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Spatial and Temporal Aspects of Evapotranspiration in Tanjung Karang Paddy Field, Peninsular Malaysia

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***Abstract*— Evapotranspiration ET_c of rice was measured using microlysimeter in TAKRIS, Malaysia. Values of ET obtained are from 4.8 to 6.2 mm/d from all sectors of the irrigation scheme and irrespective of the season. Normality of data distribution was tested using descriptive statistical parameters. Mean, standard deviation, variance skewness and kurtosis were calculated. The skewness is in the range of 0.22 to -0.96, -1.79 to -0.80 and -1.59 to -0.45 for three seasons respectively. The values were within the conventional acceptable limit of ± 2. The results of one-way ANOVA indicates that ET data for the three seasons was significantly different at the p< 0.05 level (F = 4.65 and *p* = 0.011). The Post-hoc comparison using Tukey HSD, Scheffe and Bonferroni test indicated that the mean ET values for wet season (M = 5.05 mm/d, SD = 0.84) and mid-season (M = 5.47 mm/d, SD = 0.85) are significantly different, whereas off season (M = 5.24 mm/d, SD = 0.90) did not differ significantly from either wet or mid-season. The study shows a good water management in the TAKRIS.**

***Index Terms*— Evapotranspiration, growth stage, irrigation, microlysimeter, normality test.**

I. Introduction

The world population is clocking close to 7 billion and more than 50% of these people depend on rice. Rice commodity in South Asia accounts for more than 40 % of the world's harvested rice areas [1]. The crop provides about 30% of the calories requirements. Paddy rice, as a major food crop in Malaysia, consumes large amount of water for irrigation. About 97 percent of the world's available water resources are in oceans and seas which are salty for most production uses. Out of the remaining, 76 percent are lockup in the form of ice, permafrost, glacier, swamps and deep aquifers. The global annual precipitation amounts to 108,000 billion m^3 and 60 percent (61,000 billion m^3) evaporate back into the atmosphere leaving a balance of 47,000 billion m^3. If this amount were to be distributed uniformly across the world's population, each person will receive 9000 m^3 per annum. However, water varies according to continents with North and South America receiving more water than Africa, Asia and Europe. In addition to that Asia and Africa lost a lot of its water potential to runoff caused by seasonal rains [2]. It is crucial to create a reasonable framework to evaluate productivity and manage water resources in irrigation schemes where the hydrologic cycle depends not only on natural factors (evaporation, transpiration and precipitation) but also on human activities such as irrigation and drainage operations.

Poor and uneven water distributions are the main problems for improving irrigation efficiency in most irrigation schemes. In Malaysia, rice is unique among agronomic crops where it is grown under flooded condition and ponding water is maintained at a constant depth of approximately 5–10 cm throughout the growing season [3]. Rice maturity takes 105 – 125 days after transplanting (DAT) MR219 variety is commonly planted and matures within 110 DAT. Evapotranspiration involves a highly complex set of processes, which are influenced by many factors dependent on the local conditions. These conditions range from precipitation and meteorology to soil moisture, plant water requirements and the physical nature of the land cover [4]. There are challenges in terms of development and evaluation of optimum water management strategies to ensure conservation of water resources for sustainable food and fiber. Average annual rainfall in Malaysia is approximately 2500 mm [5]. However, this rainfall is distributed unevenly both temporally and spatially, and the distribution is not optimal for rice growing seasons. To effectively and efficiently use the available water resources for irrigation supply, studies on rice water requirements for paddy field are important. On the other hand, evapotranspiration is one of the important components of the water balance in paddy fields. Evapotranspiration is simply the residual of accurate measurements of water in and out of the device [6], [7]. It includes the loss of water from both soil and plant surfaces, playing an important role in both rain-fed and irrigated field. It depends upon the evaporative demand of the atmosphere. It also depends on the transport processes of heat and water from soils and plants through the sub layers, which are next to the evaporative surfaces, and through plant canopies to the outer atmosphere [8]. It is mainly affected by climatic factors and, to some extent, is controlled by physiological functions of rice under submerged conditions [9] – [11]. There are a number of methods available to determine crop evapotranspiration [12]. Many empirical equations [13] –

[15], micro-meteorological [16], combined and hydrologic methods [17] - [19], [9] and [20] are used to compute rice evapotranspiration. Direct measurements of evapotranspiration employ the use of lysimeters which are more accurate on paddy fields. Lysimeter is a container that isolates a soil environment from the surrounding soil, but still provides a surface that represents the adjacent land [21]. It has several advantages where lysimeter measures constantly the changes in soil moisture throughout the growth cycle of crop and give an estimate of the water demand at different growth stage [22]. After being exposed to the same environmental conditions, lysimeters are more likely to mimic natural field than columns in the laboratory [23]. They also report that field experimentation is valuable for comparing water flow and solute transport in lysimeters and field soils. They are also used for drainage control, maintaining a controlled soil-water or nutrient environment for precise measurement of their use by crops and mobilization within soil. Two widely used types are weighing and non-weighing lysimeters [24]. Large weighing lysimeters are costly, labor intensive and time consuming. Their precision depends on quality and design of the load cells to measure changes in weight [21]. On the other hand an inexpensive, simple, sensitive and accurate technique has been used to measure ET from paddy field using microlysimeter tool [17]. It has an easy skill to adopt by farmers on the field and it is used as a baseline to compare and validate other ET methods and models.

The objective of the present study is first to determine the parametric or normality of both temporal (rainy, mid and off season) and spatial (upper, middle and downstream) rice ET_c data obtained using microlysimeter during 2011-2012 irrigation period. The second objective is to find the difference in evapotranspiration between seasons.

II. MATERIALS AND METHODS

A. Location

The study area Tanjung Karang rice irrigation scheme (TAKRIS) lies between latitude 3^0 25' N and longitude $101^0$1' E (Fig. 1). It has an approximate area of 19,000 ha. stretching a length of 40 km long and 5 km wide [25]. It is a flat plain located on the coastal plain of Selangor State, Malaysia.

Fig. 1: Study site Tanjung Karang rice irrigation scheme

River Bernam which meanders northwestward of the State is the primary source of water for the canal in TAKRIS. The spatial and temporal details of the study site are summarized in Table 1. Each irrigation compartment consists of about 100 lots and the size of each lot is 1.2 ha (200 × 60) m [26]. The climate in Malaysia can be southwest/northeast monsoon and warm/humid seasons. Rice variety MR219 was commonly planted on the field under this study which matures within 80 - 110 DAT. For the purpose of this study data on ET was collected on the field during June - September, August to November 2011 for mid and wet (main or rainy) season and January to April, 2012 for off (dry) season respectively. These classifications are done to facilitate adequate irrigation scheduling and double cropping in different part of the scheme.

B. Lysimetric components

This study involved the use of microlysimeter for in situ measurement of evapotranspiration. The microlysimeter consists of two parts, the cylindrical lysimeter tank and the mariotte system. The tank 1.5 cm thick is made of polyvinyl-chloride (PVC) 60 cm height and 20.32 cm internal diameter. It has two side holes which are connected to the mariotte tube to drain excess water due to rainfall or other interference. The mariotte tube is made up of outer and inner glass tubes. The outer glass cylinder serves as a reservoir to replenish the depleted water from the tank. The inner glass tube is an air compensating tubing 0.82 cm outer diameter and 75 cm long.

C. Microlysimeter Installation

After site selection in the farm lot a 25 cm diameter auger was used to excavate the soil to a depth of 50 cm. Microlysimeter tank was lowered into the hole and the excavated soil was then used to refill in and around the tank. The soil in the tank was kept at the same level with the surrounding ground surface. The mariotte tube was then connected to the lower opening of the tank via flexible rubber tubing. All connections are made air - tight and leak proof. A stand clamp was used to give a mechanical support to the mariotte system. A rice hill was transplanted into the tank to represents the adjacent paddy environment with the same rice of hill per lysimeter as shown in Fig 2.

Fig. 2: Microlysimeter under field condition

The mariotte was gradually adjusted and water level drop in the outer mariotte tube was read from attached graduated tape. Water lost in 24 hours was obtained from the difference in water level between initial and reset readings. Farmers were trained on how to add water into the mariotte. The drop in water level measurements was taken by the farmers daily at 17:00 local time. Crop evapotranspiration ETc (mm/day) was calculated using equation (1):

$$ET_c = \frac{\left[\pi R^2 - \pi r^2\right]}{A}\Delta H \qquad (1)$$

Where:

R = inner radius of the outer mariotte tube (mm),

r = outer radius of the inner bubble tube (mm),

ΔH = change in water column height for a daily basis (mm) and

A = the effective cross sectional area of the lysimeter tank (mm^2).

D. Data analysis

Data analysis was achieved using SPSS® version 19. The descriptive statistical methods were used to determine the normality of the ET data in the study area. The statistical values of skewness and kurtosis and the Shapiro-Wilk (SW) were checked. One- way ANOVA between subject effects was used to test the null hypothesis that, there is no significance differences in the mean of ETc between rainy (R), mid (M) and the off (O) seasons.

III. RESULTS AND DISCUSSION

A. Rice Evapotranspiration (ET_c)

Table 1 showed the total number of ET data collected in TAKRIS between April, 2011 and February, 2012. For the period under study 880 ETc values are obtained during wet season in the entire irrigation scheme sector (August 15th, 2011 to February 28th, 2012). A total of 670 ETc data during mid-season (April 23rd, to August 10th, 2011) irrigation activities were from farm lots in both middle and downstream part of the scheme. While a total of 290 ETc data was taken in the upperstream from farm lots 1, 2, and 3 during off season between January 18th and May 4th, 2012. However due to the bulkiness of the data, an average ETc values of 10 days (88, 67 and 29) was considered (wet, mid and off season) for both analysis and normality test of data distribution.

B. The normality test of evapotranspiration data

The descriptive statistics of evapotranspiration for the farm lots in the study site is shown in Table 2. The result provides a summary of the mean, variance, standard deviation (SD), skewness and kurtosis values of ET for the ten farm lots. Evapotranspiration were determined at least twice in a year (wet, mid or dry season) for each farm lot. The mean ET ranged from 4.91 - 5.44 mm/d for rainy season, 4.93 - 6.21 mm/d mid-season and 4.87 - 5.34 mm/d for off season respectively. From Table 2 majority of the farms studied are far from the water source. Out of the 10 plots 7 are in the middle and downstream whereas farm lots 1, 2 and 3 are in the upperstream of the scheme. This was done to determine how sampling region (spatial) influences both evapotranspiration and water distribution across the scheme. The results show that the mean ET values are generally within the same range of 6.21 – 4.87 mm/d irrespective of their temporal and spatial variations. Off season irrigation activity was carried on 3 farms (lot N0. 1O3213, 2O3244 and 3O3334), located at the upperstream part of the scheme, near the main water source river Bernam. This enhances effective water distribution in the scheme during dry season and to avoid rice yield reduction.

The skewness of the ET values is presented in Table 3. The skewness values were within the conventional acceptable limit of ± 2 indicating that the data were normally distributed. They are in the range of 0.22 to -0.96, -1.79 to -0.80 and -1.59 to -0.45 for rainy, mid and off seasons respectively. It provides an indication of the symmetry of a distribution. Positive skew ET indicate too many low values in the distribution and negative skew value indicate a clustering of ET values at high to the right side of the graph. Both skewness and kurtosis are said to be normal with value approaching zero. The results of Shapiro-Wilk statistics in Table 3 was also used to assess the normality of ET data in the study site. The S-W was used because it has more power to detect differences from normality [27]. A significant p-value, p>0.05 indicates normality. From Table 3 lower p-values of 0.04 and 0.03 are obtained in farm lot 4R14692 and 1O3213. It was also clearly depicted in the box (horizontal line) plot in which the median is closer to the upper quartile (Fig. 3, 4 and 5).

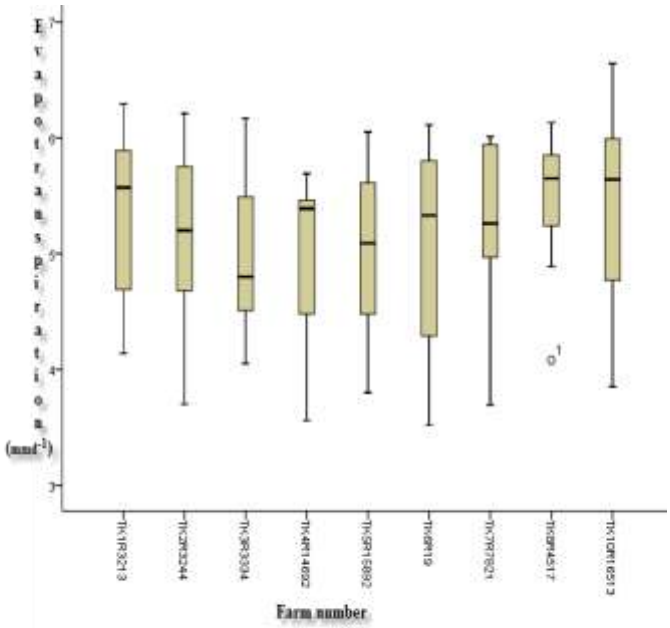

Fig. 3: Wet season box and whisker plot of evapotranspiration on paddy field

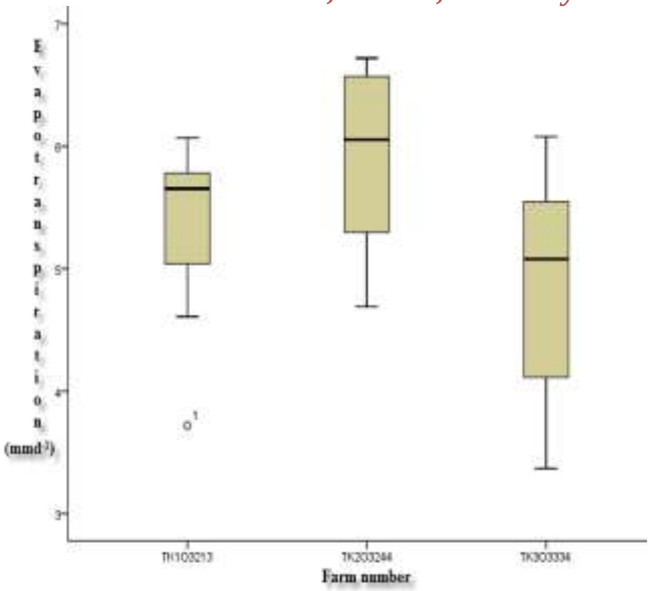

Fig. 5: Off season box and whisker plot of evapotranspiration on paddy field

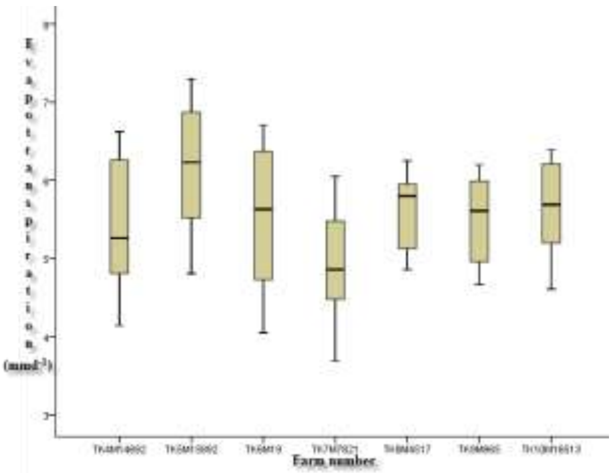

Fig. 4: Mid-season box and whisker plot of evapotranspiration on paddy field

However, the two points are quite small to violate the normality assumption considering the size of the evapotranspiration data [28]. The box and whisker plots are shown in Fig 3, 4 and 5. The box shows the paddy field ET distribution on temporal basis. The whiskers are lines protruding from the box along the vertical to the smallest and the largest ET values. From the entire field under study two outliers exist in farm 4517 and 3213 during wet and off seasons respectively. The ET values obtained are said to be normal as both the whiskers and the median (the line inside the box) are reasonably represented irrespective of irrigation season and farm lot proximity to the water source.

C. *Variation and strength of ET between seasons*

One way analysis of variance (1-way ANOVA) was conducted to explore any significant differences in the mean evapotranspiration between seasons. The hypothesis was set at 95% confidence interval (p = 0.05) H_o: there no difference in ET between seasons. H_n: there is difference in ET between seasons. Preliminary analysis was conducted to determine the assumption of normality, linearity and equality or homogeneity of variances. No violation noted since from the Levene's test, the sig. value was 0.93 greater than 0.05 and the descriptive statistics result gives correct information for each season. The 1-way ANOVA results in Table 4 shows that there was a statistically significant difference at the p< 0.05 level in ET data for the three seasons (F = 4.65 and p = 0.011). Despite reaching the statistical difference, the actual difference in the mean ET values between the seasons 5.05, 5.47 and 5.24 mm/d was quite small The hypothesis was therefore supported and the strength of association or effect size, calculated using $\eta^2 = SS_{between\ season}/SS_{total}$, was 0.05 considered [29] as small effect. Cohen classifies η^2 = 0.01 as a small effect, 0.06 as a medium effect and 0.14 as a large effect respectively. Post-hoc comparison applied using Tukey

HSD, Scheffe and Bonferroni test indicated that the mean ET values for wet season (M = 5.05 mm/d, SD = 0.84) was significantly different from mid-season (M = 5.47 mm/d, SD = 0.85). Off season (M = 5.24 mm/d, SD = 0.90) did not differ significantly from either wet or mid-season. Table 5 shows the mean difference and significant levels for both wet and mid seasons using Turkey (-0.42123*, p = 0.007), Scheffe (-0.42123, p = 0.011) and Bonferroni (-0.42123, p = 0.008).

IV. CONCLUSION

The results of this study show that there is good water management in the TAKRIS. Water distribution as well as the irrigation scheduling has effectively facilitated double cropping with minimum pressure on the water resource. It is evident from Table 1 that during wet season irrigation activities have taken place in all the compartments but during mid-season only farm lots in Sekinchan, Sungai Leman and Sungai Besar in the middle and downstream part of the river participated. However, during dry season in which water shortage was likely to cause decline in rice yield, irrigation activity was allowed (scheme authority) only in compartment C Sawah Sempadan near the upper stream water source.

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Table 1: Spatial and temporal details of irrigation sites in the study area

S/N0	Irrigation Compartment	Proximity to Bernam river	Farm lot N0.	No of ET measured per season			Farm coordinate	
				Rainy (R)	Mid (M)	Off (O)	Latitude	Longitude
1	Sawah Sempadan	Upperstream	3213	100	-	110	3^0 27' 56” N	101^0 13’ 05”E
			3244	100	-	100	3^0 27' 42” N	101^0 12’ 55”E
			3334	100	-	80	3^0 26' 58” N	101^0 12’ 41”E
2	Sekinchan	Middlestream	14692	100	90	-	3^0 31' 51” N	101^0 7’ 21”E
			15892	90	90	-	3^0 32' 59” N	101^0 06’ 45”E
3	Sungai Leman	Middlestream	19	90	90	-	3^0 35' 50” N	101^0 04’ 04”E
			7821	100	90	-	3^0 38' 42” N	101^0 04’12”E
4	Sungai Besar	Downstream	4517	100	100	-	3^0 42' 49” N	101^0 01’ 12”E
			965	-	100	-	3^0 43' 38” N	101^0 01’ 45”E
			16513	100	110	-	3^0 40' 26” N	101^0 01’24”E

Table 2: Descriptive statistics of evapotranspiration (mm/d) values for paddy field

Season					***Rainy season (R)***					
Farm S/N	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**10**	
Farm ID N0*	3213	3244	3334	14692	15892	19	7821	4517	16513	
Mean	5.24	5.09	4.97	4.91	5.07	5.06	5.21	5.44	5.44	
Variance	0.61	0.71	0.54	0.64	0.54	0.89	0.60	0.41	0.91	
SD	0.78	0.84	0.74	0.80	0.74	0.94	0.77	0.64	0.95	
Skewness	-0.21	-0.46	0.22	-0.96	-0.45	-0.53	-0.91	-1.32	-0.52	
Kurtosis	-1.67	-0.89	-1.16	-0.68	-0.69	-1.22	0.46	1.68	-0.87	
Season				***Mid-season (M)***				***Off season (O)***		
Farm S/N	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**1**	**2**	**3**
Farm ID N0*	14692	15892	19	7821	4517	965	16513	3213	3244	3334
Mean	5.41	6.21	5.58	4.93	5.58	5.48	5.66	5.34	5.91	4.87
Variance	0.79	0.85	0.92	0.61	0.25	0.36	0.37	0.62	0.62	0.86
SD	0.89	0.92	0.96	0.78	0.50	0.60	0.61	0.78	0.79	0.93
Skewness	0.09	-0.47	-0.43	-0.29	-0.22	-0.16	-0.47	-1.59	-0.76	-0.45
Kurtosis	-1.34	-1.32	-1.36	-0.90	-1.80	-1.79	-0.87	1.98	-0.91	-0.86

*as identified by TAKRIS

Table 3: Normality test for ET data using Shapiro-Wilk significance

Rainy season	p-value	Mid-season	p-value	Off season	p-value
1R3213	0.34	4M14692	0.63	1O3213	**0.03**
2R3244	0.65	5M15892	0.32	2O3244	0.16
3R3334	0.54	6M19	0.40	3O3334	0.83
4R14692	**0.04**	7M7821	0.79		
5R15892	0.82	8M4517	0.24		
6R19	0.39	9M965	0.29		
7R7821	0.28	10M16513	0.61		
8R4517	0.23				
10R16513	0.66				

Table 4: Results of One-way ANOVA

Evapotranspiration	SS	*df*	MS	F	P-value
Between season	6.751	2	3.375	4.647	0.011
Within season	131.481	181	0.726		
Total	138.231	183			

Table 5: Multiple comparison between paddy field ET and 3 seasons

	(I) Farm	(J) Farm	Mean Difference (I-J)	Std. Error	p value.
Tukey HSD	Wet season	Mid season	**-0.42123***	0.13819	**0.007**
		Off season	-0.18991	0.18249	0.552
	Mid season	Wet season	0.42123*	0.13819	0.007
		Off season	0.23132	0.18945	0.442
	Off season	Wet season	0.18991	0.18249	0.552
		Mid season	-0.23132	0.18945	0.442
Scheffe	Wet season	Mid season	**-0.42123***	0.13819	**0.011**
		Off season	-0.18991	0.18249	0.583
	Mid season	Wet season	**0.42123***	0.13819	0.**011**
		Off season	0.23132	0.18945	0.476
	Off season	Wet season	0.18991	0.18249	0.583
		Mid season	-0.23132	0.18945	0.476
Bonferroni	Wet season	Mid season	**-0.42123***	0.13819	**0.008**
		Off season	-0.18991	0.18249	0.898
	Mid season	Wet season	**0.42123***	0.13819	**0.008**
		Off season	0.23132	0.18945	0.671
	Off season	Wet season	0.18991	0.18249	0.898
		Mid season	-0.23132	0.18945	0.671

*The mean difference is significant at **0.05**.