH","RA,MM/DAY"
120 INPUT "LATITUDE OF THE STATION IN DEGREE AND MINUTE ";LD,LDM
130 FOR I=1 TO 12
140 A=3.14159265#/6
150 B=2*A
160 REM CALCULATE THE DECLINATION (ANGLE OF THE SUN) IN RADIANS
170 DEC(I)=-.00117-.40117*COS(A*I)-.042185*SIN(A*I)+.00163*COS(B*I)+.00208*SIN(B
*I)
180 REM CALCULATE THE RELATIVE DISTANCE OF THE SUN TO THE EARTH
190 ES(I)=1.00016-.032126*COS(A*I)-.0033535*SIN(A*I)
200 XLR=(LDM/60+LD)/57.2958
210 Z=-TAN(XLR)*TAN(DEC(I))
220 OM=-ATN(Z/SQR(-Z*Z+1))+3.14159/2
230 REM CALCULATE THE DAILY EXTRATERRESTRIAL RADIATION IN LANGLEYS/DAY
240 RAL=916.732*(OM*SIN(XLR)*SIN(DEC(I))+COS(XLR)*COS(DEC(I))*SIN(OM))/ES(I)
250 REM CALCULATE THE EXTRATERRESTRIAL RADIATION IN MM/DAY
260 RA=RAL*10/(595.9-.55*TC)
270 LPRINT I,RA
280 NEXT I
290 END
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