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Estimating Evapotranspiration of Paddy Field and Teak Plantation Using Remote Sensing

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ABSTRACT

The objective of this study was to investigate suitable models that can estimate actual evapotranspiration (ET_a) by using remote sensing data. To achieve this, the study compared evapotranspiration in a paddy field in Sukhothai with a teak plantation in Lampang using remotely sensed data. The investigation period covered two years and eight months from January 2002 to September 2004. 17 AVHRR images from NOAA/ satellite were used for the study.

It was found that the relationship between ET_a and remote sensing parameters such as normalized difference vegetation index (NDVI), land surface temperature (LST) and surface albedo (Sur_alb) of each site, were highly significant. The suitable model for each site and each period were as follows: in the paddy field for the whole period ET_a = -1.21+ 0.73 (NDVI) + 0.19 (LST) + 4.02 (Sur_alb), $r^2 = 0.71$, during rice planting season ET_a = 3.99 + 0.83 (NDVI) + 0.01 (LST) +1.61(Sur_alb), $r^2 = 0.65$ and after rice planting season ET_a = -1.93 + 1.42 (NDVI) + 0.2 (LST) + 7.44 (Sur_alb), $r^2 = 0.85$.

The derived equation for the teak plantation was ET_a = -2.87 + 0.18 (NDVI) + 0.27 (LST) + 0.57(Sur_alb): $r^2 = 0.4$, rainy season ET_a = 3.7 - 0.60 (NDVI) + 0.07 (LST) + 4.57 (Sur_alb) , $r^2 = 0.64$. In addition, the best suited equation for the dry season was ET_a = -4.23-0.0004(NDVI)+0.37(LST)-5.8 (Sur_alb), $r^2 = 0.60$.

It can be concluded that the remote sensing approach is applicable for ET_a estimation. Advantages of using remote sensing are that it provides spatial distribution for large-areas and it is relatively easy to find out NDVI, surface albedo and surface temperature when compared to other measurement methods.

Key words: evapotroanspiration, poddy field, plantation, remote sensing

INTRODUCTION

In a tropical region like Thailand where 90% of the mean annual rainfall occurs during April to October, the exploration and evaluation of water resource potential is essential for finding ways to store and meet demand for water throughout the year. Only 30% to 40% of annual rain water becomes subsurface and surface flow. Over a period of one year, changes in ground water storage is very small, and can be neglected. A major portion of the rain water fluxes as evapotranspiration. Accurate estimations of evapotranspiration indirectly evaluates the water resource potential for our use. Although evapotranspiration is influenced by geology,

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topography and climate it primarily depends on the types and density of vegetation. This is because evapotranspiration correlates to vegetative activities. Evapotranspiration is a limiting factor influencing soil moisture variation. The variation of soil moisture indicates the status of the watershed including its vulnerability to floods and drought.

The development of Geographic Information Systems (GIS) and Remote Sensing (RS) technology has proved that vegetation has a good response in the reflective region of electromagnetic spectrums, registered from the AVHRR sensor of satellite. Therefore, the relationship between vegetative activity and spectral reflectance from vegetation can allow the estimatation of evapotranspiration in wide areas over certain periods. The method has considerable benefits as it integrates all the spatial variations of evapotranspiration over a catchment.

Paddy fields and teak plantations represent the major land use in northern Thailand. These two types of land use usually consume a great amount of water from almost of large watersheds in Northern Thailand. Therefore, it is worthwhile to investigate evapotranspiration losses from these land use types for the benefit of future water yield management.

The objective of this study was to establish the relationship between evapotranspiration, remote sensing data and micrometeorological data of these two land use types, and then to determine suitable models that can estimate actual evapotranspiration by using remotely sensed data.

MATERIALS AND METHODS

1. Site selections

This study used materials and the sites from the GAME-T project (A Thailand and Japan collaborative project studying energy and water balance). The sites were a paddy field at Amphoe Muang, Changwat Sukhothai and a teak plantation at Amphoe Mae Moh, Changwat Lampang. Both these sites have had an automatic weather station (AWS) installed since 1997 (Figure 1)

2. Data collection

2.1 AWS data

A thirty-two channel data recorder was developed to collect and transmit data measured

(a) Paddy field (b) Teak plantation

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

by the various sensors. Data was recorded every one minute and collected by the data logger to obtain an average based on ten minutes collection. The data logger has a function which allows approximately 11 days storage of data. The data collected for this study is from January 2002 to September 2004.

2.2 Remote sensing data

This was gathered from NOAA-AVHRR satellite image data during 2002-2004, from internet downloads provided by the Yasuoka Laboratory, Institute of Industrial Science, University of Tokyo, Japan. The downloaded data was already processed automatically. The data collected from this website belonged to the Asia Institute of Technology (AIT), Pathum Thani , Province.

3. Analyzing evapotranspiration and remote sensing parameters

3.1 Normalized Difference Vegetation Index (NDVI)

The most common vegetation indices are the simple ratio of near-infrared to visible radiance. By AVHRR sensor, NOAA-14 collects data in a range of near-infrared through channel 1 and in a range of visible region through channel 2 The NDVI index in equation 1 can be written as:

$$NDVI = \frac{NIR - Vis}{VIS + NiR} \quad (1)$$

Where NDVI is Normalized Difference Vegetation Index

NIR is Near Infrared

VIS is Visible light

3.2 Surface albedo (Sur_alb)

Albedo is the ratio of reflected to incident solar radiation at the surface and is computed as the ratio of outgoing short wave radiation to incoming short wave radiation. The reflectivity of a surface is wavelength-dependent and for high accuracy data the site needs to be homogeneous as was the case in both the paddy field and teak plantation.

The broadband albedo (a) is calculated as Valiente *et al*. (1995)

$$\alpha = 0.545\rho_{ch1} + 0.32\rho_{ch2} + 0.035 \quad (2)$$

Where ρ_{ch1} is the spectral surface reflectance in channel 1

ρ_{ch2} is the spectral surface reflectance in channel 2

The solar energy reflectance might differ from surface reflectance values. For this the calibration used was as follows:

$$\alpha_0 = \frac{\alpha_p - \alpha_{path\_radiance}}{\tau_{sw}^2} \quad (3)$$

Where α_0 = surface albedo (%)

α_p = broadband albedo (%)

$\alpha_{path\_radiance}$ = reflectance from top of atmosphere through satellite(%)

τ_{sw}^2 = one-way transmittance(%)

3.3 Surface temperature (LST)

Surface emissivity and radiance temperature in the thermal band are required to estimate surface temperature. Surface emissivity is a factor that describes how efficiently the surface radiates energy compare to blackbody (Lillesand and Kiefer, 1987). The normalized difference vegetation index (NDVI), one of the vegetation indices, was used to estimate surface emissivity (ε_0) according to following equation:

$$\varepsilon_0 = 1.0094 - 0.0047 \ln(NDVI) \quad (4)$$

Where ε_0 = surface emissivity

NDVI = Normalized difference index

Following this the surface temperature of NOAA-AVHRR can be described by the split-window technique as follows:

$$LST = a_0 (T_4)^2 + a_1 (T_4) + a_2 (T_4 - T_5) + a_3 (T_5) + a_4 (T_5)^2 + offset \quad (5)$$

Where LST = surface temperature (^0K)

T_4 = brightness temperature from band 4 of NOAA-AVHRR (^{0}K)

T_5 = brightness temperature from band 5 of NOAA-AVHRR (^{0}K)

3.4 Estimation of actual evapotranspiration (ETa) by remote sensing data

Actual evapotranspiration was estimated by using remotely sensed data from the paddy field and teak plantation in the form of the functional relationship as follows:

$$ETa = f(NDVI, LST, Sur\_alb) \quad (6)$$

$$ETa = a + bNDVI + cLST + dSur\_alb \quad (7)$$

$$ETa = a + bTa + cRH + dpF + eRn + fWs + gNDVI + hLST + iSur\_alb) \quad (8)$$

Where Ta = air temperature (^{o}C)
RH = relative humidity (%)
pF = soil moisture tension
Ws = wind speed (m/s)
NDVI = normalized difference vegetation index
LST = surface temperature (^{o}K)
Sur_alb = surface albedo (%)

RESULTS AND DISCUSSION

In this study, the remote sensing technique was utilized to extract the normalized distribution vegetation index (NDVI), land surface temperature (LST) and surface albedo. These indices were then used for statistical analysis and for establishing the coefficient of determination (r^2) with evapotranspiration by using the Bowen ratio technique. Analysis of variance (ANOVA) was used for testing significance of the equation for estimating evapotranspiration.

1. Normalized distribution vegetation index (NDVI)

The analysis of NDVI during August 2002 to December 2003 used 17 images and each image consisted of ten days composite data. The NDVI can be classified by five groups: Group 1 between -1.0 – 0.0, Group 2 between 0.0 – 0.2, Group 3 between 0.2-0.4, Group 4 between 0.4-0.6 and Group 5 between 0.6-1.0. The results showed that the average of NDVI in the paddy field was almost 0.0-0.2 and followed by 0.2-0.47 while in the teak plantation the average of NDVI was almost 0.3-0.4 and 0.4-0.6 (Table 1).

The variation of the average NDVI throughout the 17 satellite images is shown in Table 1. The results indicated that NDVI in the paddy field varied from -0.98 in December to 0.75 in September with an average of 0.00218. In the teak plantation the daily average NDVI was 0.36 (lowest -0.23 in January and highest 0.95 in October). In the rice planting season, the results showed that the variation of the average NDVI during August 2002 to December 2003 was 0.33 while in the off-planting season it was -0.29. Therefore in the planting season there was canopy reflectance of rice that allowed more chlorophyll to be detected from the satellite receiver than was the case during the off-planting season which showed only bare soil reflecting. Furthermore, the teak plantation had a higher NDVI than in the paddy field with a daily average during the study period of 0.36. During the wet and dry season the daily average of NDVI was 0.57 and -0.37 respectively. This was due to teak being deciduous and the subsequent leaf fall during the dry season.

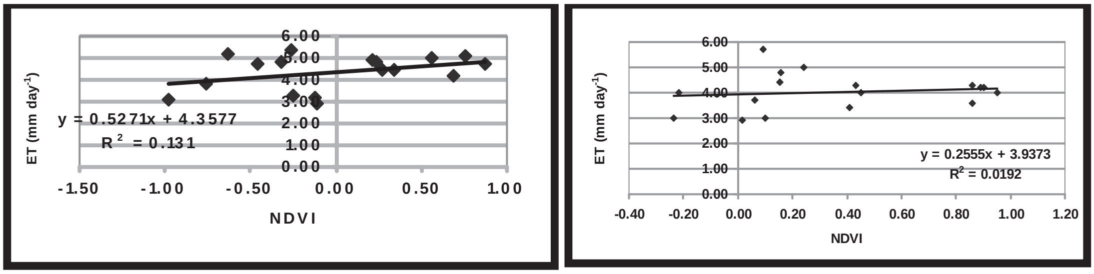
For the relationship between NDVI and ET, the results found that the relationship between daily average ET and daily average NDVI in the paddy field was not significant. For the paddy field, the coefficient of determination (r^2) was 0.131 and in the teak plantation the coefficient of determination (r^2) was 0.0192. The results indicated no significance between NDVI and ET in both sites (Figure 2). It could be said that NDVI had a minimal effect on ET_a and the main limiting factors are soil and climatic factors.

2. Land surface temperature

The land surface temperature (LST) was obtained from 17 satellite images by using the split window technique, derived by Ulivieri *et al*. (1994). Kite and Droogers (2000) and Valiente *et al*. (1995) reported that this technique showed the lowest variance value and less mistakes than other procedures.

Table 1 Actual evapotranspiration, NDVI, surface temperature and surface albedo of paddy field and teak plantation.

Year	Date	ET		NDVI		Surface temp (°C)		Surafce albedo (%)	
		Paddy field	Teak plantation	Paddy field	Teak plantation	Paddy field	Teak plantation	Paddy field	Teak plantation
2002	22 August	4.50	4.00	0.27	0.45	26.10	24.80	0.18	0.15
	15 September	5.00	4.20	0.56	0.89	27.90	26.10	0.12	0.19
	5 October	4.20	4.20	0.69	0.90	27.50	24.00	0.10	0.18
	20 November	4.50	3.60	0.34	0.86	26.00	23.90	0.13	0.16
2003	1 December	2.90	3.00	-0.11	0.10	24.90	21.90	0.09	0.17
	16 January	3.30	3.00	-0.25	-0.23	23.90	22.10	0.04	0.19
	4 Februry	3.20	4.00	-0.12	-0.22	22.80	25.90	0.12	0.20
	7 March	3.80	3.70	-0.76	0.06	28.20	27.70	0.18	0.25
	17 April	5.20	5.70	-0.63	0.09	31.90	27.20	0.23	0.23
	1 May	5.40	4.80	-0.26	0.16	28.10	25.00	0.24	0.24
	16 June	4.70	5.00	-0.46	0.24	30.40	24.30	0.19	0.19
	1 July	4.80	4.40	-0.33	0.15	28.30	23.50	0.16	0.16
	16 August	4.80	4.30	0.24	0.43	25.50	25.10	0.12	0.12
	1 September	5.10	4.30	0.75	0.86	28.60	25.00	0.11	0.16
	16 October	4.70	4.00	0.87	0.95	26.60	24.30	0.08	0.17
	7 November	4.90	3.40	0.22	0.41	26.10	23.30	0.06	0.18
	23 December	3.10	2.90	-0.98	0.02	25.00	22.40	0.04	0.16
	Average	4.36	4.03	0.00218	0.36	26.93	24.50	0.13	0.18
	Planting season	4.53	-	0.33	-	26.59	-	0.10	-
	Off planting	4.20	-	-0.29	-	27.17	-	0.15	-
	Wet season	-	4.20	-	0.57	-	24.48	-	0.17
	Dry season	-	3.68	-	-0.37	-	26.34	-	0.13



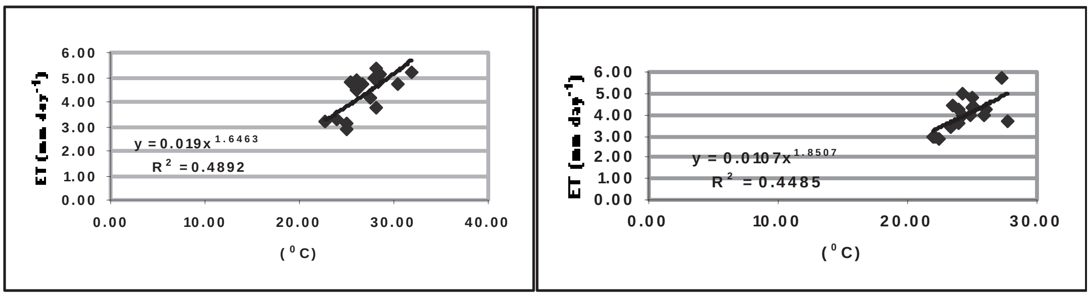
(a) Paddy field (b) Teak plantation

Figure 2 The relationship between ET and NDVI in paddy field (a) and teak plantation (b).

The surface temperature in the paddy field throughout the whole study period showed that the daily average ranged from 22.8°C to 31.9°C with an overall average of 26.93°C. In th2e teak plantation surface temperature ranged from 21.90°C to 27.7°C with an average of 24.5°C. In the paddy field, the highest surface temperature was recorded in April and the lowest in February. For the teak plantation, the highest was found in March whilst December provided the lowest surface temperature.

Table 1 shows that in the rainy season the daily average surface temperature was 26.5°C, while in the off-planting season the daily average was 27.17°C. For the teak plantation, during the wet season the daily average surface temperature was 24.48°C whilst in the dry season the daily average was 26.34°C. Therefore during the planting season, water was contained submerged in the soil. During the off-planting period there was less soil moisture and no rainfall causing the higher surface temperatures. The results were similar for the teak plantation which showed high surface temperatures in the dry season and low surface temperatures in the wet season.

Between surface temperature and ET, the results showed a moderate relationship for the paddy field with the coefficient of determination (r^2) at 0.49 while in the teak plantation it was 0.45. The surface temperature is a considerable limiting factor of ET_a at approximately 50% (Figure 3).



(a) Paddy field (b) Teak plantation

Figure 3 The relationship between ET and surface temperature in paddy field (a) and teak plantation (b).

The values of estimated LST and actual ground temperature in both stations are found in Figure 4. It could be said that estimated LST is closely correlated with measurement LST in both sites. The relationship between estimated LST and measurement LST was approximate 80% .

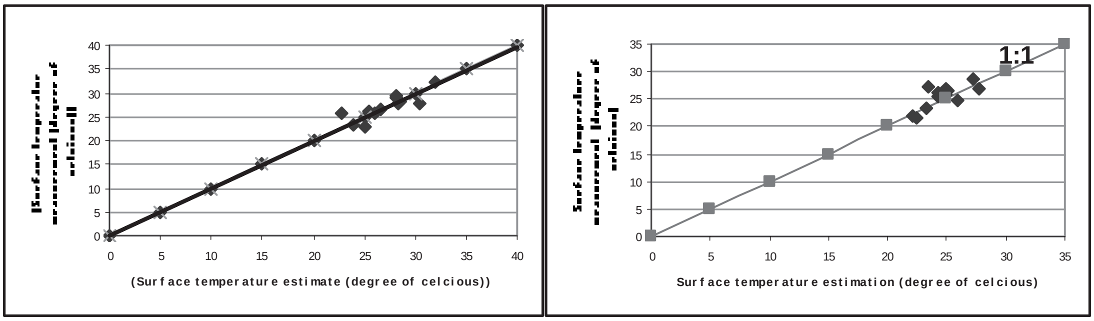
3. Surface albedo

The surface albedo of the 17 different images in both sites was derived from using the weighting method of the reflectance from NOAA/ AVHRR band 1 and band 2 based on Valiente *et al*. (1995). This method showed the average reflectance in the visible range and NIR.

In the paddy field the estimated surface albedo ranged from 0.04 to 0.24%. The highest surface albedo (0.24%) was presented in May (summer season) with high radiation and temperature. The lowest surface albedo was 0.04% in December and January and when rice growth covered the water surface causing low emissivity.

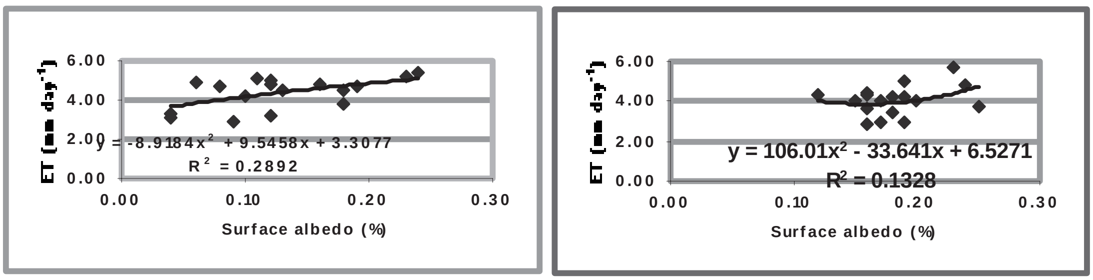
In the teak plantation, surface albedo ranged from 0.12 to 0.25%. The highest surface albedo (0.25) was in March when it was dry and leaves fell. The lowest surface albedo was found in August (0.12%) which is the rainy season, and when leaf fall from the teak canopy decreases the reflectance of emissions, thus causing less surface albedo (Table 1).

Regarding the relationship between surface albedo and ET_a, the results showed that it was not significant in both sites. The coefficient of determination, r^2 in paddy field was 0.29 while in teak plantation it was 0.13 (Figure 5).



(a) Paddy field (b) Teak plantation

Figure 4 Comparison between estimation and measurement of surface temperature in paddy field (a) and teak plantation (b).



(a) Paddy field (b) Teak plantation

Figure 5 The relationship between ET and surface temperature in paddy field (a) and teak plantation (b).

4. Statistical analysis

The statistical analysis between the dependent parameter (ET) and independent parameters (NDVI, LST and surface albedo) was established using satellite image data. To establish the relationship between the ET and RS, data in the same space and time, was studied using multiple regression analysis resulting in the coefficient of determination (r^2). The ANOVA variance analysis was used to find the significance of the equation. The result can be described as follows:

4.1 Paddy field

The average relationship between the ET and RS data in years 2002 and 2003 revealed a highly significant relationship between ET and RS parameters ($r^2 = 0.71$). The significant prediction model is shown in the equation below:

$ETa = 1.21 + 0.73(NDVI) + 0.19(LST) + 4.02(Sur\_alb)$: $r^2 = 0.71$

From the above model, it seems not logical, due to the single relationship between NDVI and ET_a was insignificant but effect of NDVI on ET_a was shown high in multiple equation. These are the limitations of this equation. In case there is a need to use this equation, using only positive NDVI should be considered.

(1) Rice planting season

The r^2 of the relationship between the ET and RS parameters was 0.65 and the equation is shown below:

$ETa = 3.99 + 0.83(NDVI) + 0.01(LST) + 1.61(Sur\_alb)$: $r^2 = 0.65$

The factors which affected ET are the same as for the whole year equation. Because of the strong relationship with NDVI and weak relationship with surface temperature, the r^2 of this equation was a little less than whole year equation ($r^2 = 0.65$).

(2) Off rice planting season

The r^2 of the relationship between the ET and RS parameters was 0.85. The significant prediction model is shown in equation below:

$ETa = 1.93 + 1.42(NDVI) + 0.2(LST) + 7.44(Sur\_alb)$: $r^2 = 0.85$

From the above model, it can be said that the trend in the off-rice planting season was similar to that of the whole period equation (NDVI and surface albedo in this period played a significant role on ET_a). The surface albedo had the most influence on the equation. However, it seems not logical and this model must be selected only if NDVI has a positive value.

4.2 Teak plantation

The r^2 of the relationship between the ET_a and RS parameters was 0.41. The significant prediction model is shown in the equation below:

$ETa = 2.87 + 0.18(NDVI) + 0.27(LST) + 0.57(Sur\_alb)$: $r^2 = 0.41$

All the RS data recorded throughout the year was used in the model derived for predicting daily ET_a in the teak plantation. It could be said that the surface albedo had the strongest effect on ET_a followed by surface temperature and NDVI respectively.

(1) Rainy season

The r^2 of the relationship between the ET and RS parameters was 0.64 and the equation is shown as:

$ETa = 3.7 - 0.60(NDVI) + 0.07(LST) + 4.57(Sur\_alb)$: $r^2 = 0.64$

From the above model, the rainy season showed the highest correlation for predicting ET by using RS data ($r^2 = 0.64$). During this period the highest effect on ET was surface albedo, NDVI and surface temperature respectively.

(2) Dry season

The r^2 of the relationship between the ET and RS parameters was 0.60. The significant equation is shown as:

$ETa = -4.23 - 0.0004(NDVI) + 0.37(LST) - 5.8(Sur\_alb)$: $r^2 = 0.60$

In the dry season, there was less of a relationship between NDVI and ET when compared with other period models. The main effect on ET was surface albedo and the coefficient of determination (r^2) was approximately 60%.

5. Evaporative fraction (EF)

The evaporative fraction which influenced the soil moisture index ranged from 0 to 1. The highest EF value meant a wet surface, the wet season, and maximum soil moisture (H = 0). The lowest EF values meant a dry surface, the dry season, and minimum soil moisture (LE = 0). EF was the constant value for the evapotranspiration index and should be used as the primary parameter for establishing evapotranspiration. The EF parameter can be estimated by the following equation:

$$E = \frac{Rn - G - H}{\lambda}$$

In the paddy field, for the variation of the average evaporative fraction (EF) throughout the 17 images, it was found that EF ranged from 0.2 – 0.98 in December and April with an average of 0.66. During the planting period and off-planting season the variation average of EF was 0.75 and 0.57, respectively.

In addition, the variation of the average EF in the teak plantation throughout the study period ranged from 0.1–0.98 in January and April, respectively and with an average of 0.63. The average of EF in the wet season was 0.70 while in the dry season it was 0.54.

6. Estimation evapotranspiration (ETest)

In the paddy field, the results showed that the highest value of ETest was found in April (5.096 MJ m^{-2} day^{-1}) and the lowest value was found in January (0.396 MJ m^{-2} day^{-1}). In the teak plantation the highest value of ETest was found in April (5.586 MJ m^{-2} day^{-1}) and the lowest value was found in January (0.3 MJ m^{-2} day^{-1}). The explanation is shown in Figures 6-7.

Furthermore, in the paddy field the daily average estimated ET throughout the study period was 3.06. During the planting season it was 3.58 mm day^{-1} and during the off-planting season it was 2.6 mm day^{-1}. On the other hand, in the teak plantation the daily average of ETest was 2.75. During the wet season the daily average of ETest was 3.2 whilst in the dry season it was 2.23.

6.1 The relationship between estimated ET (ETest) and measurement ET (ETmea)

The results indicated that the relationship between daily average ETest and ETmea in the paddy field was highly significant with a high determination of correlation (r=0.80). In the teak plantation the results were similar with the paddy field (r=0.86) (Figure 8). The close relationship between estimated ET and measurement ET was due to using the same energy balance approach. When using the same surface parameters such as temperature and albedo that affected the calculated ET.

CONCLUSION

The application of remote sensing for estimating ET_a involved using satellite image analysis (NOAA/AVHRR). For the study these images covered the Sukhothai paddy field and Lampang teak plantation from January 2002 to August 2004, and a period with a lot of clear sky. The different data was classified by using a frequency histogram analysis. Land use types were classified by using the unsupervised classification method. Plant cover was classified by using the NDVI parameter. They can be briefly concluded as follows:

1. NDVI

Based on the vegetation index detected from the remote sensing data, it implied the changing of crown cover in studied area where AWS installed. Overall, the NDVI in the paddy field ranged from -0.98 to 0.87 with an average of 0.002 and in the teak plantation it ranged -0.23 to 0.95 with average of 0.36.

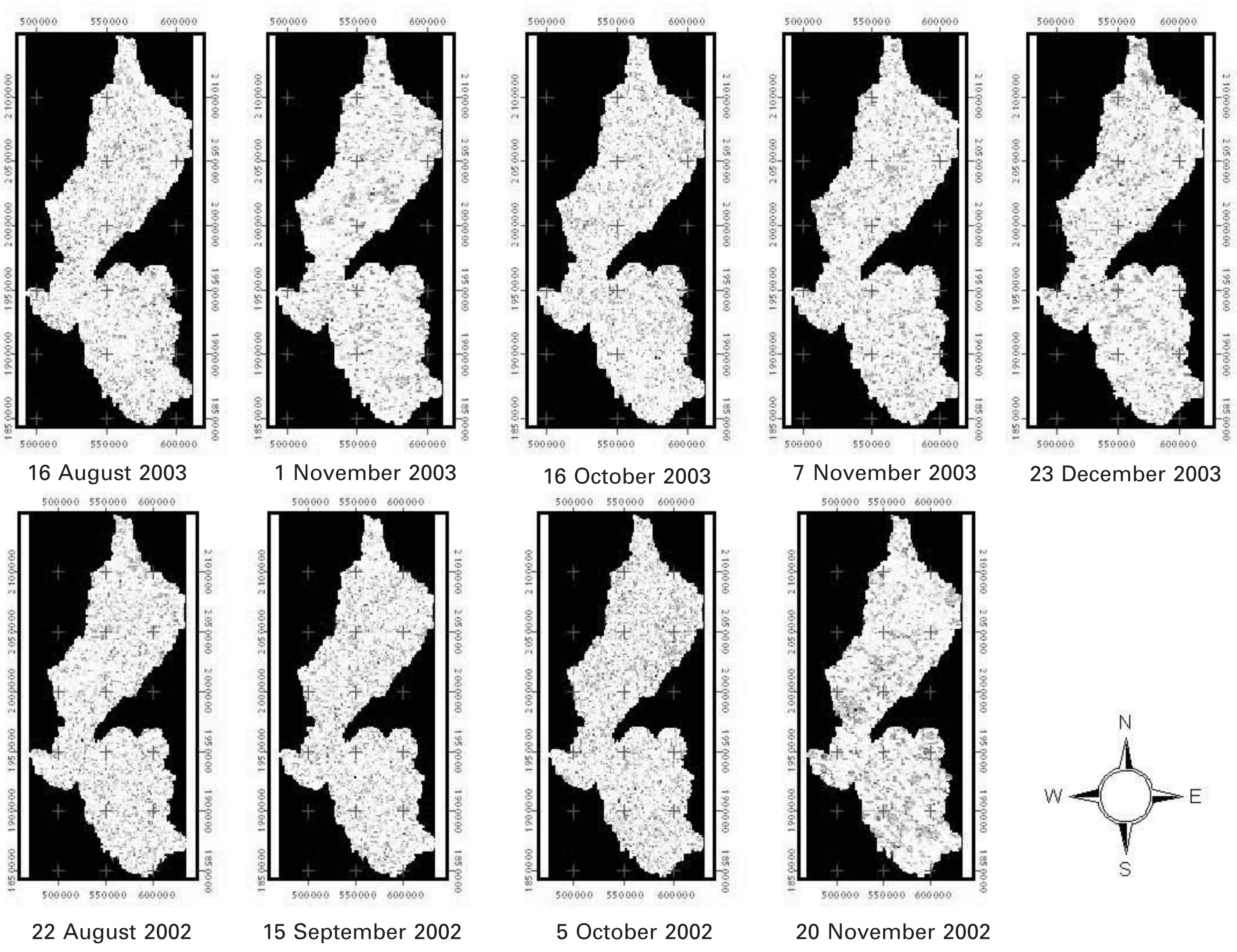


Figure 6 Estimation evapotranspiration (ETest) of paddy field and teak plantation during 16 Aug. – 20 Nov. 2003.

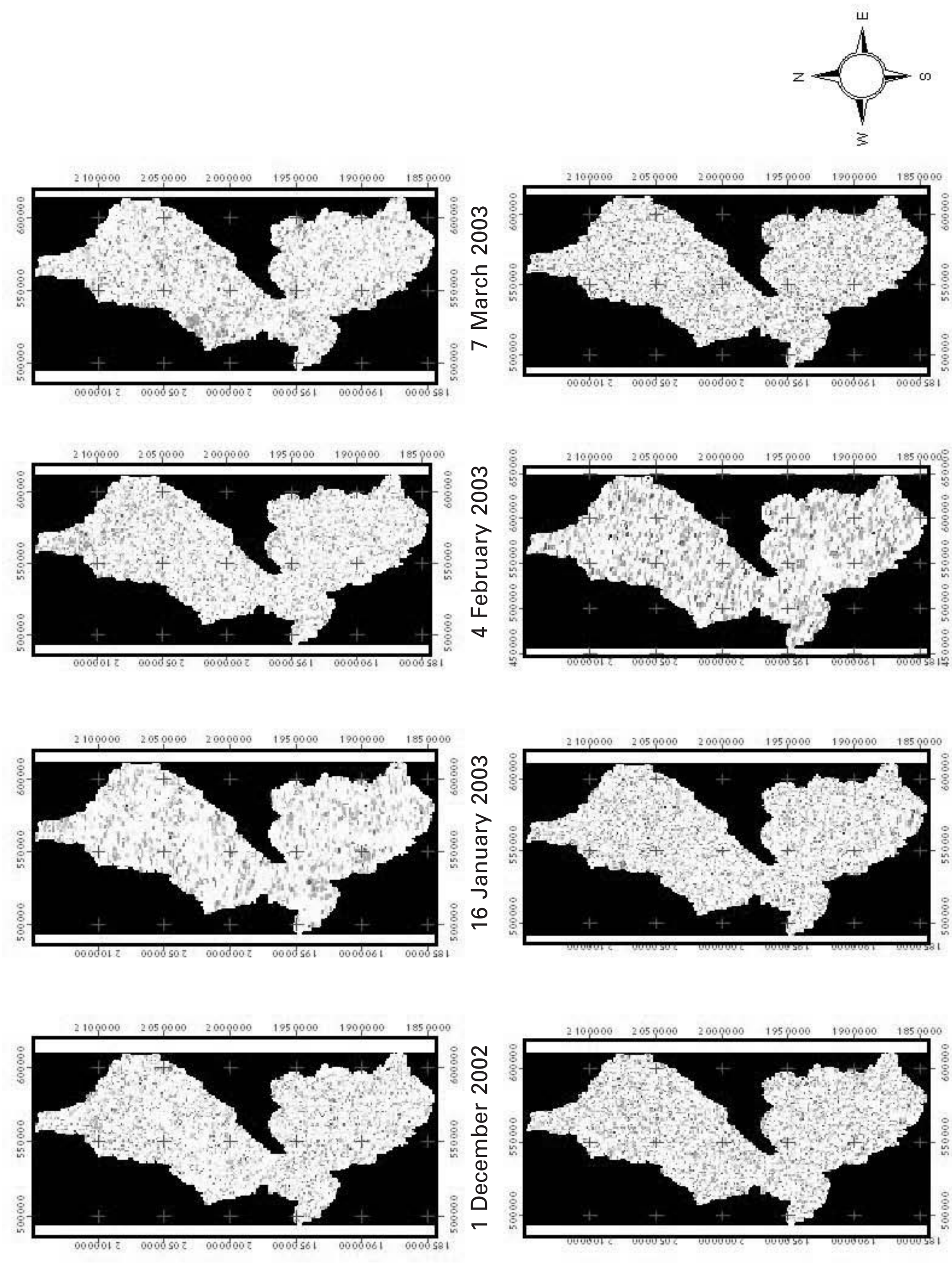
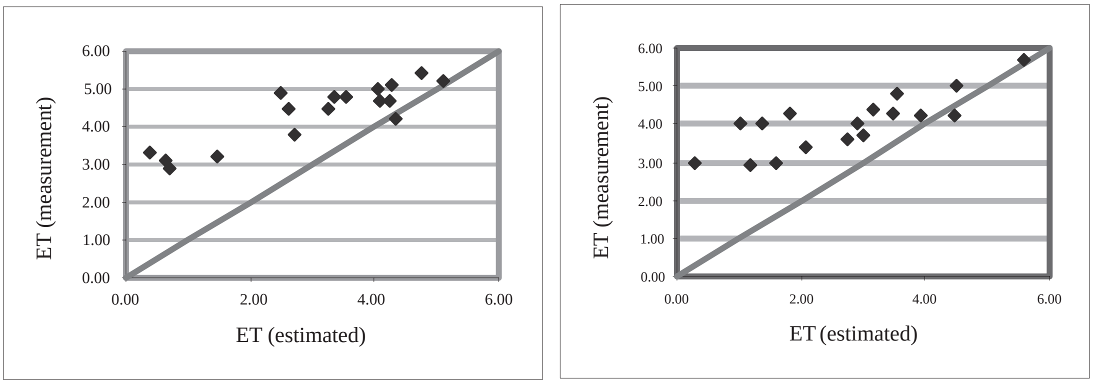


Figure 7 Estimation evapotranspiration (ETest) of paddy field and teak plantation during 1 Dec. 2002 – 1 Jul. 2003.



(a) Paddy field (b) Teak plantation

Figure 8 Relationship between ET (measurement) and ET (estimated) in paddy field (a) and teak plantation (b).

2. Surface temperature

The surface temperature calculated from the remote sensing data showed the reflectance of heat near the surface, with different degrees of skin temperature of the crown cover in the AWS area. For the paddy field, the indicated daily average of surface temperature ranged from 22.8 to 31.9°C with an average of 26.93°C. In the teak plantation it ranged from 21.9°C to 27.7°C with an averaged of 24.5°C.

3. Surface albedo

The surface albedo showed the reflecting of short waves which depended on various surface types. It can be concluded that the daily average of surface albedo in the paddy field ranged from 0.04 to 0.24% with an average of 0.13%. In the teak plantation it ranged from 0.12 to 0.25% with an average of 0.18%.

4. Estimation of evapotranspiration by using remote sensing data

The mathematical models of the actual evapotranspiration in the paddy field and teak plantation were derived from remote sensing data every few days and are shown as follows:

1) Paddy field

The suitable model throughout the period was:

$ET = -1.21 + 0.73(NDVI) + 0.19(LST) + 4.02(Sur\_alb)$: $r^2 = 0.71$

The suitable model in the rice planting season was:

$ET = 3.99 + 0.83(NDVI) + 0.01(LST) + 1.61(Sur\_alb)$: $r^2 = 0.65$

The suitable model in the off rice planting season was:

$ET = -1.93 + 1.42(NDVI) + 0.2(LST) + 7.44(Sur\_alb)$: $r^2 = 0.85$

2) Teak plantation

The suitable model throughout the period was:

$ET = -2.87 + 0.18(NDVI) + 0.27(LST) + 0.57(Sur\_alb)$: $r^2 = 0.41$

The suitable model in the dry season was:

$ET = -4.23 - 0.0004(NDVI) + 0.37(LST) - 5.8(Sur\_alb)$: $r^2 = 0.60$

The suitable model in the rainy season was:

$ET = 3.7 - 0.60(NDVI) + 0.07(LST) + 4.57(Sur\_alb)$: $r^2 = 0.64$

RECOMMENDATIONS

1. From this study

1) The ET_a equation based on satellite image data depends on the resolution of the satellite image. Images need to be focused on specific land use types relevant to the study because to ensure accurate parameters for evapotranspiration predictions. Some parts of the image which have various land use types may cause a difference between the calculation data and direct measurement.

2) Remote sensing data is useful and measurements could estimate water vapor flux by using indirect parameters such as NDVI, surface albedo and surface temperature. Therefore, further study on this point is recommended.

2. For future studies

1) A future study should select more satellite image data periods in order to better explain the values in each season throughout the year.

2) The analysis of satellite images found that some part of the images had cloud cover and therefore future studies must select clear sky images for more accurate data.

3) When using NOAA/AVHRR, studies should select land use areas that have more than three square kilometers to avoid incorrections during re-sampling.

4) Other parameters which affect ET should be considered such as soil moisture.

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