ESTIMATION OF REFERENCE EVAPOTRANSPIRATION BY THE APPLICATION OF FAO56 PM-METHOD IN ITOSHIMA AREA

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1. Introduction

This paper demonstrates how the reference evapotranspiration (ET_o) is determined from meteorological data, and presents study area, the necessary input data, and calculation results of ET_o with daily time step for seven years from 1996 until 2002, by means of FAO56-PM and computer programs. However, the present study was designed in order to be as a key factor in computing the regional and local water budget and also as a key element of managing water resources. It is hoped that this study will assist in future water resources planning and hope it presents the information in a form which can be readily understood and used as a reference by planners, engineers, managers, others requiring information on the resource in the area of Itoshima peninsula, Kyushu island, Japan

2. Study area

The area which has been selected for this study as shown in **Fig.1** is Itoshima peninsula area including the new campus (Ito campus) of Kyushu University. The total area of Itoshima is about 112 km^2. The climate in the area is characterized as having high humidity, high wind speed, and heavy precipitation. The average annual precipitation during 7 years (1996-2002) is 1646 mm year^{-1}, approximately, more than 50% of which occurs in June to August. Air temperature ranges from 19.2°C – 31.1°C in summer and 1.7°C – 15.4°C in winter months. Daily mean temperature in summer is 23.3°C and 9.6°C in winter. On the other hand, daily mean minimum and maximum relative humidity are 35% and 95% with annual average of 67% respectively. The daily average of wind speed is 2.1 m s^{-1}. The elevation of the ground surface ranges from 0.00 m at the lowest point to about 400 m.a.s.l. The lowland area is used for agriculture such as greenhouse farming and paddy fields[1), 2)].

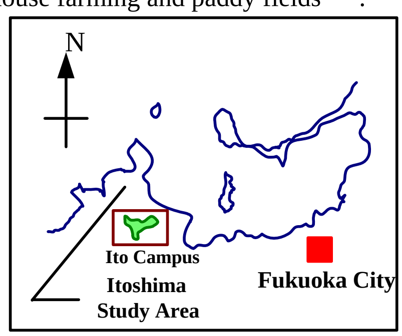

Fig. 1 Study area (Itoshima peninsula).

3. FAO56-PM equation

The FAO56-PM equation for predicting ET_o where applied on 24-hour calculation time steps has the form:

$$ET_o = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T+273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)} \quad (1)$$

where ET_o is reference evapotranspiration [mm day^{-1}], R_n is net radiation at the crop surface [MJ m^{-2} day^{-1}], G is soil heat flux density [MJ m^{-2} day^{-1}], T is mean daily air temperature at 2 m height [°C], u_2 is wind speed at 2 m height [m s^{-1}], e_s is saturation vapor pressure [kPa], e_a is actual vapor pressure [kPa], e_s-e_a is saturation vapor pressure deficit [kPa], Δ is slope vapor pressure curve [kPa °C^{-1}], and γ is psychrometric constant [kPa °C^{-1}]. In application having 24-h calculation time steps, G is presumed to be 0 and e_s is computed as

$$e_s = \frac{e^0(T_{\max}) + e^0(T_{\min})}{2} \quad (2)$$

where e0( ) is the saturation vapor function and T_{max} and T_{min} are the daily maximum and minimum air temperature. Standardized equations for computing all parameters in Eq. (1) are given in (Allen et al. 1998).

4. Procedures and results

4.1 Input meteorological data

The only factors affecting ET_o are climatic parameters. Consequently, ET_o is a climatic parameter and can be computed from weather.

Calculation of ET_o with the Penman-Monteith equation on 24-hour time scales will generally provide accurate results. The required meteorological data consist of:
- Air temperature: maximum (T_{max}) and minimum (T_{min}) daily air temperatures, - Air humidity, - Wind speed: daily average for 24 hours of wind speed measured at 2 m height (u_2), and - Actual duration of sunshine (n). The extraterrestrial radiation (R_a) and daylight hours (N) for a specific day of the month should be computed.

The meteorological data of 7 years at the Maebaru AMeDAS station covering the period of January 1996 - December 2002 were analyzed for purposes of calculating ET_o by the FAO56-PM equation. The daily average input parameters are listed in **Table 1**.

Table 1 Daily average input parameters used in the estimation of ET_o by FAO56-PM.

Input parameters	Daily average values
(T_{max}) [°C]	20.27
(T_{min}) [°C]	12.4
(u_2) [m s^{-1}]	2.1
(R_H) [%]	66.43
(n) [h d^{-1}]	4.7

4.2 Calculation procedures

Several procedures have been developed to assess the ET_o rate from required parameters. ET_o expresses the evaporating power of the atmosphere at a specific location and time of the year and does not consider the crop characteristics factors data and soil factors [3].

ET_o can be estimated by means of the calculation sheet or a computer. In the present study all the ET_o calculations were done by means of a computer. The calculation procedure consists of the following steps: 1. Derivation of some climatic parameters from the daily maximum (T_{max}) and minimum (T_{min}) air temperature, altitude (z) and mean wind speed (u_2). 2. Calculation of the vapor pressure deficit (e_s - e_a). The saturation vapor pressure (e_s) is derived from T_{max} and T_{min}, while the actual vapor pressure (e_a) is derived from the mean relative humidity (RH_{mean}). 3. Determination of the net radiation (R_n) as the difference between the net shortwave radiation (R_{ns}) and the net longwave radiation (R_{nl}). The effect of soil heat flux (G) is ignored for daily calculations as the magnitude of the flux in this case is relatively small. The net radiation, expressed in [MJ m^{-2} day^{-1}], is converted to [mm day^{-1}] (equivalent evaporation) in the FAO56-PM equation by using 0.408 as the conversion factor within the Eq. (1). 4. ET_o is obtained by combining the results of the previous steps.

The calculated values of slope of saturation vapor pressure (Δ) [kPa°C^{-1}], mean saturation vapor pressure (e_s) [kPa], actual vapor pressure (e_a) [kPa] from mean relative humidity, saturation vapor pressure deficit (e_s-e_a) [kPa], extraterrestrial radiation (R_a) [MJ m^{-2} day^{-1}], solar radiation (R_s) [MJ m^{-2} day^{-1}], clear-sky solar radiation (R_{so}) [MJ m^{-2} day^{-1}], net solar or net shortwave radiation (R_{ns}) [MJ m^{-2} day^{-1}], net longwave radiation (R_{nl}) [MJ m^{-2} day^{-1}], and net radiation (R_n) [MJ m^{-2} day^{-1}] as daily calculated parameters results are listed in **Table2**.

Table 2 Daily average values of the calculated parameters by FAO56-PM.

Calculated parameters	Daily average
(Δ) [kPa°C^{-1}]	0.128
(e_s) [kPa]	2.13
(e_s) [kPa]	2.13
(e_s-e_a) [kPa]	0.66
(R_a) [MJ m^{-2} day^{-1}]	30.29
(R_s) [MJ m^{-2} day^{-1}]	13.45
(R_{so}) [MJ m^{-2} day^{-1}]	22.73
(R_{ns}) [MJ m^{-2} day^{-1}]	10.36
(R_{nl}) [MJ m^{-2} day^{-1}]	2.75
(R_n) [MJ m^{-2} day^{-1}]	7.61

4.3 Estimating daily reference evepotranspiration (ET_o) [mm day^{-1}]

Values of ET_o [mm day^{-1}] as shown in **Fig.2** were computed on daily basis, for altitude point equals to 20 m., (z = 20m) above ground surface, using the procedures, outlined earlier. The daily average value of ET_o for 7 years is 2.79 [mm day^{-1}], the maximum value is 7.97 [mm day^{-1}], and the minimum value is 0.62 [mm day^{-1}].

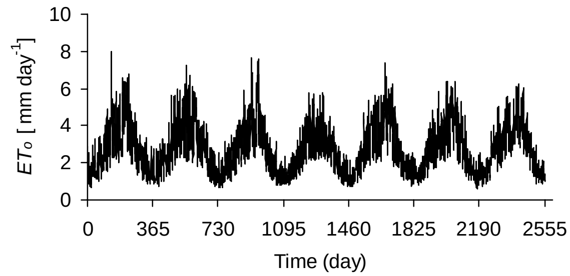

Fig. 2 Daily values of reference evepotranspiration (ET_o) [mm d^{-1}].

The result of ET_o which was obtained from the present study may be considered as basic elements of managing water resources efficiently, and also as important factors in computing water balance, irrigation system design and management, crop yield simulation, and hydrologic studies.

5. Conclusions

Seven years (1996-2002) of daily meteorological data derived from Maebaru AMeDAS station and Fukuoka local meteorological station located in Fukuoka Japan, was used as input parameters for estimating daily reference crop evapotranspiration, in Itoshima peninsula area western part of Fukuoka city, Kyushu Island, Japan by applying Food and Agriculture Organization (FAO) Penman-Monteith equation method (Allen, R.G. et al., 1998, paper 56). The major drawback is that the measured ''real'' value of evapotranspiration in the local area is unknown.

In conclusion, it can be emphasized that the use of the FAO56-PM as a standard method remains the most desirable method for estimating ET_o if accuracy of data collection is considered to be the main consideration.

The FAO Penman-Monteith method uses standard climatic data that can be easily measured or derived from commonly measured data. All calculation procedures have been standardized according to the available weather data and daily time scale of computation.

References

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