DIFFERENCE OF ENERGY BALANCE IN PADDY FIELD, SUKHOTHAI PROVINCE

Somnimirt Pukngam[1]   **Samakkee Boonyawat**[1]

ABSTRACT

Study on difference of energy balance was carried out in paddy field, Sukhothai province by using data recorded by Automatic Weather Station (AWS) during 1997-1998. The objective is to indicate the difference of energy balance in the paddy field both in the planting season and dry season. It was found that latent heat in planting season was about 10.9 MJ m^{-2} day^{-1} or 75.1 percent of net radiation which higher than sensible heat (1.8 MJ m^{-2} day^{-1} or 12.4 percent of net radiation). The heat storage in soil and water was about 0.3 and 1.6 MJ m^{-2} day^{-1} or 1.8 and 10.8 percent of net radiation respectively. In dry season, after rice harvesting, or dry season the sensible heat was higher than latent heat particularly from January to May and March to April. The sensible heat was about 7.7 MJ m^{-2} day^{-1} or 64.9 percent of net radiation while latent heat was about 3.0 MJ m^{-2} day^{-1} or only 25.2 percent of net radiation. The heat storage in soil in dry season after harvesting period was about 1.2 MJ m^{-2} day^{-1} or 9.9 percent of net radiation. The main factor in the difference of energy balance was water submerged in paddy field.

Key words: Energy balance, Sensible heat, Latent heat

INTRODUCTION

The net radiation (Rn) was a major source of the evapotranspiration (ET) process which represents the water loss from watershed and is a key component of the hydrologic cycle. Otherwise, the Rn was used for latent heat (λE), sensible heat flux exchange (H) and energy storage (S) in various components of the system. Therefore, the energy balance equation can be expressed as:

$$Rn = \lambda E + H + S \qquad ....(1)$$

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

Where, Rn is net radiation (W m^{-2}), λE is latent heat flux (W m^{-2}), H is sensible heat exchange (W m^{-2}) and S includes all energy storage in the system (W m^{-2}).

Pukngam (2001) found that the annual sensible heat in paddy field was about 23.1 % of Rn while the sensible heat in mixed deciduous forest and teak plantation was about 32.0 and 14.7 % of Rn respectively. Zhao *et al.* (1996) mentioned that to obtain the correct estimation of ET using the energy balance method, it is an important to know the total amount of the energy stored and its influence on evapotranspiration. Besides, Pukngam (2001) showed the component of energy balance in the study as follow:

$$Rn = λE + H + Gs + Gw \quad ....(2)$$

Where, Gs is the soil heat flux density (W m^{-2}), Gw is the heat storage in water (W m^{-2}). Usually, the sensible heat is less than latent heat. But in dry season, the sensible heat is higher than latent heat. Therefore, the difference of energy balance should be observed. Because of this phenomenon was always the cause of strong local wind. The objective of this study is to show the difference of energy balance in paddy field during planting season and after harvesting or dry season.

MATERIALS AND METHODS

The study was conducted in paddy field, Sukhothai province, Thailand. The geographic location of measurement site is 17°03′ N and 99°42′ E. The rice were plant in rows and clumps with respective distance of 0.75 m and 0.25 m. The average height of the plant was about 1.5 m. The data were derived as follows:

1) Equipment installation: the Automatic Weather Station (AWS) was installed in the rain-fed paddy field. The net radiation (Rn) was measured by net radiometer which installed on the tower at the height of 7.5 m above the ground surface. Three observed soil heat flux (Gs) were buried in the soil at a depth of 1 cm. Two psychometers were set up on the tower at the height of 2.0 and 9.5 meters. The wet and dry bulb temperatures were measured by T-type (copper-constantan) thermocouples. The sensible heat (H) and the latent heat (λE) were estimated based on Bowen ratio method. Air temperature (Ta) and water temperature (Tw) were also measured by thermister (Figure 1).

2) Data collection and transmitting: Each day average 10 minute of all data were collected from 15 channel data logger. The data were transmitted through modem and mobile phone to Faculty of Forestry, Kasetsart University. The data of planting season (September-October) and dry season (January-April) were selected for analysis.

3) Data analysis: the software program developed by Aoki *et al.* (1997) was employed to convert the data into text file data as daily data. Then diurnal energy balance and evapotranspiration (ET) were

calculated. The derived ET from energy balance equation and Bowen ratio method were applied in this study as follows:

From equation (2)

$$Rn = \lambda E + H + Gs + Gw$$

$$\beta = H/\lambda E = (Cp*P/0.622\lambda)(\Delta T/\Delta e) \quad ....(3)$$

$$= \frac{(1.0042*1013)(\Delta T - 0.006\Delta Z)}{(0.622\lambda)(\Delta e)} \quad ....(4)$$

$$\lambda = 2500.8 - 2.3668\ Ta \quad ....(5)$$

Where Rn   = net radiation (W m^{-2})

H   = sensible heat flux (W m^{-2})

Gs   = soil heat flux (W m^{-2})

Gw   = heat storage in water (W m^{-2})

λE   = latent heat flux (W m^{-2})

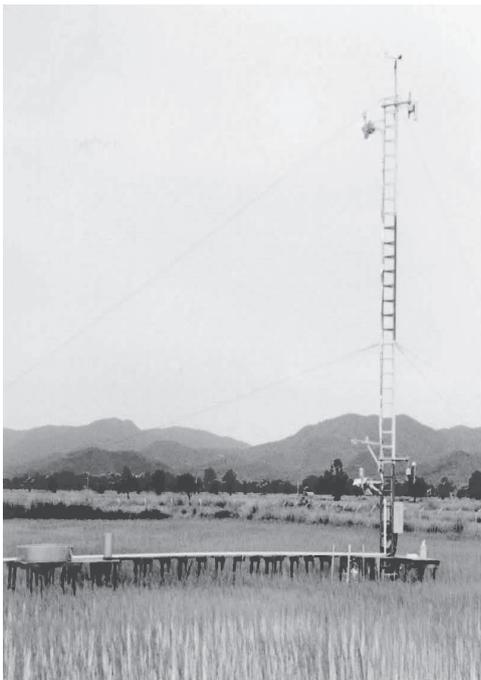β = Bowen ratio

Cp   = specific heat of air (J °C g^{-1})

P   = air pressure (mb)

Ta   = air temperature (°C)

ΔT   = difference between the lower and the upper air temperatures (°C)

Δe   = difference between the lower and the upper vapor pressure (mb)

ΔZ   = difference between the lower and the upper height (m)

(a) Paddy field during planting season   (b) Paddy field during dry season

Figure 1. Automatic Weather Station was set up in paddy field, Sukhothai province since 1996

RESULTS AND DISCUSSION

Energy Balance in Rice Planting Season

The daily λE during rice planting season, (September-October) ranged from 5.3-14.3 MJ m^{-2} day^{-1} with the average 10.9 MJ m^{-2} day^{-1} or 75.1% of Rn while the H was ranged from 0.4-3.2 MJ m^{-2} day^{-1} with the average 1.8 MJ m^{-2} day^{-1} or 12.4% of Rn. The average value of Gs and Gw were 0.3 and 1.6 MJ m^{-2} day^{-1} or about 1.8 and 10.8% of Rn respectively. These are presented in Figure 2 and summarized in Table 1. It's indicated that the average λE in the planting season was higher than H around 6 times. Because of almost of energy was used in evaporation and

storage in water.

Energy Balance in Dry Season

The daily λE in dry season, (March-April) ranged from 0.7-4.9 MJ m^{-2} day^{-1} with the average 3.0 MJ m^{-2} day^{-1} or 25.2% of Rn while the daily H was ranged from 5.5-9.8 MJ m^{-2} day^{-1} with the average 7.7 MJ m^{-2} day^{-1} or 64.9% of Rn. The daily average value of Gs was 1.2 MJ m^{-2} day^{-1} or about 9.9% of Rn. These are presented in Figure 3 and summarized in Table 1. It's indicated that the average λE in dry season is opposite with planting season. It's lower than H around 2.6 times. Because of no water was submerged in paddy field, so almost of energy was used for sensible heat,
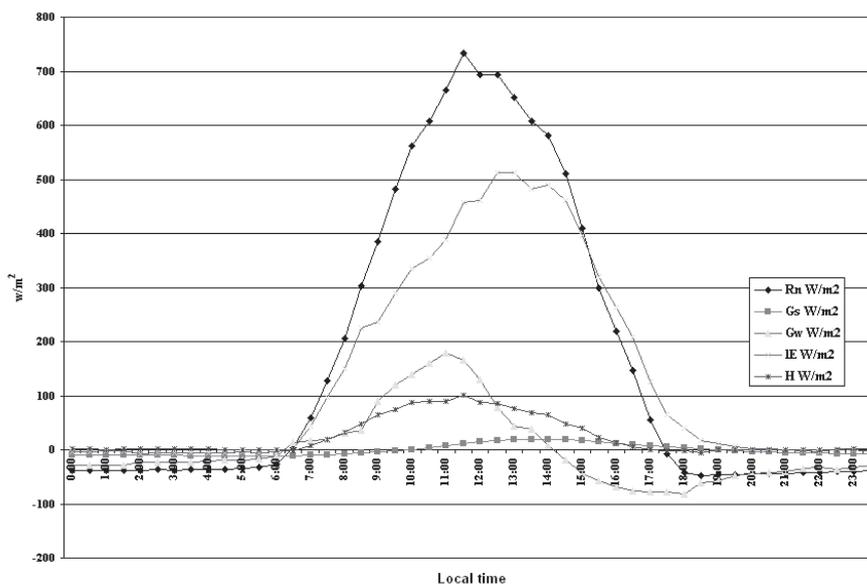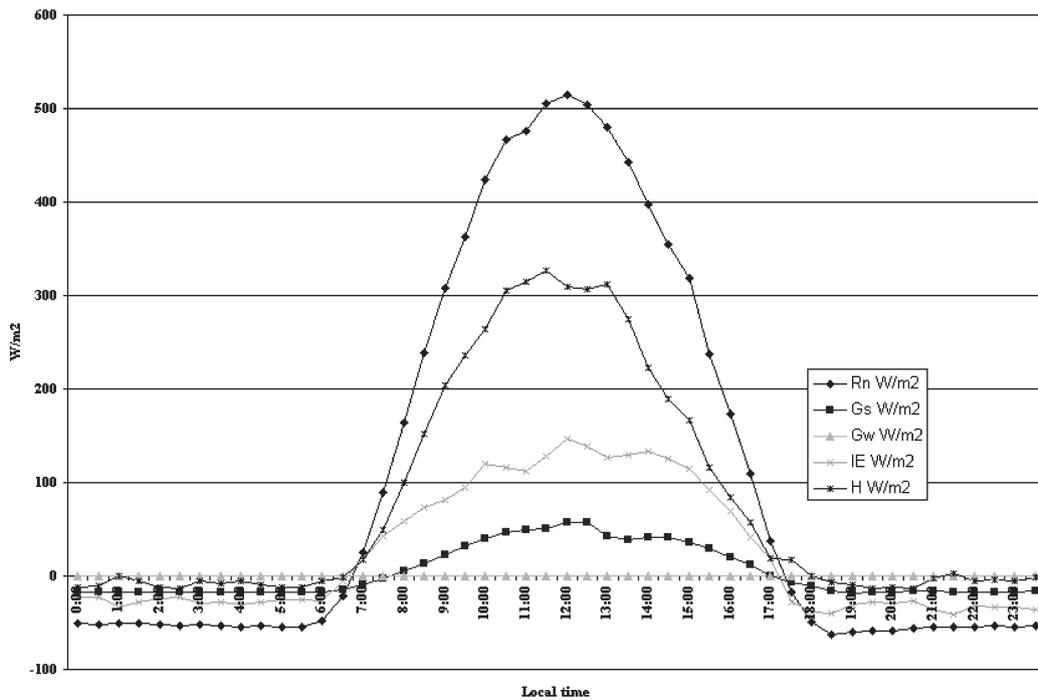

Figure 2. Energy balance in paddy field during planting season (September-October)

Table 1. Summarized of energy balance in paddy field during planting season (Septem ber-October) and dry season (March-April)

Symbols	Factors	Unit	Rice planting season		Dry season	
			Rang	average value	Rang	average value
Ta	Air temperature	°C	26.7-31.1	29.1	32.0-35.8	33.7
Ts	Soil temperature at 1 cm depth	°C	28.6-31.7	30.4	32.8-37.4	35.7
TW	Water temperature	°C	29.0-34.7	32.0	-	-
RH	Relative humidity	%	67.8-89.6	78.7	34.0-57.6	48.7
WL	Water level	cm	1.1-14.4	8.9	-	-
Ws	Wind speed	ms^{-1}	1.0-3.9	1.7	1.8-3.3	2.6
Rs	Solar radiation	W^{wm-2}	8.3-23.0	18.0	16.9-24.6	20.3
Rn	Net radiation	W^{wm-2}	6.3-19.1	14.5	9.9-13.9	11.8
H	Sensible heat	W^{wm-2}	0.4-3.2	1.8	5.5-9.8	7.7
IE	Latent hear	W^{wm-2}	5.3-14.3	10.9	0.7-4.9	3.0
Gs	Soil heat flux	W^{wm-2}	0.0-0.8	0.3	0.8-1.5	1.2
Gw	Heat storage in water	W^{wm-2}	0.2-3.3	1.6	-	-

Figure 3. Energy balance in paddy field during dry season (March-April)

Difference between Planting Season and Dry Season

The difference of λE and H in planting season

The value of λE was positive started from about 06.30 am. It was increase gradually until the highest value 512.4 W m^{-2} at 1.00 pm. After that, it was decrease gradually until the lowest value about 0.7 W m^{-2} at 9.00 pm. On the contrary, the value of λE and H were negative since 5.30 pm. This implies that the evapotranspiration still occurred after Rn was negative. It could be said that the heat storage in water was released and used for water evaporation (the value of Gw was also negative). The result indicated that almost of energy was used in evapotranspiration which just occurred after negative Rn was about 2.33% of daily ET. This is why heat storage terms were neglected in evpotranspiration estimation.

The value of H was positive started at about 07.00 am. It was increase gradually until the highest value 100.2 W m^{-2} at 11.30 am. Then, it was decrease gradually until the lowest value about 0.2 W m^{-2} at 5.00 pm. This indicated that the λE in planting season was about 6.1 times of H. the value of Gs was positive started at about 10.00 am. It was increase gradually until the highest value 19.0 W m^{-2} at 1.00 pm. And then it was decrease gradually until the lowest value about 1.3 W m^{-2} at 6.30 pm. For the value of Gw was positive started at about 06.30

am. and increase gradually until the highest value 179.2 W m^{-2} at 11.00 am. After that, it was decrease gradually until the lowest value about 8.5 W m^{-2} at 2.00 pm.

The difference of λE and H in Dry Season

The difference of λE and H in dry season were different from planting season (Figure 3). The positive value of λE occurred at around 7.00 am with a value of about 17.8 W m^{-2}. It was steadily increased to the peak, 139.1 W m^{-2} at 12.30 am, and dropped continuously and reached to negative value at about 5.30 pm. The difference of H was occurred at around 7.00 am with a value of about 17.0 W m^{-2}. It was steadily increased to the peak, 327.0 W m^{-2} at 11.30 am, and dropped continuously and reached to negative value at about 6.00 pm.

It can be summarized that in the planting season the Rn used for evapotranspiration process (λE) was greater than that in dry season, due to more water available for λE. But in dry season the Rn was used for sensible heat (H) greater than latent heat (λE). Due to the high temperature was occurred after rice harvested. The soil was bare and very dry, without plant cover so less water for evapotranspiration. The duration which the sensible heat was higher than latent heat usually starting from January to May especially during March to April 1998. It was about 7.7 MJ m^{-2} day^{-1} or 64.9 percent of net radiation while latent heat was about 3.0 MJ m^{-2} day^{-1} or only 25.2 percent of

net radiation. This phenomenon was one cause of the increasing of wind speed (Table 1) in dry season. It's very strong wind in anytime which we call local wind or whirlwind.

CONCLUSION

The energy balance in planting season, (September-October), the daily λE was 10.9 MJ m^{-2} day^{-1} or 75.1 % of Rn while the daily H was 1.8 MJ m^{-2} or 12.4 % of Rn. The result indicates that the average λE in planting season is higher than H around 6.1 times.

In dry season, the daily λE was 3.0 MJ m^{-2} day^{-1} or 25.2 % of Rn while the daily H was 7.7 MJ m^{-2} day^{-1} or 64.9 % of Rn. It indicates that the average λE value in dry season is lower than in planting season. It's lower than H around 2.6 times.

The duration which the sensible heat was higher than latent heat usually starting from January to May especially during March to April 1998. This phenomenon was one cause of the increasing of wind speed in dry season. It's very strong wind anytime a day.

ACKNOWLEDGEMENT

REFERENCES

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.

Pukngam, S. 2001. **The Comparative Study on Evapotranspiration of Paddy Field and Different Forest Types in the Northern Thailand based on Bowen Ratio Method.** Ph.D. Dissertation. Graduate School. Kasetsart University, Bangkok.

Zhao, W.G., P.R. Berliner and A. Zangvil. 1996. Heat Storage Terms in Evapotranspiration Estimation. pp. 34 - 41. 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.