EVAPOTRANSPIRATION AND ENERGY BALANCE OF PADDY FIELD AND TEAK PLANTATION

Piyapong Tongdeenok[1] Samakkee Boonyawat[1]

ABSTRACT

The objectives of this study are to compare the evapotranspiration (ET_a) and energy balance of paddy field and teak plantation and to develop regression models using simple climatic factors for estimation of evapotranspiration in paddy field and teak plantation. The automatic weather station (AWS) data observed at paddy field and teak plantation in Sukhothai and Lampang provinces collected between January 2002 - September 2004 were applied in this study.

The results shown that the daily average solar radiation (Rs) in paddy field was 19.3 MJ m^{-2} day^{-1} with Rn of 13.2 MJ m^{-2} day^{-1} (70.4 % of Rs). The Rn was used for latent heat (LE), sensible heat (H), and storage in soil and water (Gs and Gw) with the average value of 9.5, 3.0, 0.4 and 0.2 MJ m^{-2} day^{-1} or 72.3, 2.9, 3.1 and 1.7% of Rn respectively. In teak plantation, the daily average Rs was estimated at 19.0 MJ m^{-2} day^{-1},. with an avergae daily Rn of 14.8 MJ m^{-2} day^{-1} or 78.2% of Rs. The Rn was used for LE, H and Gs about 71.6, 23.0 and 5.4% of Rn respectively. The average daily ET_a of the whole peroid study in paddy field was 4.1 mm while the average daily ET_a of teak plantation was 3.9 mm.

Regarding estimation of ET_a based on general climatic factors using regression model, the most suitable model for paddy field was by found the highest correlation equation in December with r^2 = 0.86, while in teak plantation the highest correlation with r^2 = 0.84 was found in November.

It can be said that the relationship between ET_a and micrometeorological data was not applicable for almost all monthly periods. Only some month showed the significant relationship. It is thus recommended that there should be no more use the meteorological data to develop model for prediction ET_a.

[1] Department of Conservation, Faculty of Forestry, Kasetsart University, Chatuchak, Bangkok 10900, Thailand

INTRODUCTION

In the tropical region like Thailand where 90% of the mean annual rainfall occurs during April to October (Phetcharinthon, 1999), the exploration and the evaluation of water resource potential is essential to find the ways to store and meet the demand around the year. Only 30% - 40% of annual rain water become subsurface and surface flow. Over a period of one year, change in ground water storage is very small, and can be neglected. Major portion of the rain water fluxes as evapotranspiration. Accurate estimation of evapotranspiration is thus necessary to evaluates the water resource potential of our use. Although evapotranspiration depends on soil, topography, state of climate; primarily it depends on the types and density of vegetation, due to vegetative activities. Evapotranspiration is limiting factor and implied to soil moisture variation. The variation of soil moisture indicated the status of watershed that can describe to reduce the damage from flood and drought effect.

Paddy field and teak plantation represent the major land uses in northern Thailand. These types of land use usually consume great amount of water in almost all large watershed in northern Thailand. Therefore it is worthy to investigate evapotranspiration loss from these land use types for the benefit of water yield management in the future. The objectives of the present study are as follows

1. To compare the actual evapotranspiration in paddy field and teak plantation by Bowen ratio method; and.

2. To develop the suitable equation to estimate the actual evapotranspiration basing on climatic data.

MATERIALS AND METHODS

Site Selection

According to GAME-T project under corporative Thailand and Japan, paddy field at Amphoe Muang, Changwat Sukhothai and teak plantation at Amphoe Mae Moh, Changwat Lampang were selected for studying energy and water balance. Automatic weather station (AWS) was installed in each site since 1997

Equipment Installation

Automatic Weather Station (AWS) was installed at tower 10-m height. at Sukhothai paddy field, and 26-m height at Lampang teak plantation (Figure 1). The data were collected continuously. Two level of psychometer was installed at above plant canopy 30 cm and upper position depend on plant type. The instruments consist of as follows :

1. Automatic weather station tower

2. Thermo sensor and psychometer were installed at 2 levels height of plant at canopy level, the above one was higher than lower position about 4 meters in

(a) paddy field

(b) teak plantation

Figure 1. Automatic weather station (a) paddy field (b) teak plantation

forest area and 2 meters in agricultural area.

3. Pyrheliometer and Net radiometer
4. Three tensiometer at 15 cm dept of soil near tower
5. Three soil heat flux plate at 1 cm. dept of soil near tower
6. Infrared thermometer nearly the top of tower
7. Anemometer at the top of tower

Data Collection and Transmitting

A 32 channel data recorder was developed to collect all data in every one minute and sum of 10 minute data are recorded in data logger. The data logger has a function to allow storage of data for approximately 12 days. This study was collecting data between January 2002 to August 2004.

Data Transmitting of every site was transmitted to personal computer at Kasetsart University through internet by using GPRS transfer data and mobile telephone.

Data Converting

1. All measured data from data logger were transmitted into PC (DENWA software program) and averaged every ten minute's data by DAILYPRO software program.
2. All measured data in unit of millivolt were converted from error by noise sensor or DC power. The average ten minute's data was converted into the average 30 minutes data.
3. Every 30 minutes average data was calculated to the real value and the average daily data and daytime were calculated by DAILYPRO software program developed by Aoki *et al.* (1996; 1997)

Data Analysis

1. The energy balance and evapotranspiration were calculated basing on Bowen ratio method by the following equations:

$$R_n = H+G_s+G_w+LE \quad (1)$$

$$\beta = H/LE \quad (2)$$

$$\text{Here } \beta = \frac{(1.0042*1{,}013)*(\Delta T\text{-}0.006*\Delta Z)}{[0.622*(2{,}500.8\text{-}2.3668T_a)]*(\Delta e)} \quad (3)$$

$$E = E\,T_a = (R_n\text{-}G_s\text{-}G_w)/L(1+\beta) \quad (4)$$

$$L = 2{,}500.8\text{-}2.3668*T_a \quad (5)$$

Where R_n = net radiation (W m^{-2})
H = sensible heat flux (W m^{-2})
G^s = soil heat flux (W m^{-2})
LE = latent heat flux (W m^{-2})
Gw = heat storage in water (W m^{-2})
β = Bowen ratio
Ta = air temperature (°C)
ΔT = difference between the lower and the upper air temperature (°C)
Δe = difference between the lower and the upper vapor pressure (mb)
ΔZ = difference between the lower and the upper height (m)

2. Comparison between the observed and estimated values of energy balance and average daily evapotranspiration of each selected area was made.

Data Application

1. Annual variation of actual evapotranspiration at paddy field and teak plantation were study.

2. Comparison of actual evapotranspiration and varieties parameter in different types of land use in different season and annual.

3. Estimation of water loss from selected watershed area was made using water balance method.

RESULTS AND DISCUSSION

Energy Balance and Actual Evapotranspiration

Paddy field

1. Energy balance

The study of energy balance and actual evapotranspiration using energy balance and Bowen ratio method of Sukhothai paddy field found that the average daily solar radiation (Rs) of the whole period ranged between 17.0-21.9 Mj/m^2/day in January and April with annual average 19.3 MJ/m^2/day, and average daily net radiation (Rn) was 13.2 MJ/m^2/day. Of this figure of Rn, it was utilized for evapotranspiration (LE), sensible heat (H) and storage in soil (Gs) and in water (Gw) at amount of 72.3, 22.9, 3.1 and 1.7 percent of net radiation respectively. (Table 1)

2. Actual evapotranspiration

The result shown that the highest average daily ET_a was found in September 5.1 mm day^{-1} the lowest average daily ET_a was 2.8 mm/day in December. The result was similar trend in every year because in September when it was planting season there was water in paddy field for the whole growing season. Therefore, ETa was highest in September (154.5 mm) and followed by May and July 154.0 and 145.7 mm respectively. The ET_a was starting high at the beginning of rainy season due to the high average daily net radiation 21.0 $MJ/m^2/day$ in May and June, and also the high amount rainfall (129.9 mm.) which started cumulative high soil moisture from April (Table 1).

Rice Planting Season

The variation of ET_a in paddy field during rice planting season was investigated 2 years periods. (2002-2003). It was found that during planting season which states from mid of July to harvesting in November covering 108 days. The height of water in paddy field for the whole planting period was averaged at 8.5 cm. The monthly average ET_a was 137.4 mm. (average 4.5 mm/day). The highest ET_a was estimated at 154.5 mm. in September and lowest ET_a of 122.4 mm. in November. The lower in November caused by a less rainfall and solar radiation. The highest solar radiation during planting season was found in October 19.1 $MJ/m^{-2}/day$ while in August, September and November was 18.1, 18.7 and 17.7 $MJ/m^{-2}/day$ respectively

Teak plantation

The results of energy balance and evapotranspiration investigation an analysis in Lampang teak plantation was shown in Table 2 and can be explained as follows :

1. Energy balance

The average daily Rs for the study period was 16.0-24.6 $MJ/m^2/day$, the average of August and April was 19.0 $MJ/m^2/day$. The average daily Rn was 14.8 $MJ/m^2/day$ or 78.2% of Rs. The Rn was utilized for LE, H and Gs at amount of 71.6, 23.0 and 5.4 % of Rn respectively. (Table 2)

2. Actual evapotranspiration

The highest average daily ET_a was found in April 5.5 mm/day while the lowest ET_a of 2.8 mm/day in occurred in December with annual average of 3.9 mm/day. That same pattern of ET_a was found in every year because in April, there is a highest solar radiation (24.8 $MJ/m^2/day$) and net radiation (18.3 $MJ/m^2/day$) and also high soil moisture content was affected by rainfall of 63.8 mm in April.

Estimation of Actual Evapotranspiration from Simple Climatic Factor

Regression model was develop for estimating ET_a in various types of land use by using climatic factors such as air temperature (Ta), wind speed (Ws), relative humidity (RH) and analyzed by statistic analysis method (ANOVA). The suitable

Table 1. Energy balance and Evapotranspiration in Sukhothai paddy field, Jan. 2002 - Aug. 2004

Planting season/month	Rs $MJ/m^2/day$	Energy balance ($MJ/m^2/day$)					Bowen ratio	ET_a		Epan		Rain (mm)	Ta (°C)	Ws (m/s)	pF (-)	RH (%)
		Rn	LE	H	Gs	Gw		mm/day	mm/month	mm/day	mm/month					
Off planting season																
December	18.5	11.4	8.4	2.5	0.6	0.0	0.3	2.8	87.8	3.5	107.4	1.0	22.7	1.4	0.0	66.5
January	17.0	11.0	7.4	3.1	0.5	0.0	0.4	3.2	99.2	3.9	117.8	19.2	23.3	1.4	1.5	64.5
February	19.4	12.5	9.0	2.9	0.6	0.0	0.3	3.1	90.7	4.5	133.7	20.9	25.6	1.8	2.8	60.4
March	20.5	13.5	9.3	3.5	0.7	0.0	0.4	3.6	110.3	6.1	184.3	27.5	29.3	2.8	2.7	48.6
April	21.9	16.9	11.2	4.9	0.8	0.0	0.4	4.4	133.3	6.7	201.7	129.9	32.4	2.9	2.9	60.5
May	21.0	16.1	11.6	3.8	0.6	0.0	0.3	5.0	154.0	6.1	185.6	184.3	28.8	2.6	0.7	71.0
June	20.1	14.7	10.3	3.7	0.3£	0.4	0.4	4.8	144.8	4.9	146.4	93.6	27.6	2.6	0.7	71.3
July	19.0	14.1	9.6	3.9	0.3	0.4	0.4	4.7	145.7	4.7	143.9	56.5	27.8	2.8	0.5	78.0
average	19.7	13.8	9.6	3.5	0.6	0.1	0.4	3.9	120.7	5.1	152.6	66.6	27.2	2.3	1.5	65.1
percent of solar radiation	100.0	70.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
percent of net radiation	-	100.0	69.6	25.6	4.1	0.7	-	-	-	-	-	-	-	-	-	-

Table 1. (Cont.)

Planting season/month	Rs MJ/m^2/day	Energy balance (MJ/m^2/day) Rn	LE	H	Gs	Gw	Bowen ratio	ET_a mm/day	ET_a mm/month	Epan mm/day	Epan mm/month	Rain (mm)	Ta (°C)	Ws (m/s)	pF (-)	RH (%)
planting season																
August	18.1	11.7	8.7	2.5	0.2	0.4	0.3	4.3	132.6	4.7	141.2	156.4	26.1	2.7	0.0	76.2
September	18.7	11.6	9.0	2.0	0.1	0.5	0.2	5.1	154.5	4.1	123.7	231.2	28.0	2.4	0.0	77.9
October	19.1	12.8	10.3	1.8	0.1	0.6	0.2	4.5	140.2	3.7	112.7	285.4	26.6	1.1	0.0	79.6
November	17.7	11.9	9.4	1.9	0.2	0.3	0.4	4.0	122.4	3.7	110.2	24.7	25.9	1.0	0.0	71.1
average	18.4	12.0	9.4	2.0	0.1	0.4	0.3	4.5	137.4	4.0	121.9	174.4	26.7	1.8	0.0£	76.2
annual average	19.3	13.2	9.5	3.0	0.4	0.2	-	4.1	26.3	4.7	142.4	102.6	-	-	-	-
percent of solar radiation	100.0	70.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-
percent of net radiation	-	100.0	72.3	22.9	3.1	1.7	-	-	-	-	-	-	-	-	-	-

Table 2. Energy balance and evapotranspiration in Mae-Moh teak plantation, Lampang Jan. 2002 - Aug. 2004

season/month	Rs	Energy balance (MJ/m²/day)				Bowen	ET_a		Epan		Rain	Ta	Ws	pF	RH
	MJ/m²/day	Rn	LE	H	Gs	ratio	mm/day	mm/month	mm/day	mm/month	(mm)	(°C)	(m/s)	(-)	(%)
Dry season															
November	18.1	13.2	9.5	2.8	0.8	0.3	3.2	96.0	3.2	95.5	33.7	23.5	1.0	2.5	78.9
December	17.1	13.9	10.0	3.0	0.9	0.3	2.8	85.0	2.9	89.3	8.8	21.7	1.0	2.6	75.9
January	20.7	14.0	10.1	3.0	0.9	0.3	3.0	90.4	3.3	100.2	4.3	21.9	1.1	2.8	67.4
February	18.6	13.5	8.9	3.8	0.8	0.4	3.6	105.1	3.7	109.9	35.9	24.8	1.4	2.7	67.3
March	20.8	15.9	10.3	4.6	1.0	0.4	4.1	125.3	4.7	140.8	13.4	26.9	1.7	2.8	61.0
April	24.6	18.3	10.7	6.4	1.1	0.6	5.5	166.4	5.7	165.7	63.8	28.5	1.8	2.6	69.5
average	20.0	14.8	9.9	3.9	0.9	0.4	3.7	101.3	3.9	106.6	24.3	22.0	1.2	2.4	61.4
percent of solar radiation	100.0	74.1	-	-	-	-	-	-	-	-	-	-	-	-	-
percent of net radiation	-	100.0	67.0	26.7	6.3	-	-	-	-	-	-	-	-	-	-

Table 2. Energy balance and evapotranspiration in Mae-Moh teak plantation, Lampang Jan. 2002 - Aug. 2004

season/month	Rs	Energy balance ($MJ/m^2/day$)				Bowen	ET_a		Epan		Rain	Ta	Ws	pF	RH
	$MJ/m^2/day$	Rn	LE	H	Gs	ratio	mm/ day	mm/ month	mm/ day	mm/ month	(mm)	(^oC)	(m/s)	(-)	(%)
Rainy season															
May	19.5	17.3	12.1	4.4	0.8	0.4	5.2	158.5	4.8	154.2	167.6	26.9	1.5	2.3	76.9
June	20.1	17.3	12.8	3.8	0.8	0.3	4.7	141.9	5.0	148.2	107.6	26.1	1.2	1.9	79.2
July	18.9	13.3	9.7	3.0	0.7	0.3	3.9	117.4	5.6	161.2	117.3	27.2	1.6	1.7	82.9
August	16.0	12.8	9.3	2.9	0.7	0.3	3.8	114.0	4.6	146.0	184.4	26.4	1.5	1.4	81.2
September	16.7	13.5	11.1	1.8	0.6	0.2	3.5	103.8	4.1	123.0	216.0	25.7	1.0	1.6	82.1
October	16.9	14.4	12.3	1.4	0.7	0.1	3.7	111.9	3.9	120.0	107.1	25.4	1.8	0.5	79.2
average	18.0	14.8	11.2	2.9	0.7	0.3	4.1	112.6	4.1	128.6	132.1	23.4	1.3	1.4	71.3
annual average	19.0	14.8	10.6	3.4	0.8	0.3	3.9	128.2	3.9	136.1	101.2	25.9	1.4	1.9	77.4
percent of solar radiation	100.0£	78.2	-	-	-	-	-	1283.4	-	1411.4	938.0	-	-	-	-
percent of net radiation	-	100.0£	71.6	23.0	5.4	-	-	-	-	-	-	-	-	-	-

model was selected by all possible regression method considering statistic parameters r^2 and F-ratio as criteria. The monthly significant equation of land use type can summarize in Table 3 and Table 4.

From Table 3, the significant prediction models in paddy field were found in January, February, May, July, August, October, November and December while the non significant prediction model were shown in March, April, June and September. It could be said that, the air temperature, relative humidity, soil water tension and wind speed had non significant influence on ET_a at 95% confidence interval.

In teak plantation there were non significant prediction model in February and April. The factors which affect to ET_a were as same as in paddy field, the results indicated that the r^2 was highest in July and November, it can said that this period have high effect on ET_a and climatic factor influence on ET_a was higher that other month (Table 4).

Data Application for Estimating Actual Evapotranspiration of Selected Watershed Area

Mae-Mok watershed which was a branch of Yom river basin and located

Table 3. Mathematical model for estimation actual evapotranspiration from climatic factors of Sukhothai paddy field

month	model	R^2	F-ratio	MSE
January	ET_{Jan} = -1.355+1.226WS	0.32	5.83**	0.29
February	ET_{Feb} = 2.811+0.318T_a	0.5	8.99**	0.64
March	insignificant	-	-	-
April	insignificant	-	-	-
May	ET_{May} = 25.537-0.043RH-0.484WS	0.55	7.75**	1.44
June	insignificant	0.41	-	-
July	ET_{Jul} = -7.042+0.413T_a	0.4	10.36**	0.13
August	ET_{Aug} = 10.337-0.091RH	-	6.27**	2.03
September	insignificant	0.4	-	-
October	ET_{Oct} = 20.684-0.18RH	0.4	15.50**	2.02
November	ET_{Nov} = -2.102+0.275T_a	0.15	4.56**	1.45
December	ET_{Dec} = 9.079+0.352T_a-0.176RH	0.86	42.09**	0.18

Remark ** = Significant at confident level 99%

Table 4. Mathematical model for estimate actual evapotranspiration from climatic factors of Lampang teak plantation

month	model	R^2	F-ratio	MSI
January	ET_{Jan} = 10.26-0.365T_a	0.2	2.64*	0.79
February	insignificant	-	-	-
March	ET_{Feb} = 4.546-0.039RH	0.38	7.35**	0.87
April	insignificant	-	-	-
May	ET_{May} = 9.791-0.054RH-1.353WS	0.75	10.21**	0.2
June	ET_{Jun} = 16.77-0.151RH	0.58	40.83**	0.63
July	ET_{Jul} = -8.905+0.547T_a	0.84	47.28**	0.09
August	ET_{Aug} = -13.961+0.637Ta	0.36	9.67**	0.56
September	ET^{Sep} = 1.724+0.45T_a-0.091RH	0.77	24.17**	0.23
October	ET_{Oct} = -10.501+0.449T_a	0.39	8.32**	0.64
November	ET_{Nov} = 4.947+0.433T_a-0.117RH-0.429WS	0.84	37.00**	0.18
December	ET_{Dec} = 3.963+0.241T_a-0.023RH	0.31	6.13**	0.57

Remark * = Significant at confident level 95 %

** = Significant at confident level 99 %

nearby AWS paddy field study site was selected for estimating ET_a. The results can be explained as follows :

Water balance method

Using the annual average data during studied period the actual evapotranspiration in Mae-Mok watershed area, calculated base on water balance equation is as follows :

ET_a = R - Q ± ΔS

R = Annual rainfall (1,106.5 mm)

Q = Annual discharge (54.8 mm)

ΔS = Soil moisture storage (for annual value, ΔS=0)

Therefore ET_a = 1,106.5 - 54.8+/- 0

= 1,051.7 mm/year

Energy balance and bowen ratio method

By using energy balance and Bowen ratio method the result can summarize in Table 5 and can be explained as follow :

The calculated annual average evapotranspiration is equal to 1,351 mm. The ET_a of this method is higher than water balance method (1051.7 mm) 28.5 percent and higher than pan evaporation (1,126.9 mm) about 19.9 percent. As for water balance method the limiting factors of ETa was not use directly for calculate ET_a. Only annual data of rainfall and discharge were used to calculate ignoring annual soil moisture parameter. Therefore calculated ET_a from water balance was less than energy balance method. While pan evaporation method was use only climatic factor affect to less ET_a than energy balance method that use more factors than others method.

CONCLUSION AND RECOMMENDATION

Conclusion

The study of evapotranspiration and energy balance of paddy field and teak plantation can be concluded as follow :

1. Energy balance

A study of energy balance in Sukhothai paddy field during January 2002 to August 2004 (total 2 years and 8 months) can be con-

Table 5. Comparison on derived ET_a among different methods in Mae-Mok subwatershed, Amphoe Thuen, Changwat Lampang

Land use type	Area		ET_a	ET_a	Epan	ET (water balance)
	Km²	%	(mm day^{-1})	(mm year^{-1})	(mm year^{-1})	(mm year^{-1})
1. Paddy fiel	167.6	14.5	4.1[1/]	-		-
2. Corn field	1.1	0.1	3.9[2/]	-		-
3. Shifting area	3.6	0.3	3.2[4/]	-		-
4. Mix deciduous forest	160.1	13.8	4.5[2/]	-		-
5. Dry evergreen forest	146.5	12.6	2.5[4/]	-		-
6. Deciduous forest	586.5	50.6	3.7[3/]	-		-
7. Teak plantation	8.1	0.7	3.9[1/]	-		-
8. Agricultural area	84.6	7.3	3.5[5/]	-		-
9. banana field	1.0	0.1	2.7[1/]	-		-
Total	**1,159.1**	**100.0**	**-**	**1,351**	**1,126.9**	**1,051.7**

Remark : [1/] from this study, [2/] from Piyapong (2001), [3/] from Somnimirt (2001), [4/] from Chankao (1971), [5/] approximated value cluded that the daily average of solar radiation (Rs) throughout study period was 19.3 MJ m^{-2} day^{-1} while the daily averaged of net radiation (Rn) was 13.2 MJ m^{-2} day^{-1} which was 70.4% of Rs. The average of net radiation (Rn) and percentage of latent heat (LE), sensible heat (H) and storage in soil and water (Gs, Gw) were averaged at 9.5, 3.0, 0.4 and 0.2 MJ m^{-2} day^{-1} or 72.3, 22.9, 3.1 and 1.7% of Rn, respectively. The daily average of Bowen ratio throughout period was 0.4.

In teak plantation, it can be also concluded that the daily averaged net radiation (Rn) throughout period was 14.8 MJ m^{-2} day^{-1} or 78.2 % of Rs. The Rn was used for LE, H and Gs with value of 10.6, 3.4 and 0.8 MJ m^{-2} day^{-1} or 71.9, 23.2 and 5.5% of Rn, respectively while bowen ratio was 0.4 throughout study period.

2. Evapotranspiration

The daily average of actual evapotranspiration (ET_a) in paddy field during rice planting season was 4.5 mm while the daily averaged of pan evaporation (Epan) was 4.0 mm. In off planting period, the daily average of ET_a was 3.9 mm while the daily averaged of Epan was 5.1 mm.

The daily average of ET_a in teak plantation during dry season was 3.7 mm while the daily averaged of Epan was 3.9 mm. In rainy season, the daily average of ET_a was 4.1 mm while the daily averaged of Epan was 4.7 mm.

3. Estimation ET from general meteorological data

To establish mathematical models for estimating daily actual evapotranspiration (ET_a) for paddy field and teak plantation for particular month, the meteorological factors such as air temperature (Ta), wind speed (Ws), relative humidity (RH) and soil water tension (pF) were employed in the regression analysis. The most suitable models have been selected by possible regression .

When the whole data recorded throughout the year were used in model derivation for predicting daily ET_a for paddy field, the significant prediction models were shown in January, February, May, July, August, October, November and December while the non significant prediction model were shown March, April, June and September. It could be said that, the air temperature, relative humidity soil water tension and wind speed had insignificant influence on ET_a at 95% confidence interval during March to June and in September.

In teak plantation there were non significant prediction model in February and April. The factors that affect to ET_a are as same as those in the paddy field, the results indicated that the r^2 was highest in July and November.

4. Estimation actual evapotranspiration of selected watershed area

Mae-Mok watershed which branch of

Yom river basin was selected for estimating ET_a. Water balance method, energy balance method and pan evaporation method were selected for calculating ET_a. The results found that annual evapotranspiration base on water balance, energy balance and pan evaporation were 1,051.7 , 1,351 and 1,126.9 mm respectively.

The calculation of annual average evapotranspiration by using energy balance and Bowen ratio method was higher than that of water balance method (1051.7 mm) 28.5 percent and pan evaporation (1,126.9 mm) about 19.9 percent respectively

Recommendation

1. There are not significant between meteorological data and ET_a, owing to location and distance from meteorological station and AWS, and also slighty error of collecting data. Therefore, it is not recommend to use meteorological data for developing model ET_a predicting.

2. This study results could be roughly to estimate the water loss in small watershed.

REFERENCES

Aoki, M., T. Machimura, Y. Hideshima, N. Obase and S. Maruya. 1996. Estimate of Bowen Ratio by Climatic Factors. pp. 341 - 345. *In* C.R. Camp, E.J. Sadler and R.E. Yoder (eds.). **Evapotranspiration and Irrigation Scheduling, Proceeding of the International Conference.** November 3 - 6, 1996. San Antonio, Texas, USA.

AOKI, M., T. Machimure, Y. Hideshima, N. Obase, N. Wada and T. Sato. 1997. A Data Acquisition System for Evapotransporation Measurement in Remote Fields Using Mobile Telephone and Small D.C. Generator. **J.Agri. Meteorology.** 52(5) : 605-608.

Chunkao, K. 1971. An Analysis of Evapotranspiration of Dry-Evergreen Forest of Sakaerat, Thailand. **Forest Research Bulletin** no. 16 October 1971. Faculty of Forestry, Kasetsart University, Bangkok. 91 p.

Phetcharinthon, S. 1999. **Evaluation of Evapotranspiration in Thailand Using Remote Sensing Data.** M.S. thesis, Asia Institute of Technology.

Piyapong, T. 2001. **Determining Evapotranspiration by Bowen Ratio Method in Various of Land - Use, Sukhothai Province.** M.S. thesis, Kasetsart University.

Somnimirt, P. 2001. **The comparative studies on evapotranspiration of paddy field and different forest types in the northern Thailand based on bowen ratio method.** Ph. D. thesis, Kasetsart University.