THE DETERMINATION OF POTENTIAL EVAPOTRANSPIRATION BASED ON DATA UMP WEATHER STATION

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ABSTRACT

Potential evapotranspiration (PET) is an important index of hydrologic budgets at different spatial scales and is a critical variable for understanding regional biological processes. It is often an important variable in estimating actual evapotranspiration (AET) in rainfall-runoff and ecosystem modeling. However, PET is defined in different ways in the literature and quantitative estimation of PET with existing mathematical formulas produces inconsistent results. The objectives of this study were to determine the potential evapotranspiration using the penman procedure based on Hydrological Procedure 17 (HP17 1999) and compare it with the interpolation map produced by the Meteorology Malaysian Department (MMD). The studied found that PET values calculated were favorably within the interpolation value (3.5 to 4.00). Based on the criteria of availability of input data and the value of PET computed from the Universty Malaysia Pahang (Ump) weather station are suggested in the future as one of the weather station or for validation.

ABSTRACT

Potensi Evapotranspirasi (PET) adalah sangat penting dalam indeks hyrologi terkawal di ruang sekala yang berlainan dan ianya adalah pemalar yang kritikal untuk memahami mengenai kawasan peroses biologi. Ia biasanya pembolehubah yang penting untuk menentukan evapotranspirasi yang sebenar (AET) dalam pengaliran air hujan dan model ekosistem. Walaubagaimanapun, PET membawa bermadsud yang berlainan dari segi bahasa dan juga pengiraan PET yang berlainan dengan kewujudan jalan pengiraan yang tidak seragam. Objectif kajian ini adalah untuk menentukan PET menggunakan kaedah Penman berdasarkan Hyrologycal Procedure 17(HP 17 1999) dan membandingkan keputusan dengan peta interpolasi yang dihasilkan oleh Malaysian Meteorology Departmant (MMD). Kajian ini mendapati keputusan yang diperolehi hampir sama dengan peta interpolasi(3.0-4.0). Berdasarkan ciri-ciri kebolehan data dikira dan nilai PET yang dihasilkan daripada stesen cuaca Universiti Malaysia Pahang (UMP), adalah disarankan supaya menjadi satu daripada stesen cuaca yang unggul di masa hadapan.

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C the effective (lateral and vertical) conductance of aquifer, [T-1]

$\bar{E}i$ average evapotranspiration rate over time interval $((i - 1)\Delta t, i\Delta t)$, [L/T]

PET potential ET, in millimeters per day

e(t) evapotranspiration rate, [L/T

E1 modified coefficient of efficiency, [dimensionless]

E1' baseline-adjusted modified coefficient of efficiency, [dimensionless]

G soil heat flux at land surface, in watts per square meter

Gcon a constant rate of ground-water flow, [L/T]

Gi average ground-water flow rate over time interval $((i - 1)\Delta t, i\Delta t)$, [L/T]

g(t) ground-water flow rate, [L/T]

HB depth below datum of the water level at boundary, [L]

Hi depth of water level below a datum (typically land surface) at timestep i, [L]

hi–1 depth of water level below a datum (typically land surface) at timestep i–1, [L]

HL depth below which specific yield changes (typically mean land surface), [L]

HR depth below datum above which surface runoff occurs (typically mean land surface), [L]

h(t) depth of water level below a datum (typically land surface), [L]

hzi depth of water level below a datum (typically land surface) at time step *i* computed assuming surface runoff is zero, [L]

hz(t) depth of water level below a datum (typically land surface) computed assuming surface runoff is zero, [L]

I discretization index representing time $i\Delta t$

N number of values in time series

P I average precipitation rate over time interval $((i - 1)\Delta t, i\Delta t)$, [L/T]

p(t) precipitation rate, [L/T]

Ra	extraterrestrial radiation, in watts per square meter
Ri	average surface runoff rate over time interval $((i - 1)\Delta t, i\Delta t)$, [L/T]
Rn	net radiation, in watts per square meter
r(t)	surface runoff rate, [L/T]
S	storage (water held in pore space or ponded above land surface), [L]
Sy1	specific yield at depths greater than or equal to HL, [dimensionless]
Sy2	specific yield at depths less than HL, [dimensionless]
T	time, [T]
Tavg	mean air temperature, in degrees Celsius
Tmax	mean maximum air temperature, in degrees Celsius
Tmin	mean minimum air temperature, in degrees Celsius

W	change in storage of energy in the water column above land surface, in watts per square meter
x^i	measured value of the quantity of interest at time step i
^xi	predicted value of the quantity of interest at time step i
$\bar{X}$	mean measured value of the quantity of interest at time step i
Yi	value of the baseline time series at time step i
α	the Priestley-Taylor coefficient [dimensionless
γ	psychrometric constant, in kilopascals per degree Celsius
Δ	slope of saturation-vapor pressure curve, in kilopascals per degree Celsius
Δt	time interval for discretization, [T]
λ	latent heat of vaporization, in Joules per gram
ρw	density of water, in grams per cubic centimeter

CHAPTER 1

INTRODUCTION

1.1 Introduction

Potential evapotranspiration (PET) is the amount of water that could be evaporated and transpired if there was sufficient water available. This demand incorporates the energy available for evaporation and the ability of the lower atmosphere to transport evaporated moisture away from the land surface. PET is higher in the summer, on less cloudy days, and closer to the equator, because of the higher levels of solar radiation that provides the energy for evaporation. PET is also higher on windy days because the evaporated moisture can be quickly moved from the ground of plants, allowing more evaporation to fill its place. PET is expressed in terms of a depth of water, and can be graphed during the year. There is usually a pronounced peak in summer, which results from higher temperatures (Allen *et al.*, 1998).

PET is usually measured indirectly, from other climatic factors, but also depends on the surface type, such free water (for lakes and oceans), the soil type for bare soil, and the vegetation. Often a value for the potential evapotranspiration is calculated at a nearby climate station on a reference surface, conventionally short grass. This value is called the reference evapotranspiration, and can be converted to a potential evapotranspiration by multiplying with a surface coefficient. In agriculture, this is called a crop coefficient. The difference between potential evapotranspiration and precipitation is used in irrigation scheduling (Allen *et al.,* 1998).

A good estimation of potential evapotranspiration is vital for proper water management, allowing for improve efficiency of water use, high water productivity and efficient farming activities. PET can be obtained by many estimation methods. Some of these methods need many weather parameters as inputs while others need fewer. Numerous methods have been developed for evapotranspiration estimation out of which some techniques have been developed partly in response to the availability of data. Factors such as data availability, the intended use, and the time scale required by the problem must be considered when choosing the PET calculation technique. (Stein, J., R. Caissy *et al.,* 1995).

Nowadays, MMD in researching agriculture produce map in 10 days data which conquer the peninsular Malaysia and east Malaysia by interpolation. Table 1 shown weather station in Malaysia.

Table 1: Weather Stations in Malaysia

Station	Elevation	Latitude(DD)	Longitude (DD)
Alor star/Kepala	50	+06200	+100417
Bintulu/Kalimantan	50	+03200	+113033
Butterworth	40	+05467	+100383
Cameron Highlands	14700	+04467	+101383
Ipoh	390	+04567	+101100
Johore Bharu/Senai	400	+01633	+103667
Kota Bharu	50	+06167	+102283
Kota Kinabalu	30	+05933	+116050
Kuala Krai	650	+05533	+103083
Kuala Lumpur/Sepang	160	+02733	+101700
Kuala Lumpur/Subang	220	+03117	+101550
Kuala Terengganu	320	+05333	+103133
Kuantan	160	+03783	+103217
Kuching	270	+01483	+110333
Kudat	50	+06917	+116833
Labuan	300	+05300	+115250
Langkawi International Airport	70	+06333	+099733
Malacca	90	+02267	+102250
Mersing-in-johore	450	+02450	+103833
Miri/Kalimantan	180	+04333	+113983
Penang/Bayan Lepas	40	+05300	+100267
Petaling Jaya	570	+03100	+101650
Sandakan/Kalimantan	130	+05900	+118067
Sibu	80	+02333	+111833
Sitiawan	80	+04217	+100700
Sultan Abdul Aziz	270	+03133	+101550
Tawau/Kalimantan	200	+04267	+117883
Temerloh	400	+03467	+102383

1.2 Problem statement

Evpotranspiration is a major compenent of the catchments water balance and PET data should be a key input to rainfall runoff model. Thus, is it the data from UMP weather station reliable in estimating PET.?

1.3 Objective of study

The objectives of this study are as follows:

- To estimate the PET from UMP weather station data with penman procedure method based on Hydrological procedure 17 (HP 17, 1999).
- To compare PET estimated value with PET value provided by Malaysian Meteorology Department (MMD).

1.4 Scopes of study

This study was based on;

- Data from year 2007 to 2009 with focus on July

  Estimate PET with refer to HP 17 1999.

- For the further supported data obtained from literature.

1.5 significant of study

To prove reliable data collected based on Ump weather stati

CHAPTER 2

LITERATURE RIVIEW

2.1 Introduction

This chapter review of the post research related to estimate PET method. PET is used as an index to represent the available environmental energies and ecosystem productivity (Currie, 1991). For example, in the four vertebrate classes studied, Currie (1991) found that 80 to 93 percent of the variability in species richness could be statistically explained by ecosystem PET. Although the PET concept has many uses, it has been regarded as a confusing term because the reference evaporation surface, usually the vegetation type is vaguely defined (Nokes, 1995). Consequently, the PET concept has been gradually replaced in the past decade by other more narrowly defined terms, such as reference crop evapotranspiration (Jensen *et al.*, 1990), or surface dependent evapotranspiration (Federer *et al.,* 1996). Typically, reference crops are grass and alfalfa because most equations were developed for agricultural purposes, but a land surface can contain

2.2 Concept of PET

Groundwater discharge by evapotranspiration from phreatophytes in arid and semiarid regions is a principal mechanism for water loss, and in some areas the sole mechanism (Nichols 1993 and Nichols 1994). Saltcedar is one of the phreatophytes that have spread throughout these regions in the United States. Several studies have been conducted to determine the water use (evapotranspiration) by this plant. The estimated rate of water use by saltcedar varies depending on method of measurement, location of study and other factors.

Potential evapotranspiration can be measured directly by lysimeters, but generally, it is estimated by theoretical or empirical equations, or derived simply by multiplying standard pan evaporation data by a coefficient (Grismer et at., 2002). Because of the large size of a tree, there havebeen few attempts to directly measure forest PET or AET by lysimeter studies and develop associated equations to estimate PET or AET (Stein *et al.,* 1995; Riekerk, 1985). Forest PET values at stand or landscape levels are often indirectly estimated using modified mathematical models that were developed for free water surface or short crops, such as the Thornthwaite Kolka and Wolf, 1998).

There are approximately 50 methods or models available to estimate PET, but these methods or models give inconsistent values due to their different assumptions and input data requirements, or because they were often developed for specific climatic regions (Grismer et al., 2002). Past studies at multiple scales have suggested that different PET methods may give significantly different results (Crago and Brutsaert, 1992; Amatya et al., 1995; Federer et al., 1996; Vorosmarty et al., 1998). By using intensive meteorological data from three sites in eastern North Carolina, Amatya et al. (1995) contrasted six PET computation methods, which included one combination method (Penman-Monteith), three radiation based (Makkink, Priestley-Taylor, and Turc) and two temperature based (Thornthwaite and Hargreaves-Samani) methods.They found that the Thornthwaite method performed the worst, and that the Makkink and Priestley-Taylor methods performed the best when compared to the Penman-Monteith predictions, which were used as the standard for comparisons. Federer et al. (1996) compared five reference surface PET methods (Thornthwaite, Hamon, Jensen-Haise, Turc, and Penman) and four surface dependent PET methods (Priestley-Taylor, McNaughton-Black, Penman- Monteith, and Shuttleworth-Wallace) using data from seven locations across a large climatic gradient in the continental United States and Puerto Rico. They defined reference surface PET as the evapotranspiration that would occur from a land surface specified as a "reference crop" (usually defined as a short, complete, green plant cover) in designated weather conditions if plant surfaces were externally dry and soil water was at field capacity; and surface dependent PET was defined as the evapotranspiration that would occur from a designated land surface in designated weather conditions if all surfaces were externally wetted, as by rain (Federer et al., 1996).

A large proportion of precipitation (50 to 80 percent) is returned to the atmosphere as evapotranspiration, a region that is largely covered by forests and has diverse topographic features (i.e., coastal plains, piedmonts, and hilly mountains) (Sun et al., 2002; Liang et al., 2002; Lu et al., 2003). Streamflows, water quality, and ecosystem processes can respond substantially to small changes in precipitation or evapotranspiration. This is especially true for the coastal regions where evapotranspiration is the dominant factor on surface and ground water flow patterns. Thus, it is important to identify the differences among the PET methods when PET is used to predict AET, because different PET methods give widely different annual values at particular locations as demonstrated in previous studies (Federer et al., 1996). Even for the PET methods that give similar values, the method or methods that require the least input parametersfvariables are most useful and practical for regional scale studies (Fennessey and Vogel, 1996).

2.3 Below shown the essential in the estimation PET

2.3.1 Mean Temperature

The (average) daily maximum and minimum air temperatures in degrees Celsius (°C) are required. Where only (average) mean daily temperatures are available, the calculations can still be executed but some underestimation of ET_o will probably occur due to the non-linearity of the saturation vapour pressure - temperature relationship (Figure 11). Using mean air temperature instead of maximum and minimum air temperatures yields a lower saturation vapour pressure e_s, and hence a lower vapour pressure difference (e_s - e_a), and a lower reference PET estimate.

2.3.2 Mean Relative Humidity

The (average) daily actual vapour pressure, e_a, in kilopascals (kPa) is required. The actual vapour pressure, where not available, can be derived from maximum and minimum relative humidity (%), psychrometric data (dry and wet bulb temperatures in °C) or dewpoint temperature (°C) according to the procedures outlined.

2.3.3 Radiation

The (average) daily net radiation expressed in megajoules per square metre per day (MJ m^{-2} day^{-1}) is required. These data are not commonly available but can be derived from the (average) shortwave radiation measured with a pyranometer or from the (average) daily actual duration of bright sunshine (hours per day) measured with a (Campbell-Stokes) sunshine recorder.

2.3.4 Wind speed

The (average) daily wind speed in metres per second (m s^{-1}) measured at 2 m above the ground level is required. It is important to verify the height at which wind speed is measured, as wind speeds measured at different heights above the soil surface differ.

2.4 Potential Evapotranspiration Estimated method

- Thornthwaite

- Priestley-Taylor
- Hargreaves-Samani
- Turc
- Makkins
- Penman-procedure

2.4.1 Three temperature based methods, Thornthwaite (1948)

That quote appeared in the 1957 Foreword by D. B. Carter (who published site-specific water balances while at the Laboratory of Climatology, and while not absolutely certain of the authorship, he appears to have been attempting to call attention to the difference between the 1955 and 1957 publications, cited herein as C. W. Thornthwaite and J. R. Mather's "Instructions and Tables for the Computing Potential Evapotranspiration and the Water Balance," (Publications in Climatology X(3):311 pp. published in 1957).

However, in 1955, C. W. Thornthwaite and J. R. Mather had published the first version entitled simply "The Water Balance." It subsequently received legitimate criticism for having the potential evapotranspiration (PET) too low in winter and too high in summer. Accordingly, adjusted the tables used to calculate the unadjusted PET values by hand so that they were no longer a family of straight lines on log-log paper, but slightly curved. Discovery of that fact and converted the 80+ pages of tables into equations for use in the original Fortran II-D version for calculating the annual water balance.

The estimated value of daily ET_0 by the Thornthwaite method was obtained by using the average daily temperature (T_{ave}), effective daily temperature (T_{ef}) and corrected effective daily temperature (T'_{ef}). The factor for calculation of T_{ef} and (T'_{ef}) was 0.64. Using the adjusted Thornthwaite method without modifing the Willmott et al. equation indicates that (T'_{ef}) is more appropriate than using T_{ave} and T_{ef}. However, for daily air temperature higher than 26°C, the Willmott et al. equation was modified and used along with the adjusted Thornthwaite method with T_{ef}. These results are more accurate than those obtained by the adjusted Thornthwaite method especially by using T_{ef} in daily ET_0 estimation. By calibration of the Hargreaves-Samani equation, its original coefficient (0.0023) was modified to 0.0026. Comparing the results of daily ET_0 estimated by the modified Hargreaves-Samani method and the modified adjusted Thornthwaite method and daily ET_0 measured by weighing lysimeter show that the accuracy of the modified Hargreaves-Samani method is higher than that obtained by the modified Thornthwaite method.

2.4.2 Penman equation

The Penman equation describes evaporation (E) from an open water surface, and was developed by Howard Penman in 1948. Penman's equation requires daily mean temperature, wind speed, relative humidity, and solar radiation to predict E. Simpler Hydro meteorological equations continue to be used where obtaining such data is impractical, to give comparable results within specific contexts, eg. humid vs arid climates.

Numerous variations of the Penman equation are used to estimate potential evapotranspiration (PET) from water, and land. Specifically the Penman-Monteith equation refines weather based *ET* estimates of vegetated land areas. It is widely regarded as one of the most accurate models, in terms of estimates.

The original equation was developed by Howard Penman at the Rothamsted Experimental Station, Harpenden, UK.

The equation for evaporation given by Penman is:

$$E\,mass = \frac{mR_n + \rho_c c_p(\delta e)g_a}{\lambda_v(m+\gamma)} \tag{2.1}$$

where:

m = Slope of the saturation vapor pressure curve (Pa K^{-1})

R_n = Net irradiance (W m^{-2})

ρ_a = density of air (kg m^{-3})

c_p = heat capacity of air (J kg^{-1} K^{-1})

g_a = atmospheric conductance (m s^{-1})

δe = vapor pressure deficit (Pa)

λ_v = latent heat of vaporization (J kg^{-1})

γ = psychrometric constant (Pa K^{-1})

Which (if the SI units in parentheses are used) will give the evaporation E_{mass} in units of kg/(m^2·s), kilograms of water evaporated every second for each square meter of area.

This equation assumes a daily time step so that net heat exchange with the ground is insignificant, and a unit area surrounded by similar open water or vegetation so that net heat & vapor exchange with the surrounding area cancels out.