Kasetsart J. (Nat. Sci.) 30 : 392-399 (1996)

Monthly Potential Evapotranspiration of Thailand

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ABSTRACT

Monthly potential evapotranspiration was studied using 3 well-known methods of Penman-Monteith, Modified Penman and Pan Evaporation. Long term average climatological data from 74 climatological stations (30- year period) and 29 agroclimatological stations (25-year period) were used in the study.

ETo calculated by Penman-Monteith method was very similar to those calculated from Pan evaporation but was 18.5% lower than those calculated by Modified Penman method. Mean monthly ETo of Thailand varied between 101 mm in December to 148 mm in April. The average annual ETo was 1,434 mm. The minimum annual ETo was 1,200 mm at Umphang climatological station while the maximum 1,683 mm at Chainat climatological station.

Key words : potential evapotranspiration, reference crop evapotranspiration, Penman method.

INTRODUCTION

Potential evapotranspiration or reference crop evapotranspiration is defined as the rate of evapotranspiration from an extensive surface of 8 to 15 cm tall, green grass cover of uniform height, actively growing, completely shading the ground and not short of water (Doorenbos and Pruitt, 1984). Potential evapotranspiration is therefore depending on climatic conditions such as air temperature, solar radiation, relative humidity, wind velocity, sunshine hours, etc.

Potential evapotranspiration is the basic data for calculation of crop and project water requirements which is important parameters for irrigation planning and management. When potential evapotranspiration (ETo) is multiplied by crop coefficient (Kc), the crop evapotranspiration or crop consumptive use (ETc) is obtained. There are several methods for determining potential evapotranspiration including direct measurement from lysimeter, calculation from climatological data and calculation from pan evaporation data.

Although the potential evapotranspiration for any crop can be measured by lysimeter, this method is expensive and time consuming. The result is site specific, subjected to the climatic environment during the measurement, which may not be applicable to other areas with different climatic conditions. Therefore calculation from climatological data is a more popular method for irrigation planning and management purposes.

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There are several formulas including Thornthwaite, Blaney-Criddle, Makkink, Radiation, Hargreaves, Hargreaves-Samani, Turc, Priestley-Taylor, Penman, Modified Penman, Penman-Monteith and etc. Thornthwaite's formula is the most simple requiring only air temperature data, while Penman's formula is the most complicated requiring both radiation and aerodynamic parameters of climatological data. Among the above methods, Penman's is the most well-known method in Thailand. Boonyatharokul (1975) concluded from his calculation of monthly potential evapotranspiration of 19 provinces of Thailand that Penman's formula provided the best estimate. Doorenbos and Pruitt (1975) introduced Modified Penman formula and developed parameter tables to facilitate the calculation. Kirdpitugsa (1984) used the Modified Penman formula for calculation of monthly potential evapotranspiration of 49 climatological stations of Thailand using the average data of 25-year period (1951-1975). His calculated ETo has been used frequently until today for irrigation planning and managemant in Thailand. Although the long term average climatological data may not change drastically, Kirdpitugsa's monthly potential evapotranspiration data need to be revised.

In 1990, FAO expert recommended that the Modified Penman's formula (Doorenbos and Pruitt, 1975) be replaced by Penman-Monteith's (Smith 1993). Amatya *et al.* (1995) did the comparative study of 6 potential evapotranspiration formulas namely Penman-Monteith, Makkink, Priestley-Taylor, Turc, Hargreaves-Samani and Thornthwaite using climatological data from 3 stations in North Carolina. In the study, the Penman-Monteith's formula was selected as the standard method for comparison. The monthly potential evapotranspiration calculated by Penman-Monteith's method was about the average of those 5 methods. Vudhivanich (1996) calculated monthly potential evapotranspiration of 29 agroclimatological stations of Thailand (25-year period, 1969-1993) by Penman-Monteith and Modified Penman. He found that the monthly potential evapotranspiration calculated by Penman Monteith's formula were about 19% less than those by Modified Penman's. Similarly, Bos *et al.* (1996) reported that the potential evapotranspiration calculated by Penman-Monteith's formula was 18% less than those by Modified Penman's.

ETo can also be calculated from pan evaporation data using the following equation :

$$ETo = Kp*Epan \qquad (1)$$

where

ETo = monthly potential evapotranspiration
Epan = monthly pan evaporation
Kp = pan coefficient

Vudhivanich (1996) found that the mean monthly Kp of Thailand ranged between 0.785-0.915 as shown in Table 1 and the overall average Kp was 0.84, which was very similar to 0.85 from the study of Boonyatharokul (1975).

At present, Meteorological Department has 74 climatological stations and 29 agroclimatological stations throughout Thailand with long period of records. The objective of this study is to calculate monthly potential evapotranspiration of Thailand which can be used for irrigation planning and management purposes.

MATERIALS AND METHODS

Materials

1. 25-year period (1969-1993) agroclimatological data of Thailand (Meteorological Department, 1994a).
2. 30-year period (1961-1990) climatological data of Thailand (Meteorological Department, 1994b).
3. CROPWAT 5.5 computer program (Smith, 1989)

Methods

1. Develop computer programs for calculation of monthly potential evapotranspiration.
2. Calculate monthly potential evapotranspiration from agroclimatological data (25-year period, 1969-1993) and from climatological data (30-year period, 1961-1990) using program developed in (1).
3. Compare the monthly potential evapotranspiration calculated by Penman-Monteith, Modified Penman and those calculated from pan evaporation.
4. Group the agroclimatological and climatological stations indicating similar monthly potential evapotranspiration characteristics.

Penman-Monteith Formula

The following Penman-Monteith formula was used in the computer algorithm for calculation of monthly potential evapotranspiration:

$$ETo = \frac{\frac{\Delta}{\lambda}(Rn - G) + \gamma\left(\frac{AERCOEFF}{T + 273.16}\right)U_2\left(e_a - e_d\right)}{\Delta + \gamma\left(1 + \frac{CROPRES}{AERRES} \cdot U_2\right)} \quad (1)$$

where

ETo	=	Potential evapotranspiration (mm/day)
Rn	=	Net radiation at crop surface ($MJ/m^2/day$)
G	=	Soil heat flux ($MJ/m^2/day$)
T	=	Average air temperature (°C)
U_2	=	Windspeed measured at 2 m height (m/s)
e_a	=	Saturated vapor pressure (kPa)
e_d	=	Actual vapor preseure (kPa)
AERCOEFF	=	Aerodynamic coefficient
CROPRES	=	Crop resistance
AERRES	=	Aerodynamic resistance

$$Rn = Rns - Rnl \quad (2)$$

$$Rns = (1-\alpha)\left(0.25+0.5\frac{n}{N}\right) Ra \quad (3)$$

$$Rnl = 2.45 * 10^{-9} (0.34 - 0.139 \sqrt{ed}) (0.1 + 0.9 \frac{n}{N}) * 2 (T + 273.16)^4 \quad (4)$$

where

Rns = Net shortwave radiation ($MJ/m^2/day$)

Rnl = Net longwave radiation ($MJ/m^2/day$)

Ra = Extraterrestrial radiation ($MJ/m^2/day$)

n = Actual sunshine hour (h/day)

N = Maximum possible sunshine hour (h/day)

$\propto$ = Reflection coefficient ; use $\propto = 0.23$

$$G = 0.14 (Ti - Ti\text{-}1) \quad (5)$$

where

Ti = Mean air temperature for Month i (°C)

Ti-1 = Mean air temperature for Month i-1 (°C)

$$\Delta = \frac{2 * 2049 * e_a}{(T + 237.3)^2} \quad (6)$$

$$\lambda = 2.501 - 0.002361T \quad (7)$$

$$\gamma = 0.0016286 \frac{BPRES}{\lambda} \quad (8)$$

$$BPRES = 101.3 \left[\frac{293 - 0.0065\ ALT}{293}\right]^{5.256} \quad (9)$$

$$CROPRES = \frac{200}{0.24\ CROPHGT} \quad (10)$$

$$AERRES = \frac{\ln\left(\frac{WINDHGT - 0.667CROPHGT}{0.123CROPHGT}\right) * \ln\left(\frac{TEMPHGT - 0.667CROPHGT}{0.12CROPHGT}\right)}{(0.41)^2} \quad (11)$$

WINDHGT = 200 cm

TEMPHGT = 190 cm

CROPHGT = 12 cm (for grass as a reference crop)

$$AERCOEFF = \frac{0.622 * 3.486 * 86400}{1.01\ AERRES} \quad (12)$$

$$U_2 = COR * U_z \quad (13)$$

COR (Seetapan, 1992) = $1.158446\ z^{-0.19514}$ (14)

where

ALT = Altitude of the Area (m)

U_z = Windspeed measured at z m height (m/s)

In climatological data report, many stations did not record actual sunshine duration (n). Only data of cloudiness cover (value of 0-10) were recorded. Seetapan (1992) stowed the relationship between $\frac{n}{N}$ and cloudiness cover of Thailand in form of polynomial equation as follow :

$$\frac{n}{N} = 0.592+0.088\,C_c - 0.013\,C_c^2 \qquad (15)$$

where

C_c = Cloudiness cover

RESULTS AND DISCUSSIONS

The computer programs namely PENMAN-A and PENMAN-C were developed for calculation of monthly potential evapotranspiration by Penman-Monteith formula. The formula was shown in the equation 10 PENMAN-A program calculates monthly ETo based on monthly average of agroclimatological data, while PENMAN-C calculates monthly ETo from monthly average of climatological data. These two programs can transform wind speed from any measurement height to 2 m above the ground level by using equations 14 and 15. Since most of the 74 climatological stations did not have the actual sunshine duration record, the equation 15 was used for calculation of n/N from cloudiness cover in the PENMAN-C program.

From the 25-year period (1969-1993) average data of 29 agroclimatological stations and the 30-year period (1961-1990) average data of 79 climatological stations, the monthly ETo was calculated by program PENMAN-A and PENMAN-C respectively. The analysis of monthly and annual ETo of 103 stations indicated that the arithmetic mean of the annual ETo of Thailand was 1,434 mm. The minimum annual ETo was 1,200 mm/year at Umphang climatological station in Tak province, while the maximum annual ETo was 1,683 mm/year at Chainat climatological station. Mean monthly ETo ranged from 101 mm in December to 148 mm in April.

Since ETo of Thailand varies considerably from one station to the other, the calculated ETo values of 103 stations are categerized into 14 groups according to the range of annual ETo value and the distribution of monthly ETo. The graphs of monthly ETo of the 14 groups are shown in Figure 1. Figure 1(a) represents the smallest annual ETo group (between 1,200-1,250 mm/year). There are 3 stations including Umphang, Nan and Loei in North and Northeast of Thailand in this group. Figure 1(n) including Pilot Station in Samut Prakan, Ko Sichang (Chon Buri province) and Chainat shows the largest annual ETo group (between 1,600-1,700 mm/year). The distribution of monthly ETo in Figure 1(a)-1(n) shows similar characteristics. ETo increases from January to reach the peak in April and then decreases to the minimum value in December.

The overall mean, maximum and minimum values of the monthly ETo of 103 stations are shown in Figure 2. The maximum monthly ETo of 30 year period (1961-1990) was 184 mm occurring in April at Nakhon Sawan and Tak stations. The minimum monthly ETo was 71 mm occurring in December at Chiang Rai agroclimatological station. The overall mean monthly ETo of Thailand was 119.5 mm/month.

Although the Penman-Monteith's formaula is the FAO's recommended method for ETo calculation, the Modified Penman is still a well-known formula in Thailand because the Thai irrigation engineers have been using it for the last 17 years. In this study, the monthly ETo was also calculated by Modified Penman's formula using CROPWAT 5.5 porgram and data of all 103 stations. The values from both formulas showed that the average annual ETo calculated by Penman-Monteith method was 18.5% less than the ETo calculated by Modified Penman. The comparison is shown in Figure 3. This result was similar to the study of Bos *et al.* (1966) and Vudhivanich (1996) (when only data from 29 agroclimatological stations was used in the study).

When Penman-Monteith's monthly ETo of Mae Hong Son, Chiang Mai and Wichian Buri was compared with the monthly ETo calculated by multiplying pan evaporation data with Kp in Table 1, the results showed similar values as shown in Figure 4. This indicated that pan evaporation data could be used to estimate monthly ETo using Kp in Table 1. This conclusion is useful for a remote irrigation project without a climatological or agroclimatological station.

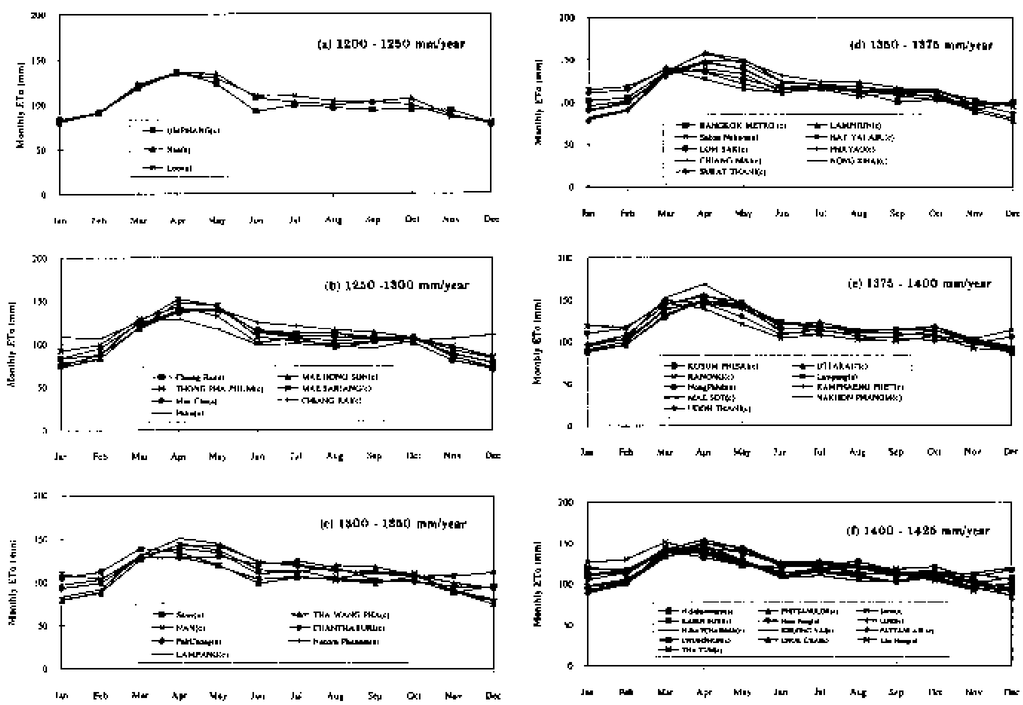

Figure 1 Monthly potential evapotranspiration of Thailand based on Penman-Monteith's formula. (a) = agroclimatological station (c) = climatological station.

Table 1 Mean monthly pan coefficient for Thailand.[1]

Monthly	Kp	Month	Kp	Month	Kp
Jan	0.795	May	0.845	Sep	0.905
Feb	0.785	Jun	0.860	Oct	0.915
Mar	0.795	Jul	0.865	Dec	0.860
Apr	0.800	Aug	0.885	Nov	0.810

[1] based on ETo calculated by Penman-Monteith's formula

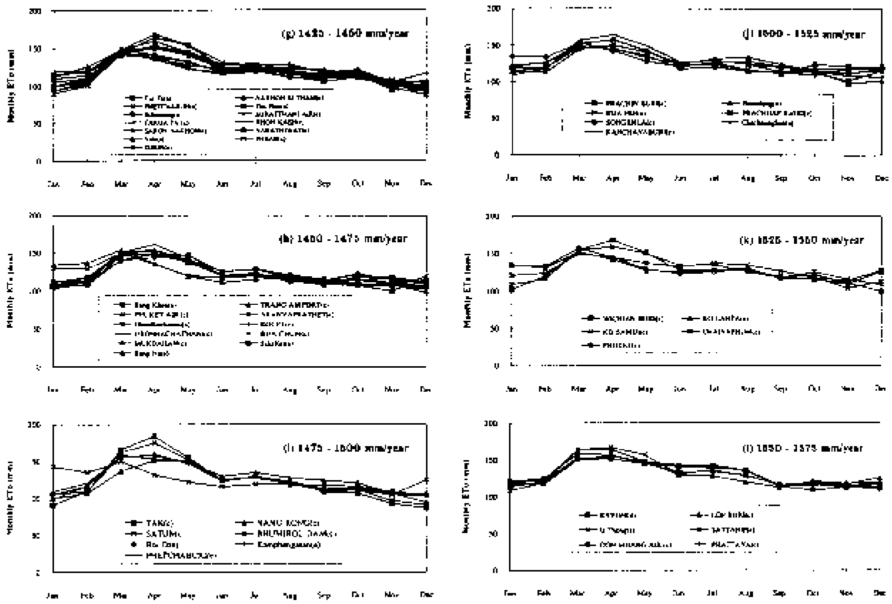

Figure 1(cont'd) Monthly potential evapotranspiration of Thailand based on Pemman-Monteith's formula.
(a) = agroclimatological station (c) = climatological station

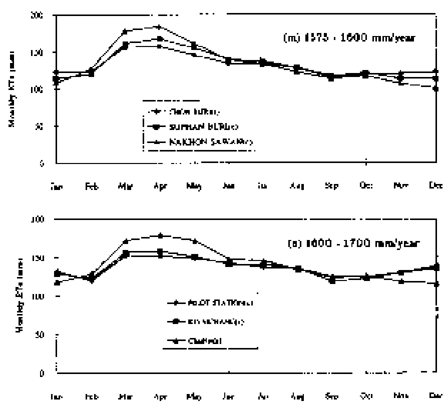

Figure 1 (cont'd) Monthly potential evapotranspiration of Thailand based on Pemman-Monteith's formula.

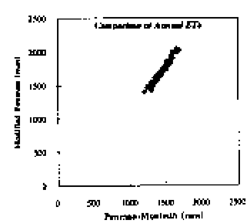

Figure 3 Comparison of annual ETo calculated by Penman-Monteith and Modified Penman formulas.

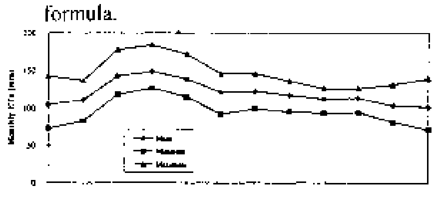

Figure 2 Overall mean, minimum and maximum monthly potential evapotranspiration of Thailand. (Pemman-Monteith's formula)

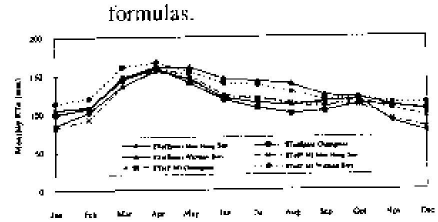

Figure 4 Comparison betwen ETo calulated by Penman-Monteith-Modified (P-M) and ETo calculated from Pan Evaporation (Epan) for 3 stations.

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