Seasonal change of evapotranspiration and crop coefficient in a rain fed paddy field, cassava plantation and teak plantation in Thailand

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Abstract

The evapotranspiration (ET) is an essential factor to estimate crop water use. It is also one of the factors in soil water storage and water resource in a region. This study is to compare the trend of actual evapotranspiration (AET) and crop factor (K_c) among three measurement sites in Thailand that are a rain fed paddy field, cassava plantation and teak plantation. Bowen ratio energy balance technique (BREB) was applied in this investigation to measure the AET and heat flux between ground surface and atmosphere. Penman-Monteith equation recommended by FAO was used to calculate crop coefficients. Measurements were carried out during 1999-2003 in the paddy field, and teak plantation and 2002-2003 in the cassava plantation. Results showed that the amount of daytime AET during the rainy season in the paddy field and cassava plantation varied between 1 and 7 mm/daytime and in the teak plantation between 2 and 6 mm/daytime. The average amount of daytime AET in the rainy season was about 4 mm in all sites although the variations of AET were different. In the dry season, AET of cassava plantation was around 2.7 mm/daytime, slightly lower than those of other sites. During the growing season, K_c factor varied in the paddy between 0.4 and 1.2 and in the cassava between 0.3 and 1.2. Variation of K_c factor in teak plantation was smaller than those of others. In the rainy season, LE/R_n ratio in the cassava plantation and paddy field was around 70% but in the teak plantation was about 73%. K_c factor in paddy field was more affected by soil moisture in paddy field than other sites.

Keywords*: actual evapotranspiration, cassava plantation, crop factor, paddy field, teak plantation*

1. Introduction

Thailand locates in tropical Monsoon Asian region. The dry season begins in November and ends in April. Rice, cassava and teak are one of the most important crops and timber production tree which cover a large portion of land use in the Chao Phraya River basin and North-East region of Thailand. In artificial and natural ecosystems including agricultural lands, it is essential to evaluate the evapotranspiration (ET) for developing more efficient and sustainable water management techniques and planning the irrigation scheduling. Also vegetative productivity is closely related to ET. The crop coefficient K_c which is the ratio of actual evapotranspiration (AET) to the reference evapotranspiration (ET_0) calculated by the FAO Penman-Monteith method (Allen et al., 1998). K_c values can be useful to plan the irrigation scheduling in tropical Monsoon Asian region. Since researches on the ET and K_c values in the tropical region are relatively scarce, the objective of the present study is thus to find out the trend of ET and crop factors in three crop covers including a rain fed paddy field, cassava plantation and teak plantation in Thailand and also comparison of ET value among the mentioned vegetations.

2. Materials and methods

2.1. Experimental sites and plants

The measurements were carried out in three measurement sites in Thailand that are a rain fed paddy field in Sukhothai province (17° 03′ N, 99° 42′ E, elevation 50 MSL), a cassava plantation near Nakhonratchasima (14° 47′ N, 102° 38′ E, elevation 311MSL) and a teak plantation in Lampang province (18°, 40′ N, 99° 47′ E, elevation 241 MSL) which are GAME-T and CEOP project sites. Measurements were performed during 1999-2003 in the paddy field and 1999-2003 teak plantation and 2002-2003 in the cassava plantation. Measurement sites of paddy field and cassava were selected in farmer lands. Rice seeds are sown every year by a farmer after starting the rainfall period in the late July and harvested in the end of November. Cassava is also planted mostly every year in March and harvested in dry season and grown without irrigation. Teak, a 38-year deciduous plantation, is mostly started to open leaves in May and the leaves start to shed in January. At each field, microclimate measurements have been carrying out using an automatic weather station system developed by AOKI, et al. (1996)

2.2. Evapotranspiration

Bowen ratio energy balance system (BREBS) was employed to measure AET. The dry and wet-bulb temperatures were measured at two levels above canopy (paddy, cassava: 1-3 and 10 m; teak: 12 and 24m) using a hand made 10 paired copper-constantan thermocouple thermometer (shielded and ventilated). The instruments installed on a 10 m tower in paddy field and cassava and on a 24 m tower in teak plantation. A net radiometer (MF -11 EKO) was used above canopy to measure the net radiation flux density.

The fetches are around 500 m in paddy field, at least 2 km in cassava and 400 m in teak plantation. Two or three heat flux plates (P-MF-81, EKO) were placed in 1 cm in the soil surface. Two tensiometers were also set at 15 cm depth in soil near the tower of ET measurement. Their instantaneous data of every one minutes was collected by a data logger to get ten minutes average, and all data were finally averaged into the daytime mean (R_n positive). Daytime latent heat flux was calculated from the equation:

$$LE = (R_n - G - G_w)/(1+\beta) \qquad (1)$$

in which R_n (MJm^{-2}/daytime) is the net radiation, G (MJm^{-2}/daytime) soil heat flux, and G_w (MJm^{-2}/daytime) heat flux in water (paddy field) .The daytime latent heat flux (LE) then converted into the daily actual evapotranspiration (AET) in mm per daytime. The average contribution of the latent heat flux to net radiation (LE/R_n) was calculated to understand the energy allocation to evapotranspiration process.

2.3. Reference evpotranspiration and Crop coefficient

Daily reference crop evapotranspiration (ET_0) was calculated using the form of Penman-Monteith equation recommended by the FAO (Allen, et al., 1998) for a hypothetical grass crop with an assumed height of 0.12 m, a fixed surface resistance ($70sm^{-1}$) and an albedo (0.23) as follows:

$$ET_0 = \frac{0.408\Delta(R_n - G - G_w) + \gamma(900/T + 273))u_2(e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)} \qquad (2)$$

where T the daily air temperature (0C), u_2 wind speed at the height of 2 m (ms^{-1}), e_s the saturation vapor pressure (kpa), e_a the actual vapor pressure(Kpa), Δ is the slope of the vapor pressure curve (kPa°C^{-1}), and γ is the psychrometric constant (kPa°C^{-1}). Daily average values for each crop were used for R_n , T and e_a. To calculate the wind speed at 2 m above the surface, the wind speed data were converted by the following equation recommended by FAO:

$$u_2 = u_z(4.87/\ln(67.8z - 5.42)) \qquad (3)$$

where u_2 wind speed at 2 m above ground surface (ms^{-1}), u_z measured wind speed at z m above ground surface (ms^{-1}) and z height of measurement above ground surface (m). Crop coefficients (K_c) for paddy field, cassava and teak plantation was calculated using the relation K_c =AET/ET_0.

3. Results and discussion

3.1. Seasonal change in evapotranspiration

Figure1. shows seasonal changes in daily AET expressed in a year for the paddy field taken from June 1999 to Dec. 2003, for the cassava plantation from May 2002 to Dec. 2003 and for the teak for plantation from May 1999 to Dec. 2003. AET in Jan. was lowest in three sites (Average; paddy: 2.7mm; cassava: 1.7mm; teak: 2.9 mm). It started to increase

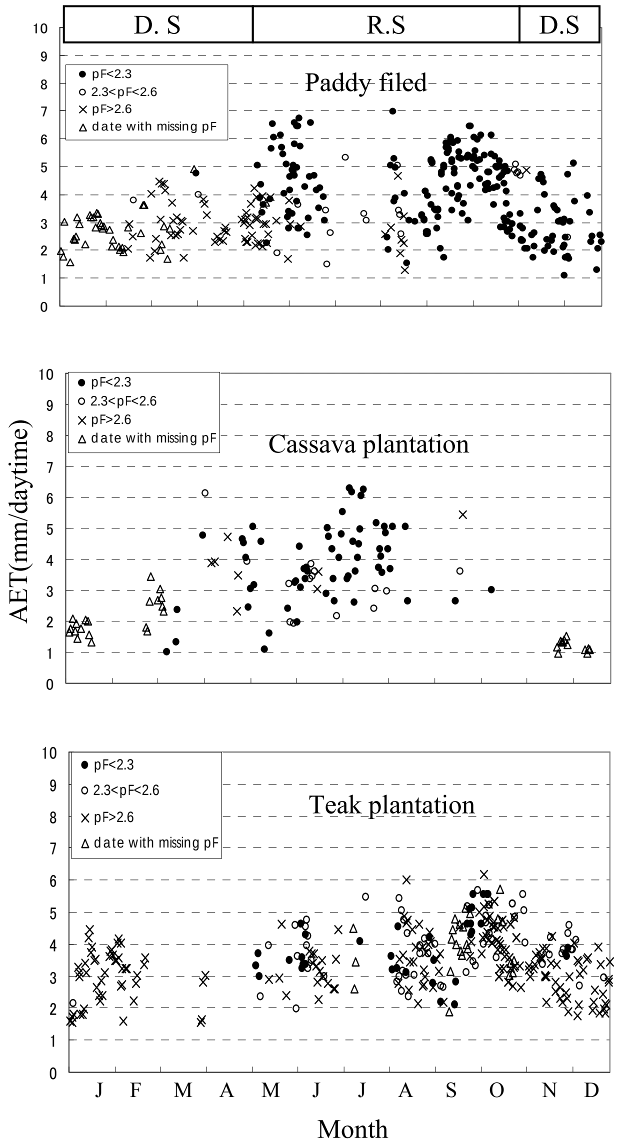

Fig.1. Seasonal change in daily evapotranspiration for paddy field, cassava and teak plantations (D.S: Dry Season and R.S: Rainy Season).

around May (Average: 3.2mm in all sites) when the growing season started, and reached its peak (Average; paddy and cassava: 4.5mm, teak: 4.1 mm) during the mid growing season in Sep. and Oct. Increase in net radiation and LE/R_n ratio in May and April might increase the evaporation from the submerged water in paddy field before starting the growing season. Increase in AET of cassava in May and April is explained by presence of the plants before starting the rainy season. The peak of AET in three sites synchronized by peak of net radiation and peak of LE/R_n ratio. During the rainy season, AET for paddy field and cassava ranged between 1 and 7

mm. The range of AET for teak plantation was between 2 and 6 mm. Data were classified to four groups based on soil moisture condition. Group 1 (closed circles), Group 2 (open circles) and Group 3 (crosses) correspond to the data obtained on days when the pF values at 15 cm are less than 2.3, between 2.3 and 2.6 and greater than 2.6, respectively. Group 4 (triangles) represents the date with missing pF value. Data showed that soil moisture had more influence on AET in paddy field than two other sites.
The average contribution of latent heat flux to net radiation (LE/R_n), actual evapotranspiration (AET) and reference evapotranspiration (ET_0) in the three sites during the dry and rainy seasons are shown in table 1. In the rainy season, average of AET was about 4 mm in all sites, although the variations of AET were different (paddy field: σ =1.28; cassava: σ =1.42; and teak: σ = 0.88).

Table1. Daily average of actual evapotranspiration (AET), LE/R_n ratio and reference evapotranspiration (ET_0) in the three measurement sites (D.S: Dry Season and R.S: Rainy Season).

	AET (Mm/daytime)		(LE/R_n) %		ET_0 (Mm/daytime)	
	D.S	R.S	D.S	R.S	D.S	R.S
Paddy	3.0	4.1	60	70	4.9	4.4
Cassava	2.7	3.9	54	72	4.5	5.1
Teak	3.0	3.8	67	73	4.1	4.6

This variation is partly relates to the variation of R_n. In the dry season, AET of teak plantation showed less variation in compare with paddy field and cassava (paddy field: σ = 0.99; cassava: σ =1.25; teak: σ = 0.80). In the dry season, average amount of AET in the paddy field and teak plantation were nearly same around 3 mm and in cassava slightly lower than those of other sites, about 2.7 mm. The average of LE/R_n which mostly depends on the variation of R_n showed different values (paddy =60, cassava: 54 and teak: 67) in the dry season. LE/R_n was about 70% during the rainy season for paddy field, whereas teak and cassava plantation had somewhat higher LE/R_n.

3.2. Crop coefficients for paddy field, cassava plantation and teak plantation

Figure2. shows the seasonal change of crop coefficients (K_c) for paddy field, cassava and teak. Extreme maximum of K_c factor in paddy field, cassava and teak plantation which observed in Sep. and Oct. were approximately 1.2, 1.2 and 1.3, respectively. It decreased gradually thereafter in all sites and reached to its minimum in Jan. And the average values for paddy field, cassava and teak plantation were 0.66, 0.48 and 0.82, respectively.
During the growing season, K_c factor varied in paddy field between 0.40 and 1.2, and in cassava between 0.3 and 1.2. Variation of K_c factor in teak plantation was between 0.4 and 1.3. For cassava, our extreme

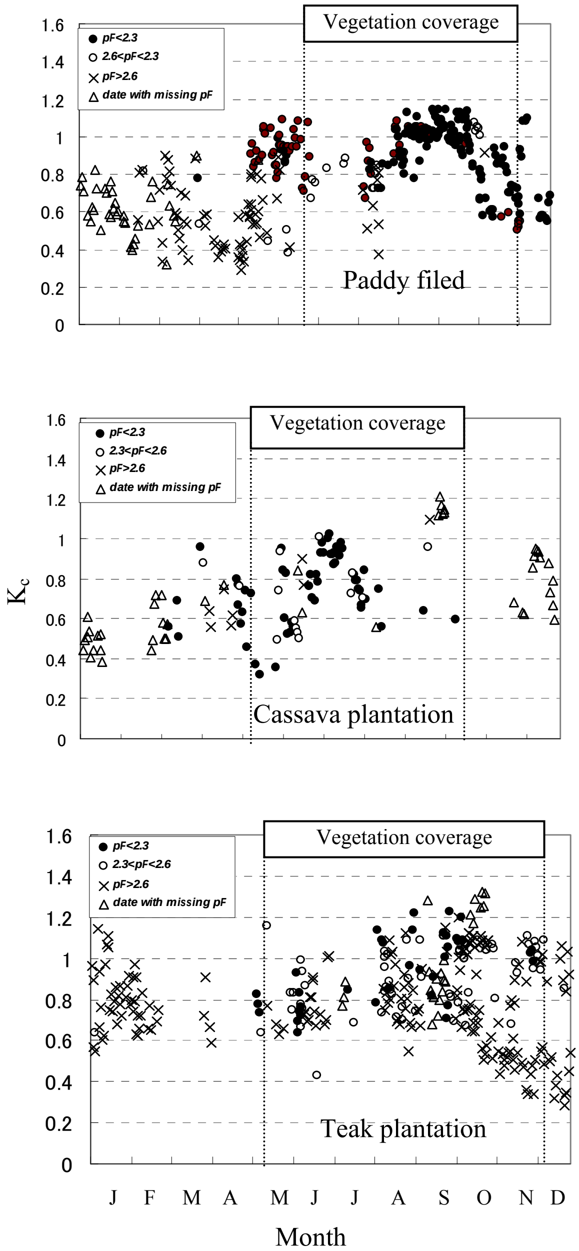

Fig.2. Change in crop coefficients for paddy field, cassava and teak plantations

maximum of K_c value was 1.2 in Sep. According to Watanabe et al., (2004), the K_c value in a cassava plantation which planted in Nov. in Khon Kaen, Northeast Thailand, was about 1.2 in June. The difference of peak occurrence times may be attributed to the difference of planting months in two cassava fields. Data were classified to four groups same as previous categorizations. Cassava and teak plantations showed no tendency of soil moisture influence on K_c factor while in paddy field K_c factor was affected by soil moisture. This fact implies that cassava plants and teak trees uptake water from deeper soil layers because of deeper root zones and that cassava and teak plantations are tolerable vegetations to drought.

3.3. Dependency of k_c factor on pF

Fig.3. shows pF value against k_c factor in three sites. Data were divided in two groups in paddy field and teak plantation, with crop coverage (filled triangles) and without crop coverage (open circle) and one group in cassava plantation, with crop coverage (filled triangles). Although the data points in cassava and teak plantations are more scattered than in paddy field, confirming again that soil moisture has more effect on the K_c factor in paddy field than cassava and teak plantations, the tendency of soil moisture influence on K_c factor in paddy field and teak plantation are nearly similar.

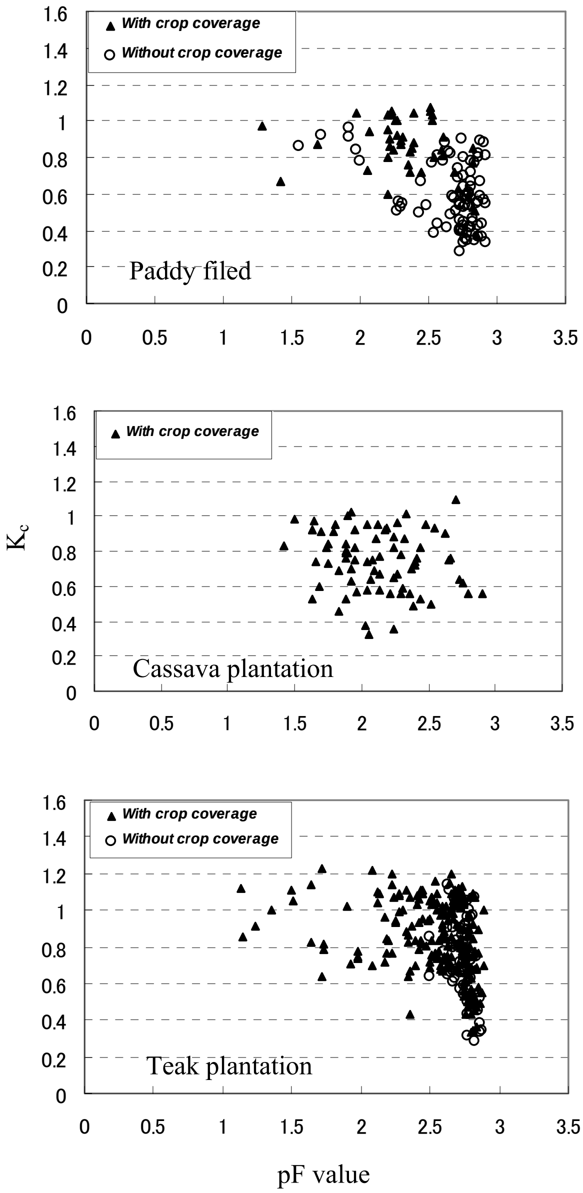

Fig.3. Relation between pF and crop factor in paddy field, cassava and teak plantation

4. Conclusion

During the rainy season, range of AET in paddy field and cassava plantation was between 1 and 7 mm/day time and in teak forest between 2 and 6 mm/daytime. The average amount of AET in rainy season was nearly same in the three sites. AET initiate to increase when the growing season started in May and reached its peak in Oct. or Sep. in all sites. During the dry season, AET of cassava plantation was around 2.7mm/daytime, slightly lower than other sites. In the dry season, average AET of teak plantation showed no significant trend. During the rainy season, LE/R_n ratio in paddy field and cassava plantation were less than teak plantation. Our results showed that maximum K_c factor in paddy field, cassava and teak plantations observed in Sep and Oct. and that is different month with other reports. The difference may be attributed to the difference of plantation was smaller than those of others. K_c factor in the paddy field was more affected by soil moisture than cassava and teak plantations suggesting that cassava plants and teak trees tolerate the water shortage during the dry season.

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