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SURFACE ENERGY COMPONENTS, CO_2 FLUX AND CANOPY RESISTANCE FROM A RICE PADDY IN TAIWAN

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1. Introduction

In East and South Asia, rice is the major food provision and the major crop. According to Food and Agricultural Organization of the United Nations (FAO) (2004), the area of paddies in this region is about 87% of total area in the world. In paddies, the soil is always wet under cultivation, especial at the first stages that the fields are cover with water completely. The rice sector is the biggest water user and half of irrigated water is used for rice production (Guerra et al., 1998). The water-fed rice paddy field may modify energy and water cycle and cloud/precipitation system of this region. Yasunari (2002) hypothesized that the recent decreasing trend of monsoon rainfall in Thailand was suggested to be partly due to deforestation combined with the expansion of paddy field, while the paddy field in south China plain was likely to enhance convective rainfall and water cycle there. For resolving the hypothesis and for quantifying the water usage of a rice paddy, a better knowledge of the mass, momentum and energy exchanges between rice paddy and the atmosphere is necessary. The observation of the energy exchange and CO_2 flux between rice paddy and the atmosphere is still sparse. There are only a few studies in China (Gao et al., 2003) and Japan (Harazono et al., 1993; 1998). This study tries to report data observed at a rice paddy site in Taiwan. Nonetheless, in Taiwan, it is very difficult to find a site with sufficient fetch where the horizontal advections can be neglected for the study of the interactions between rice paddy and the atmosphere. There are always buildings, roads and trees near a rice paddy site. A more careful treatment of horizontal advected fluxes should be conducted.

Besides, many field experiments have been conducted to examine the surface energy budget and show that the surface energy budget fails to close such as in Gao et al. (2003), in the FIFE experiment (Sellers et al.,1992), in the Monsoon'90 experiment (Stannard et al., 1994), in the Southern Great Plains 1997 Hydrology Experiment (Twine et al., 2000), in the OASIS project (Brotzge and Crawford, 2003), in the International Rice Experiment (Harazono et al., 1998) and at many Fluxnet sites (Aubinet et al., 2000; Baldocchi et al., 2001; Wilson et al., 2002a; 2002b; Heusinkveld et al., 2004; Meyers and Hollinger, 2004). They indicate that there is a general lack of closure at most sites, with energy balance ratio (EBR) ranging from 70% to 95%.

The purposes of this study are 1) to evaluate the surface energy closure by incorporation of the advected effects in a rice paddy, 2) to compare observed CO_2 flux with the biomass budget method,

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and 3) to determine the canopy resistance (r_c) for evapotranspiration.

2. Methodology

Surface energy budget is based on the fundamental conservation principles. The major component in the conservation of energy equation can be showed that the sum of surface latent heat and sensible heat flux should be equivalent to all other energy sinks and sources (e. g. Wilson et al., 2002b) as illustrated in Figure 1 as:

$$\begin{aligned} V &\equiv R_n - G - S - W - C - A - F \\ &= LE_c + H_c \end{aligned} \quad (1)$$

and

$$R_n = R_s - R_{sr} + R_{ld} - R_{lu} \quad (2)$$

$$S = \rho_a c_g z_g \frac{\partial T_g}{\partial t} \quad (3)$$

$$W = \rho_w c_w z_w \frac{\partial T_w}{\partial t} \quad (4)$$

$$C = \rho_a c_p h_c \frac{\partial \theta}{\partial t} + \rho_a L_v h_c \frac{\partial q}{\partial t} \quad (5)$$

$$A = \rho_a c_p h_c (u\frac{\partial \theta}{\partial x} + v\frac{\partial \theta}{\partial y}) + \rho_a L_v h_c (u\frac{\partial q}{\partial x} + v\frac{\partial q}{\partial y}) \quad (6)$$

$$F = \frac{C_{CO_2}}{M_{CO_2}} F_{CO_2} \quad (7)$$

where R_s is the incoming solar radiation (plus downward); R_{sr} is the reflected solar radiation (plus upward); R_{ld} is the atmospheric longwave radiation (plus downward); and R_{lu} is the terrestrial longwave radiation (plus upward); V is the available heat flux. It is defined as the sum of R_n-G-S -W-C -A-F. R_n is the net radiation (plus downward); LE_c is the latent heat flux at the canopy height (plus upward); H_c is the sensible heat flux at the canopy height (plus upward); G is the ground heat flux measured by the heat flux plate sensors (plus downward); S is the soil heat storage between the soil surface and the depth of the heat flux plate sensors (e.g. Brotzge and Crawford, 2003; Tsuang, 2005); W is the heat storage in the paddy water; C is the canopy heat storage between the land surface and the height of the eddy covariance system; A is the local advected heat flux; F is the photosynthesis energy; C_{CO_2} is the energy required for each mole of CO_2 fixed by photosynthesis (=422 kJ/gmole); M_{CO_2} is the molecular weight of CO_2; F_{CO_2} is the flux of CO_2 measured by the EC system; ρ_a and ρ_w are density of the air and the water, respectively; c_p and c_g are specific heat capacity of the air and the wet soil, respectively; L_v is the latent heat of vaporization; θ is potential temperature; q is specific humidity; T_g and T_w are air temperature and water temperature, respectively; z_g is the depth from the land surface to the heat flux plate sensor; h_c is the height where the EC system installed; z_w is the depth of water in paddies; u and v are wind components in x direction and y direction, respectively.

2.1. Examination of energy balance closure

Energy balance closure is examined using three methods in this study. The first method is to derive regression coefficients from the ordinary least squares (OLS) relationship between the hourly sums of the turbulence heat fluxes (LE + H) against the available heat flux (V). As described in Wilson et al. (2002b), the OLS regression is technically valid only if there are no random errors in the independent variable. The second method is to evaluate the energy balance ratio (EBR) (Wilson et al., 2002b; Brotzge and Crawford, 2003) between the sum of the turbulence heat fluxes (LE_c + H_c) and the available heat flux (V) over a specific time period, i.e.,

$$EBR \equiv \frac{\sum(LE_c + H_c)}{\sum(V)} \quad (8)$$

The time period is set at one hour in this study. Quantifying the discrepancy between the available heat flux and turbulence heat flux is important, because it provides information about whether the turbulence heat flux observed by the EC system to be overestimated or underestimated. Therefore, the residual of the energy closure is defined as:

$$R \equiv V - H_c - LE_c \qquad (9)$$

where R is the residual heat flux (W m^{-2}). The residual heat flux should equal to zero when the surface energy budget is closed.

2.2. Evaluation of aerodynamic resistance and canopy resistance

Adopting the concept of resistances to heat and vapor transferred to the atmosphere, the sensible heat and the latent heat flux at the measurement height h_c can be parameterized as:

$$H_c = \frac{\rho c_p (T_s - T)}{r_a} - \rho_a c_p h_c \frac{\partial \theta}{\partial t} - \rho_a c_p h_c \left(u \frac{\partial \theta}{\partial x} + v \frac{\partial \theta}{\partial y} \right) \qquad (10a)$$

$$LE_c = \frac{\rho_a L_v (q^* - q_r)}{r_a + r_c} - \rho_a L_v h_c \frac{\partial q}{\partial t} - \rho_a L_v h_c (u \frac{\partial q}{\partial x} + v \frac{\partial q}{\partial y}) \qquad (10b)$$

where r_a is aerodynamic resistance and r_c canopy resistance. The first term on the right-hand-side of the above Eq. is the latent heat flux from the surface. And the second and the third terms are storage and local advected latent heat fluxes between the height h_c and the surface, respectively. As described by Brutsaert (1982), aerodynamic resistance and canopy resistance can be determined as:

$$r_a = \frac{\rho c_p (T_s - T)}{H_c + \rho_a c_p h_c \frac{\partial \theta}{\partial t} + \rho_a c_p h_c \left(u \frac{\partial \theta}{\partial x} + v \frac{\partial \theta}{\partial y} \right)} \qquad (11a)$$

$$r_c = \frac{\rho L_v (q^* - q)}{LE_c + \rho_a L_v h_c \frac{\partial q}{\partial t} + \rho_a L_v h_c \left(u \frac{\partial q}{\partial x} + v \frac{\partial q}{\partial y} \right)} - r_a \qquad (11b)$$

3. Characteristics of rice paddy and site description

The study site is located at Taiwan Agricultural Research Institute (120°41'E, 24°01'N, 50 m above sea level) in the Taichung basin in central Taiwan. The purpose of the Institute is to improve the cultivation technique of agricultural products, to investigate plant pathology and to measure agricultural micrometeorology. The major landuse fraction in the area is farmland and more than a half belongs to rice paddies (Figure 2) (CTCI, 2003). Soil at the experimental site was predominantly loam, of which the volumetric heat capacity $\rho_g c_g$ is set at 2.99 × 10^6 J m^{-3} K^{-1} for wet soil (Hillel, 1982).

In central Taiwan, there are two growth seasons for rice paddies, starting from February and from July. From sowing to harvest, it usually takes 120 days for the first growth season and 90 days for the second growth season. The rice (named as Tainung 67) after budded were planted in the study site (Figure 3) at the beginning of April and were harvested at the end of June 2005. Figure 4 shows the leaf area index (LAI), the height of paddy and the dry biomass of the rice paddy during the study period. Flux measurement was carried out from 15 April to 12 May 2005. During the experimental period the canopy height increased from 26 cm to 73 cm. The rice field was flooded throughout the entire experiment. The depth of the water layer ranged from 0.02 to 0.06 m. The distance between rice plants was 30 cm × 15 cm. Several patches of similar rice paddies composed a rectangular paddy field, about 0.45 km in the N-S direction × 0.2 km in the E-W direction. The experiment site was almost surrounded by farmlands (Figure 2).

An EC system and a micrometeorology station were setup almost at the center of the paddies field. The measured items include each component of radiation, atmospheric pressure, wind speed and direction, air temperature, relative humidity, soil temperature and ground heat flux. During the study period, wind directions alternate day and night. It is likely part of a valley-mountain wind system, regularly observed in the Basin.

CO_2 flux, sensible heat flux and latent heat flux were measured directly from an EC system. The EC system consists of a three-dimensional sonic anemometer (CSAT3, Campbell Scientific Inc.) to measure the means and standard deviations of wind velocity components (i.e., u, v, and w) and potential temperature, a fine-wire thermocouple (FW05) to measure the mean and standard deviation of air temperature, and an open path CO_2/H_2O fast response infrared gas analyzer (LI7500, LICOR) to measure fluctuations in CO_2 concentration and water vapor density. The open path analyzer with a 0.125 m span open-path was installed at the same height as the sonic anemometer with a horizontal separation of about 0.20 m. All sensors were mounted on a mast at a height of 5 m agl. All signals for the sensors were recorded at a sampling rate of 20 Hz and were averaged over 10 min periods.

A Solar Infrared Radiation Station (SIRS) system was used in this study to measure each component of the radiations. SIRS consisted of four individual sensors, included upward and downward pyranometers (PSPs) and pyrgeometers (PIRs) manufactured by the Epply Labortary, Inc. The observing wavelength of PSPs are 0.3 ~ 3 m with uncertainty of ±0.5%, and the observing wavelength of PIRs are 3 ~ 50 m with uncertainty of ±1%. Each component of this system is mounted on a mast at a height of 5 m above ground level (agl). In addition, a net radiation detector, Q*7.1 (made by Radiation and Energy Balance Systems, Seattle, WA), was also used to double-check the net radiation determined from the SIRS.

Ground heat flux *G* was obtained using the mean value of two soil heat flux plate sensors, which are REBS' HFT-3.ls and were buried at a depth of 8 cm. The soil temperature between the HFT-3.ls and the surface was measured using four TCAV (Averaging Soil Thermocouple Probe) which were divided into two groups and buried at a depth of 3 cm and 6 cm respectively. The distance between the TCAV in the same level was 1 m. The mean values of TCAV were served as the mean soil temperature (T_g) between the instrument and the surface.

4. Surface energy components

Figure 5 shows the daily variation of each surface energy component during the study period. During the experiment, there were three overcast periods (12 – 17 April, 26-29April, 6-15 May, 2005). It can be seen that under the overcast periods, the magnitudes of solar radiation, latent heat flux, sensible heat flux and CO_2 flux were much lower than in partial-cloudy or clear-sky days.

Figure 6 shows the hourly composite of each energy component during the period. The energy components can be grouped into 4 categories grouping according to their magnitudes. R_s, R_{sr}, R_{ld} and R_{lu} belong to the highest magnitude group ranging from 0 to 900 W m^{-2}. R_n, *LE* and *H* belong to the second highest group ranging from -100 to 700 W m^{-2}. *G*, *S* and *W* belong to the third highest group ranging from -100 to 150 W m^{-2}. *A*, *C* and *F* belong to the lowest group ranging from -5 to 10 W m^{-2}. Table 1 summarizes the results and expresses each budget component as a function of available heat flux. During the daytime, net radiation was the dominated contributor to the surface and latent heat flux was the main receiver from the surface. As for the nighttime, ground heat flux and soil heat storage were the dominated energy contributors, and net radiation and latent heat flux were the major receivers.

In the rice paddy during the experiment, there was always water, ranging from 2 - 6 cm deep. For the largest specific heat in nature, heat stored in the wet soil and in the water should not be neglected. The wet soil storage is determined according to Eq. (3). The paddy water heat storage is determined according to Eq. (4). During the day, the ground heat flux, the soil heat storage and the paddy water storage consist of 9%, 14% and 6% of available heat flux, respectively (Table 1).The EBR increases by 29% after the incorporation of the three terms during the day.

Table 2 and Figure 7 show the Energy balance ratio (EBR) and the regression coefficients from the ordinary least squared (OLS) relationship between the hourly sums of the turbulence heat fluxes (*LE* + *H*) against the available heat flux (*V*) of various corrections. It can be seen that both the EBR and the regression coefficient of the OLS relationship become closer to 1 after each correction. The corrections include 1) Webb et al. (1980) correction, 2) coordinate rotation, 3) canopy heat storage (C) correction, 4) advected heat flux (A) correction, and 5) photosynthetic energy (F) correction,.

During the daytime, the EBR distributed from 0.86 to 0.98 with a mean value of 0.94 that increased gradually from the morning to the late afternoon. The similar daytime patterns were also detected by Wilson et al. (2002b) and it was deduced that EBR approached 1 resulted from the turbulence mixing within atmospheric boundary layer during the late morning and afternoon (Brotzge and Crawford, 2003). Around the sunrise and sunset, the mean magnitudes of *LE* + *H* and *V* were close to zero that the EBR is not especially meaningful on this condition. Besides, the standard deviations of EBR raised suddenly compared to that during daytime. During the nocturnal period, there is no evident rule for the patters of EBR and the deviations of EBR were also larger than those during the daytime (not shown).

Although several corrections have been conducted to improve the EBR, the EBR is still less than 1, and the surface energy budget is still not closed. The residual heat flux during the study period is shown in Figures 6 and Table 1. This section tries to identify which energy component being likely to be underestimated. The residual appeared to be proportional to the net radiation, in other word, the residual increased with the net radiation. The relative maximum value occurred around noon with a magnitude 40 W m^{-2} and the mean was 16 W m^{-2} with a standard deviation 9 W m^{-2} during the daytime.

5. CO_2 flux

The CO_2 fluxes above the rice canopy measured by the EC method during the experiment was shown in the bottom panel of Figure 4. During the daytime, the flux was downward, but during the nighttime, the flux was upward. The downward flux is likely due to CO_2 being absorbed by the rice paddy for photosynthesis. The upward flux is likely due to CO_2 being released by the rice paddy for respiration.

The absorbed CO_2 flux reaches it maximum at noon at the study site with a magnitude at 1.1 mg m^{-2} s^{-1} and smaller than those reported by Miyata et al. (2000) and Gao et al. (2003), 1.5 and 1.7 mg m^{-2} s^{-1}, respectively. Since this experiment was carried out in the transplanting of paddies, our results were reasonable compared with the observed data in the initial stage of Gao et al. (2003).

It is found that the nocturnal flux of CO_2 was, on average, 0.11 mg m^{-2} s^{-1} upward during the experiment (17 PM -6 AM). This value is close to those measured by Miyata et al. (2000) and Gao et al. (2003). They assessed the exchanges of CO_2 from intermittently flooded rice paddies in Japan and in China, respectively. They concluded that during the nighttime, on average, the mean of the respiration CO2 flux was <0.2 mg m^{-2} s^{-1} in Japan and 0.12 mg m^{-2} s^{-1} in China in the flooded period.

In addition, to check whether the CO_2 flux measured by the EC system is reasonable, the observed CO_2 flux is used to estimate mass fraction of carbon in the rice straw, and the result is compared with that measured by the biomass budget method. Carbon (C) of rice straw increases due to photosynthesis during the daytime and decreases via respiration during the nighttime. That is, the mass of carbon in the rice straw is equal to the accumulated mass calculated from the CO_2 flux (F_{CO_2}) as:

$$\Delta m_{paddy}\Big|_{t_0}^{t_1} \times p_c = \int_{t_0}^{t_1} F_{CO_2} dt \times \frac{M_C}{M_{CO_2}} \quad (12)$$

where m_{paddy} is the dry biomass of paddy (g m^{-2}); p_c the mass fraction of carbon of dry rice straw (= 40%, Tsuang et al., 1992); M_{CO_2} and M_c are the molecular weight of CO_2 and C, respectively. Biomass of paddy was sampled weekly and the measurements of the first three weeks were presented in Figure 4. The figure shows that the values of the accumulated carbon mass estimated by the EC during the experiment were close to those calculated according to the above biomass budget Eq.

6. Land surface parameters for rice paddy

The EBR of this study is as high as 94%, higher than previous studies over rice paddies mentioned above. Therefore, the parameters derived from the experimental data may be useful for determining mass, momentum, and energy exchange rates between rice paddy and the atmosphere. The following parameters will be derived, including albedo, aerodynamic resistance and canopy resistance. Table 3 compares the derived parameters with other studies over rice paddies.

6.1. Albedo

The albedo at the site was observed varying from 0.05 to 0.17, as determined by dividing the reflected solar radiation by the incoming solar radiation. This value lies in the range between soil and water (Brustsaert, 1982).

6.2. Aerodynamic resistance and canopy resistance

Figure 8 showed the daytime hourly magnitude of r_a and r_c where both patterns were presented as a “U” shape. For r_a, it was obviously affected by the wind speed that it decreased when the wind speed increased. For r_c, it was of the minimum value around noon where radiation was the maximal and rapidly increases around the early morning and late afternoon. The range of r_a was between 50 – 80 s m^{-1} and r_c was about 42 s m^{-1} (around noon) and 152 s m^{-1} (4 PM) during daytime. The magnitudes of r_c are closer to those for rice paddies (ranged about from 50-200 s m^{-1}) but larger than those reported for well-watered agricultural crops (20-50 s m^{-1}) (e.g. Harazono et al., 1998; Yoshimoto et al., 2005).

7. Conclusions

A field measurement was conducted to examine the surface energy balance closure over rice paddies at the study site using the EC system. It was found that there was a general lack of the surface energy balance closure existed. Not only the surface sensible heat flux but also the latent flux heat fluxes may be underestimated measured by the eddy covariance systems. During the daytime, there was a mean EBR of 0.94 increased gradually from the morning to the late afternoon.

Bowen ratio estimated from the EC system and the BR system has been estimated. During the daytime, the mean β_{EC} was 0.16 with a standard deviation 0.04. In this study, the energy stored within the soil is the second largest term in the available heat flux, next to the net radiation. The wet loam with a large volumetric heat capacity should not be ignored over a rice paddy.

Aerodynamic resistance and canopy resistance over paddies was also evaluated in this study. The mean value for daytime r_a was between 50 – 80 s m^{-1} and about 42 s m^{-1} (around noon) to 152 s m^{-1} (4 PM) for daytime r_c. The magnitudes of r_c are similar to those reported for rice paddies.

In addition to the site representative affects the surface energy closure, the instrument used to measure and the theoretical assumptions may cause the deviations. (e.g. Brotzge and Crawford, 2003). To interpret the surface energy closure clarified, complete instruments that measure each term, especial for the ground heat flux, in the energy budget collocated with a careful-considered assumptions carried out for a long time is necessary for further research.

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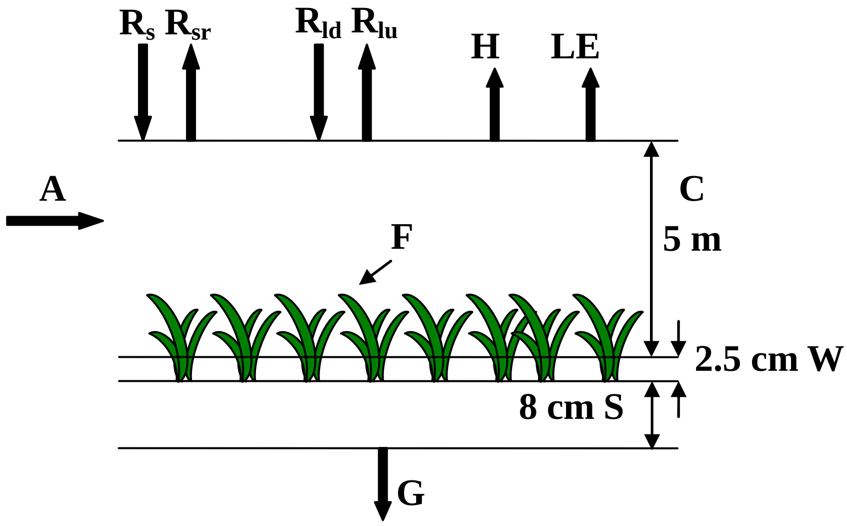


Figure 1. Schematics of the surface energy components of a rice paddy.

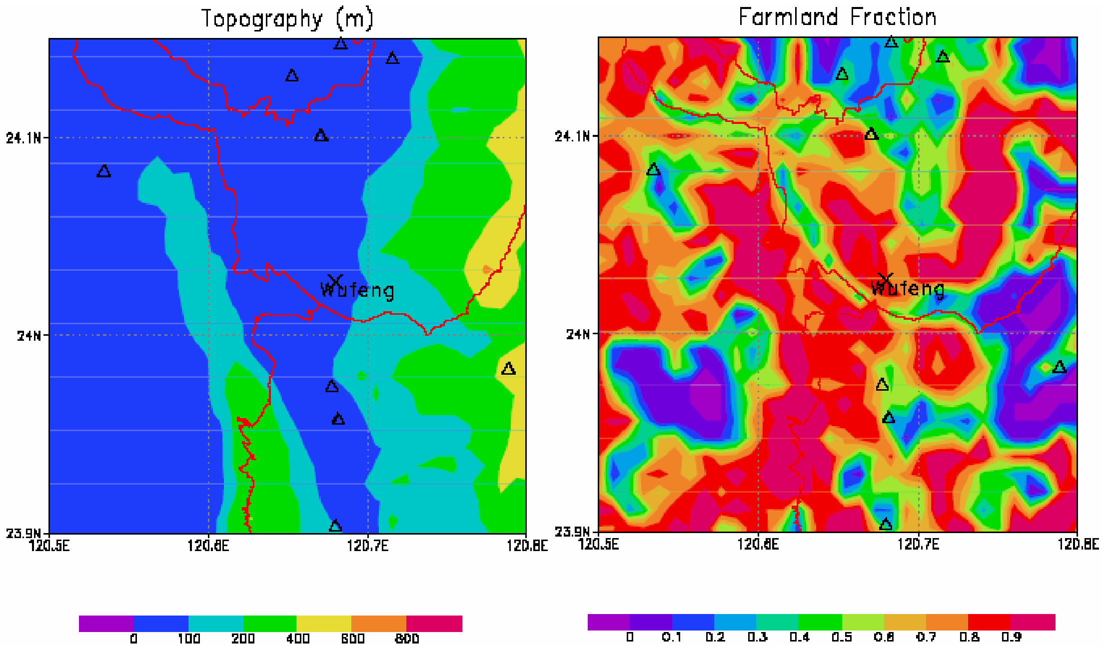
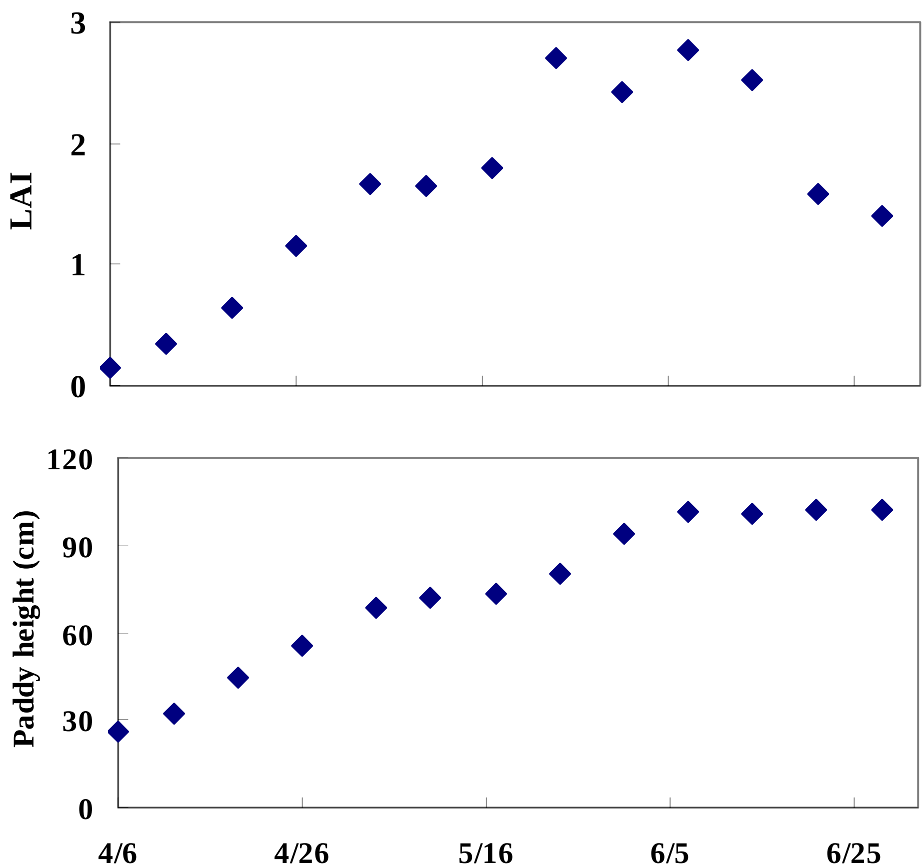


Figure 2. Topography and Farmland fraction distribution around the study site in central Taiwan. Where the cross represents the study site and the triangles are meteorological stations around the site.

Figure 3. Photograph taken to the north from 80 m south of the study site (star) in Wufeng, Taichung County, Taiwan on 1 May 2005.



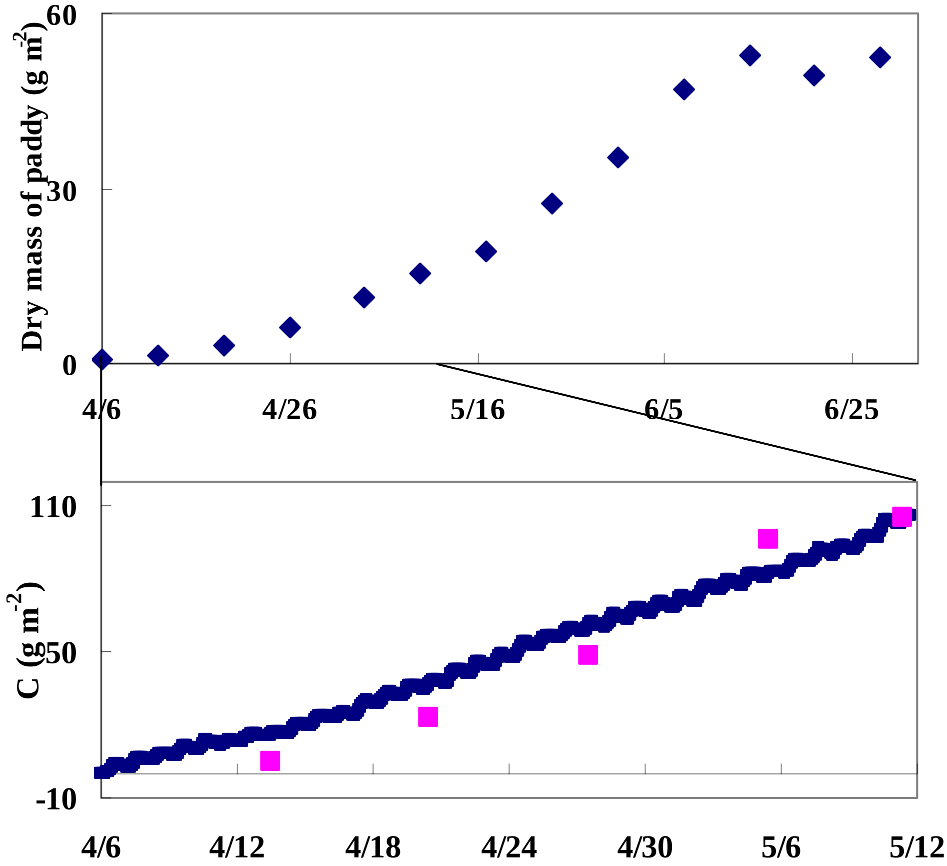
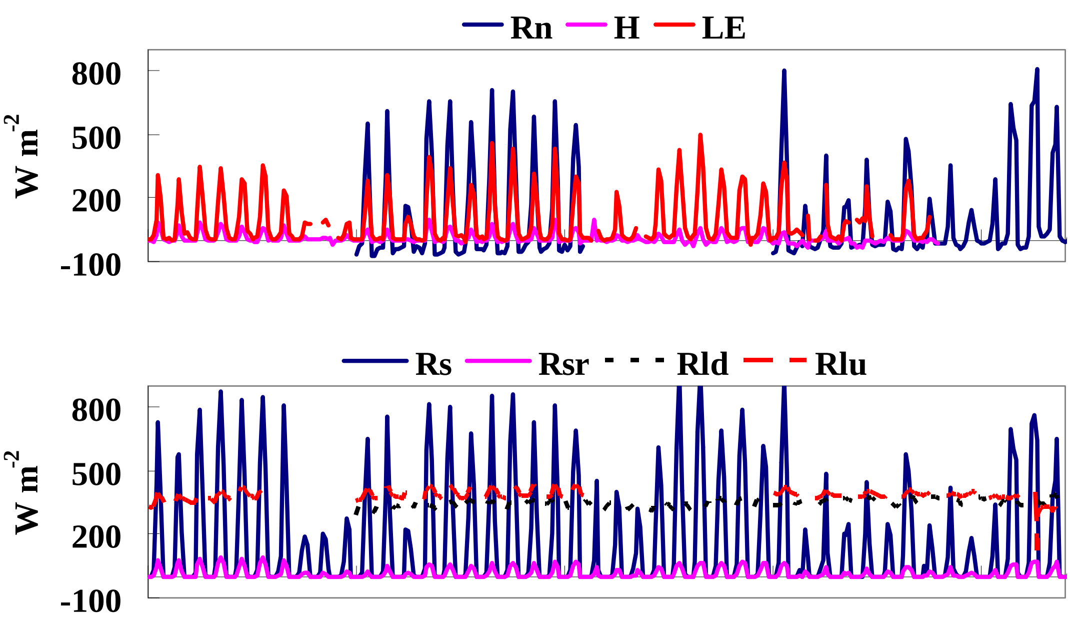


Figure 4. a) Leaf Area Index (LAI), b) paddy height, c) dry biomass of paddy measured in the filed from 6 April to 28 June and d) comparison of carbon (C) mass fraction measured in the filed (square) and that calculated from the CO_2 flux measured by the EC system (line) from 15 April to 4 May 2005.



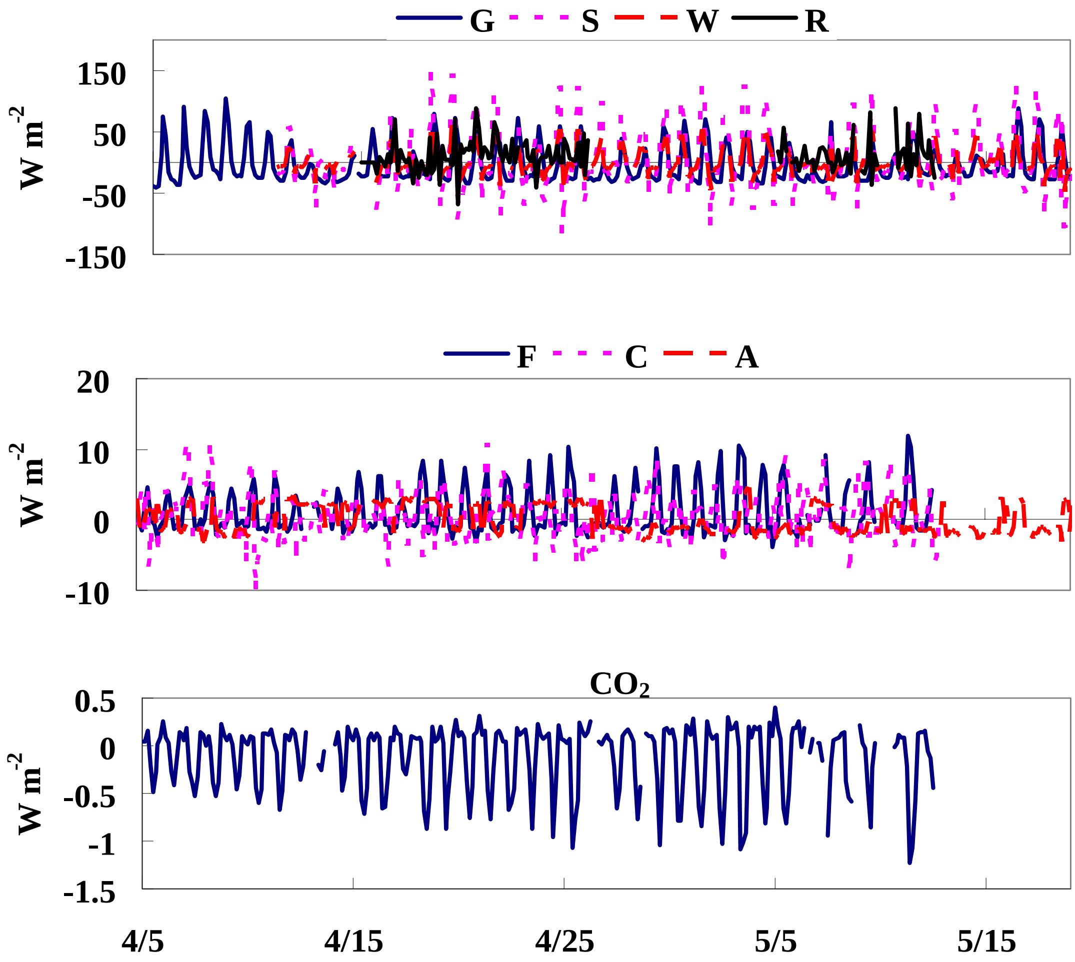
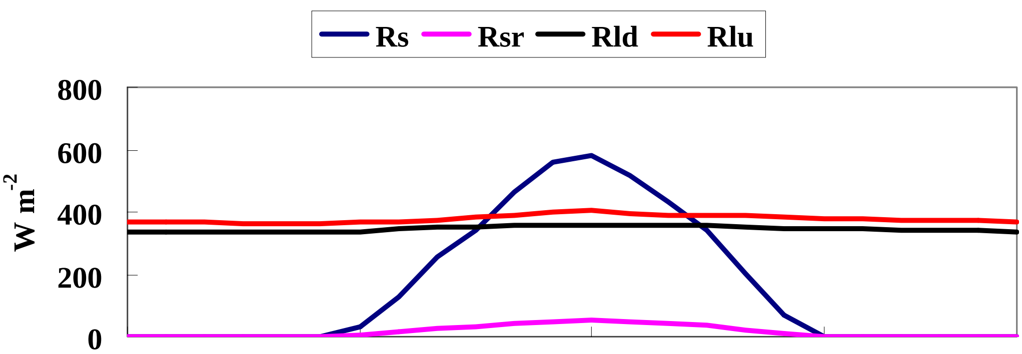


Figure 5. Net radiation (R_n), sensible heat flux (*H*), latent heat flux (*LE*), ground heat flux (*G*), soil heat storage (*S*), liquid water heat storage (*W*), canopy heat storage (*C*), photosynthesis heat flux (*F*), advected heat flux (*A*), Residual (*R*) and CO_2 flux measured at a rice paddy in Wufong from 5 April to 19 May 2005.



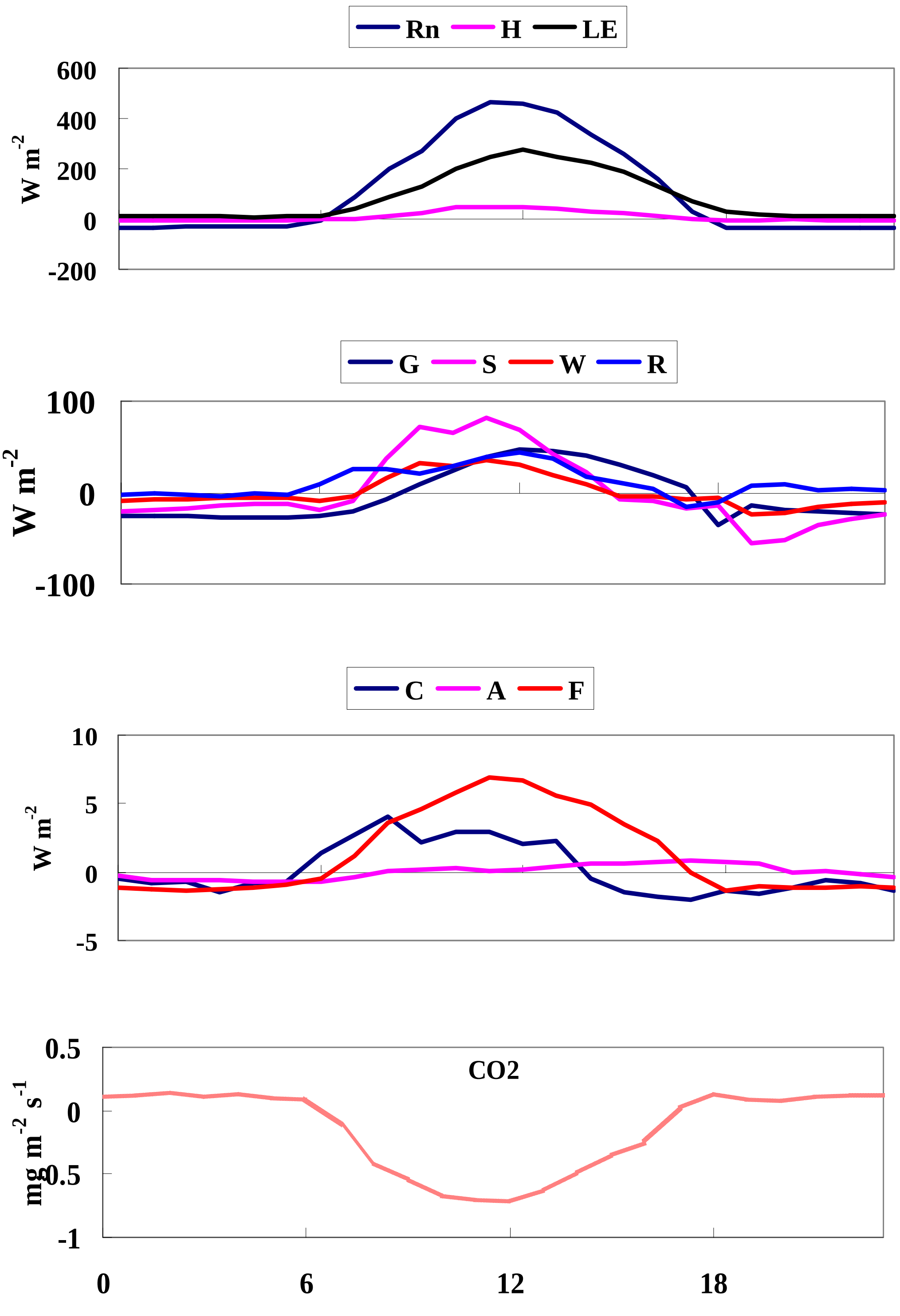


Figure 6. Hourly composites of net radiation (R_n), sensible heat flux (*H*), latent heat flux (*LE*), ground heat flux (*G*), soil heat storage (*S*), liquid water heat storage (*W*), canopy heat storage (*C*), photosynthesis heat flux (*F*), advected heat flux (*A*) , Residual (*R*), and CO_2 flux measured at a rice paddy in Wufong from 5 April to 19 May 2005.

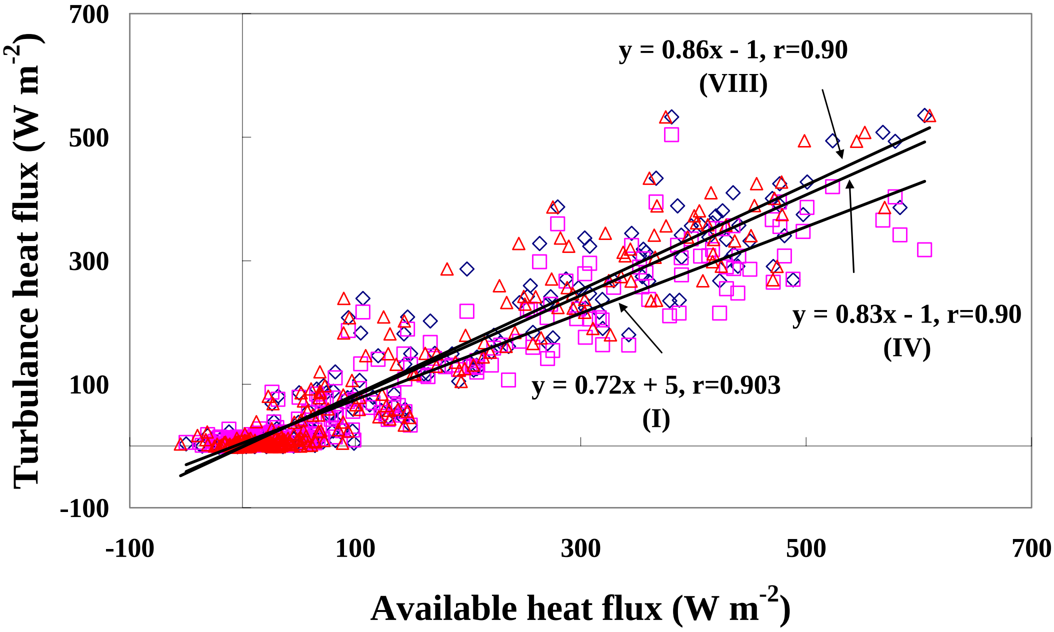


Figure 7. Turbulence heat flux measured by the EC system (*LE* +*H*) as a function of available heat flux ($V \equiv R_n$-G-C-S-W-F-A).

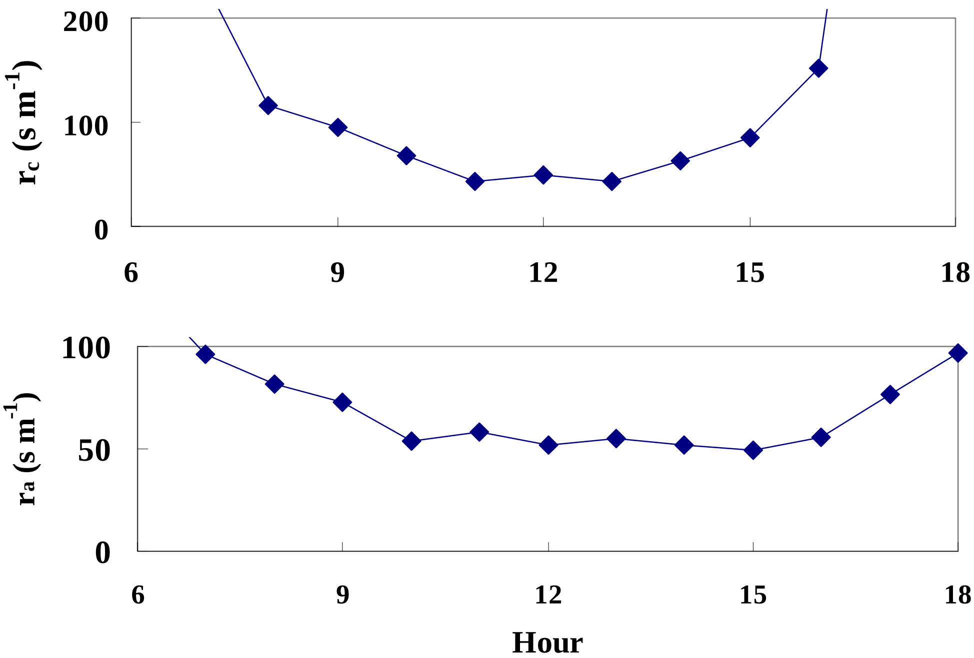


Figure 8. Daytime hourly composites of aerodynamic resistance (r_a) and canopy resistance (r_c) from 15 to 25 Apr. 2005.

Table 1. Summary of energy components and parameters measured in a rice paddy at tillering stage in Taiwan. Where daytime: 7AM-6PM; nighttime: 7PM-6AM; $V=R_n$-G-S-W-F-C-A

Variable	Mean		range	
	daytime	nighttime	daytime	nighttime
Bowen ratio	0.16	-0.29	0.07 – 0.20	-0.18 – -0.40
R_n (W m^{-2})	257	-33	131% V	-165% V
R_{sn} (W m^{-2})	296	0	-152%V	0% V
R_{ld} (W m^{-2})	353	338	-181% V	-1684% V
R_{lu} (W m^{-2})	386	370	198% V	1840% V
LE_c (W m^{-2})	154	20	79% V	99% V
H_c (W m^{-2})	24	-4	12% V	-20% V
G (W m^{-2})	17	-21	-9% V	104% V
S (W m^{-2})	27	-22	-14% V	109% V
C (W m^{-2})	1	-1	-0.6% V	5% V
F (W m^{-2})	4	-1	-2% V	6% V
A (W m^{-2})	0.3	-0.2	-0.1% V	1% V
W (W m^{-2})	12	-8	-6% V	40% V
V (W m^{-2})	195	20	-	-
R (W m^{-2})	17	4	8% V	20% V

Table 2. Energy balance ratio (EBR) and the regression coefficients from the ordinary least squared (OLS) relationship between the hourly sums of the turbulence heat fluxes (LE_c + H_c) against the available heat flux (V).

Scenario	Variable	EBR		OLS	
		full day	daytime	slope	r
Ⅰ	Raw LE, H	0.755	0.855	0.721	0.903
Ⅱ	Ⅰ+Webb et al. (1980) correction	0.774	0.889	0.765	0.903
Ⅲ	Ⅰ+Coordinate rotation	0.786	0.904	0.794	0.95
Ⅳ	Ⅰ+Ⅱ+Ⅲ (Corrected LE, H)	0.803	0.921	0.836	0.90
Ⅴ	Ⅳ+C correction	0.791	0.930	0.845	0.901
Ⅵ	Ⅳ+A correction	0.798	0.922	0.838	0.899
Ⅶ	Ⅳ+F correction	0.801	0.931	0.848	0.895
Ⅷ	Ⅳ+Ⅴ+Ⅵ+Ⅶ (final)	0.810	0.941	0.861	0.90

Table 3. Comparison with other studies over ice paddy.

Variable	this study		Gao et al. (2003)	Harazono et al. (1998)	Li et al. (2005)
area	450 m length * 200 m width		600 m * 600 m	300 m * 300 m	
	daytime	nighttime	full day	daytime	daytime
Bowen Ratio	0.16	-0.29	0.06	0.07 – 0.15	-
h	26 cm – 73 cm		65 cm	-	-
LAI	0.71		-	-	-
albedo	0.09		0.08 -0.17	-	-
$\rho_g c_g$	2.99 × 10^6 J m^{-3} K^{-1}		-	-	-
r_c	42 s m^{-1} (around noon) 152 s m^{-1} (4 PM)	-	-	90 s m^{-1}	50 s m^{-1} - 166 s m^{-1}
r_a	50 – 80 s m^{-1}	-	-	44 s m^{-1}	40 s m^{-1} - 166 s m^{-1}