Investigating Role of Field Management on Energy Budgets and Soil Moisture in Tea Fields

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Abstract

The surface energy balance from canopy to landscape scales in crop fields plays an essential role in surface-atmosphere interactions. It is strongly influenced by the management strategies and field practices of farmers. These practices also affect the micrometeorological parameters, including energy partitions, soil temperature, and soil moisture. To characterize how different agricultural practices of farmers affect the microenvironment in perennial crop fields, a long-term observation of the radiation budget, energy components, canopy temperature, vapor pressure deficit, soil temperature, and soil water content was conducted in two neighboring tea fields with different management strategies (a conventional operation field (CONV) and an organic-certified field (ORG) managed by different farmers) in a hilly terrain area in northern Taiwan. The results showed that the difference in the radiation budget in these two tea fields was minor (only 1% for net radiation). However, the differences in the energy components were more significant (sensible heat was 10% lower and latent heat was 25% higher in the organic-certified field than in the conventional field) due to highly distinct practices in these two fields. Furthermore, the higher diurnal soil temperature (0.45°C) contributes to the more considerable sensible heat flux in the conventional field. On the other hand, in the organic-certified field, the faster-decreasing rate of (-0.93% d-1) soil water content is consistent with the greater latent heat flux. This finding implies that the organic-certified application could lower the partitioning of sensible heat flux and increase the latent heat flux, thereby reducing the temperature variation and decreasing the vapor pressure deficit. The organic-certified field reduced the surface heating in terms of the long-term energy patterns. The findings of this study also indicate that field practices in the conventional field can increase the sensible heat flux (51.5% at noontime) on short-term time scales, while it is only 9.6% in the organic-certified field. Furthermore, this study offers primary data in the comprehensive understanding of tea field practices, a scientific basis for in-field water conservation, quantitative analysis for modeling from micro to regional scales, and essential information for estimating heat stress index for field workers under different future climate scenarios.

Study Site and Methods

$$LW + SW = Rn = H + LE + G$$

The energy and soil components are measured in a rural community, Pinglin 坪林, a water protection area about 25 km southeast of Taipei in northern Taiwan (Fig.1). Pinglin is hilly terrain with about 4,000 mm annual rainfall, and the annual mean temperature is 15.9 °C in Jan and 25.6 °C in Jul. Tea farmers here manage their fields and make tea products with their long-term local climate knowledge. Measurement data in two neighboring tea fields were quantified from 2018 winter to 2020 summer (Fig.2). Field properties are summarized in Table 1. The most obvious difference is that CONV is herbicide usage and mechanical harvest, and ORG is organic-certified and harvested by hand. These operations led to fields having different canopy structures (estimated by LAI and FAPAR, LP-80, Decagon) (Table 2). Albedo (Table 3), radiation flux (longwave (LW), shortwave (SW) and net radiation (Rn)) (CNR1, Kipp & Zonen), sensible heat flux (H) (CSAT-3, Campbell Scientific), latent heat flux (LE) (Fig.3 & 4) (Li-7500, Li-Cor), ground heat flux (G) (Fig.3) (HFT3.1, REBS), soil temperature, and water content in 5 cm depth (Fig.6) (Drill & Drop, Sentek) have also measured in the fields.

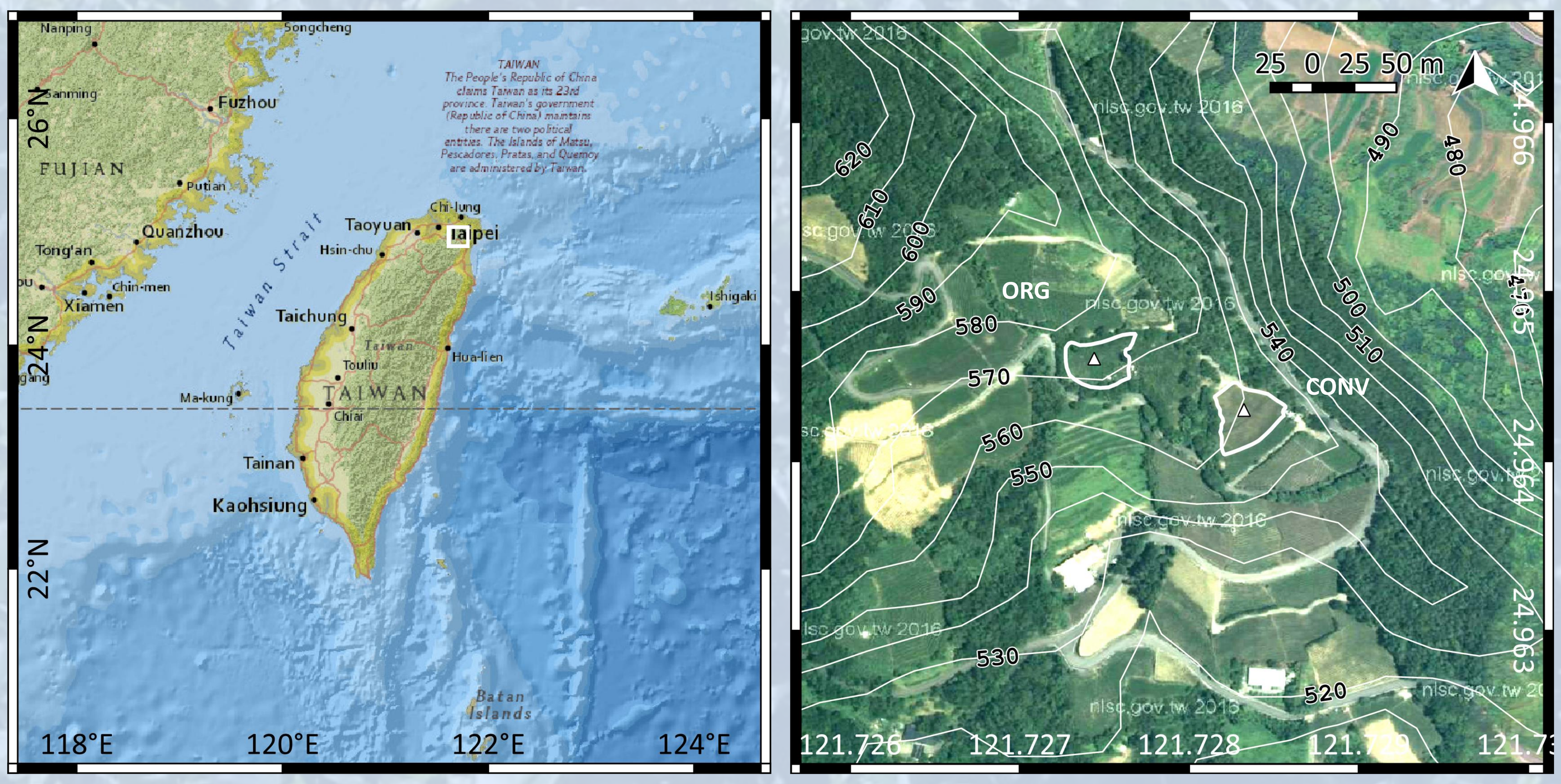


Fig.1 Location of the tea fields (CONV and ORG). Triangles in the right panel are locations of flux towers. The map (left panel) was generated by National Geographic and was obtained from Academia Sinica. The orthophoto (right panel) was obtained from the Forestry Bureau Aerial Survey Office. The contour (m) in the right panel is the digital elevation model (DEM) data from the Ministry of the Interior in Taiwan. Reproduced from Esri (2021). Content may not reflect National Geographic's current map policy. Sources: National Geographic, Esri, Garmin, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, INCREMENT P. Reproduced from National Land Surveying and Mapping Center (2021).

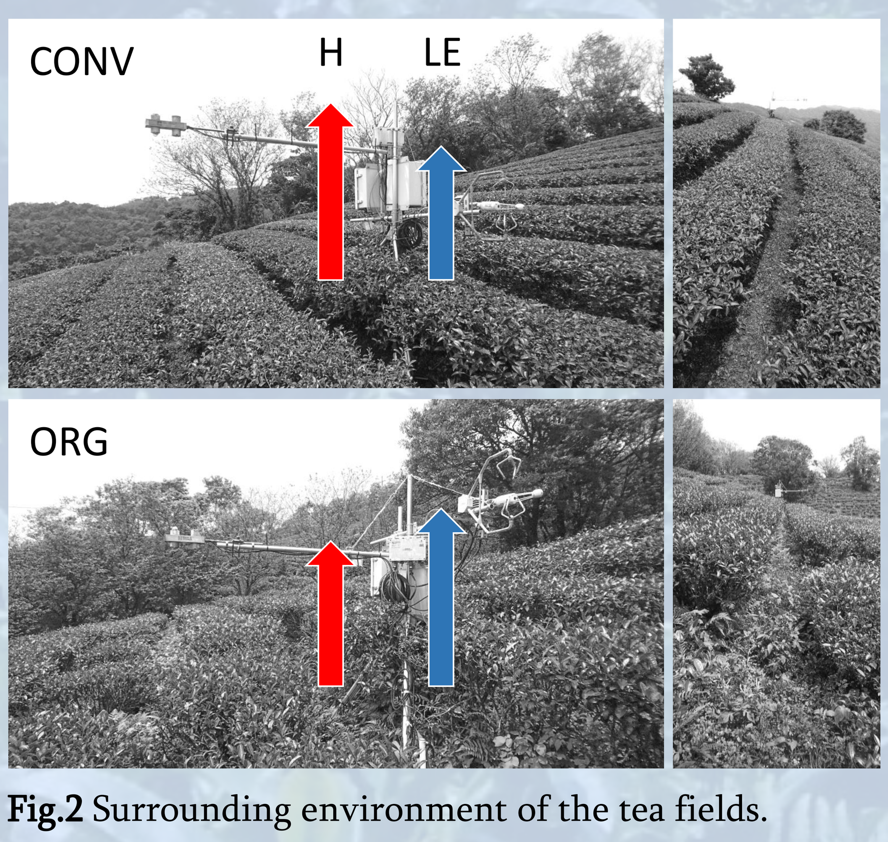


Fig.2 Surrounding environment of the tea fields.

Management practices (organic vs. conventional)

➔ Affect canopy structure

➔ Influence energy partitioning

Organic farming better eases the temperature variation with lower sensible heat and release more water with higher latent heat.

➔ More capable to mitigate the variations of microclimate in tea fields.

About the Author

An early career researcher is interested in the surface-atmosphere interaction when human activities interfere, primarily focusing on agricultural activities.

Results

Table 1 Field properties measured in this study.

Properties		CONV	ORG
Geographical properties	Elevation (m)	575	580
	Slope (%)	33.0	31.7
	Heading (°)	143.1	170.3
	Area (m²)	1234	1051
Management	Planted species	TTES #13 [a]	TTES #12
	Harvest	Machine	Manual
	Weeding	Herbicide	Manual
	Soil surface	Slight amount of moss and dry leaves	Weed
	Canopy structure	Flat	Rough
	Interrow spacing (m) [b]	1.00	1.25
EC parameters	Measurement height (m)	1.0	1.5
	Residual (%) [c]	15.7	3.1

[a] TTES: Taiwan Tea Experiment Station.
[b] Horizontal distance, not including tilt.
[c] From 10:00 to 14:00.

Table 2 Canopy properties in the fields with different management strategies. FAPAR in 2018 did not pass the statistical comparison test, whereas all other parameters in 2018 and 2020 passed the Wilcoxon rank sum test.

Properties		CONV	ORG
Canopy on 11 Nov 2018	LAI_{Field}	2.73 ± 0.60	4.62 ± 0.79
	LAI_{Crown}	3.88 ± 0.70	5.62 ± 1.28
	FAPAR	0.88 ± 0.05	0.90 ± 0.06
	Canopy height (cm)	49.4 ± 3.34	97.7 ± 9.05
Canopy on 14 May 2020	LAI_{Field}	1.04 ± 0.29	4.11 ± 0.91
	LAI_{Crown}	1.52 ± 0.21	5.32 ± 1.03
	FAPAR	0.48 ± 0.05	0.89 ± 0.04
	Canopy height (cm)	40.5 ± 2.55	80.5 ± 4.50

Table 3 Albedo average in 11:30-12:00

Period		CONV	ORG
ALL	Nov 2018 – Nov 2020	0.127	0.134
A1	Before harvest in summer 2019	0.151	0.149
A2	Harvest in both field	0.126	0.147
B1	Before harvest in spring 2020	0.118	0.119
B2	Harvest in both field	0.089	0.130

Energy and Radiation Components

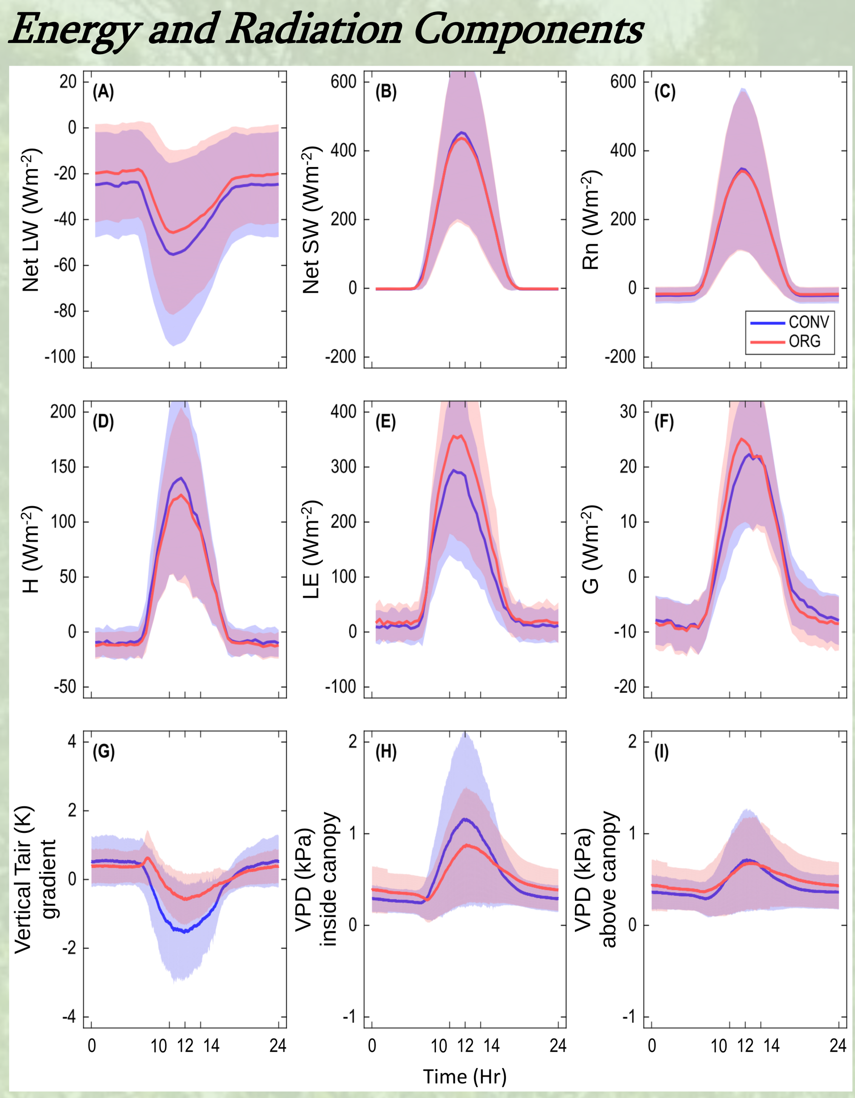


Fig.3 Half-hourly ensemble average of the radiation budget (**A**, **B**, **C**), energy components (**D**, **E**, **F**), canopy air temperature gradient (**G**) and VPD inside and above the canopy (**H**, **I**) over the entire observation period. Shading represents one standard deviation. During the noontime period (10:00-14:00), $NetLW$, LE, the vertical Tair gradient and VPD inside the canopy passed the two-sample t-test (p < 0.001), G passed the two-sample t-test between 10:00 and 12:00, H passed the two-sample t-test at 12:00, and other components and periods did not pass the statistical comparison test.

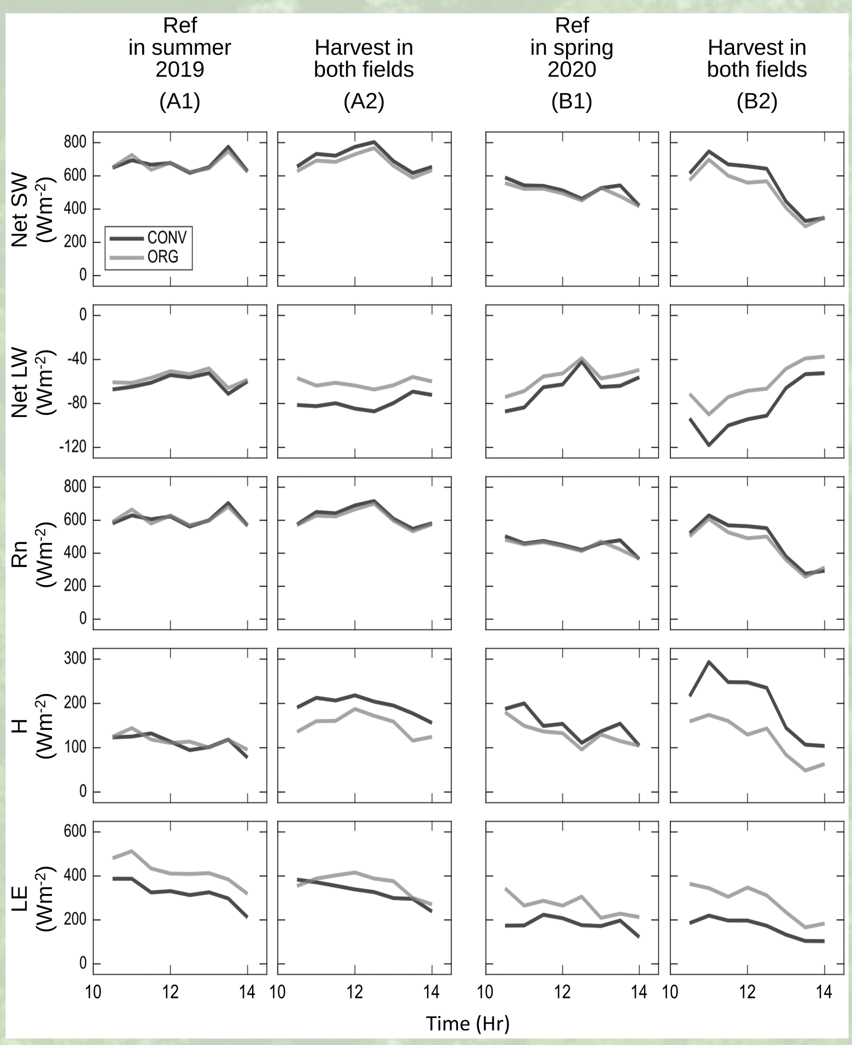
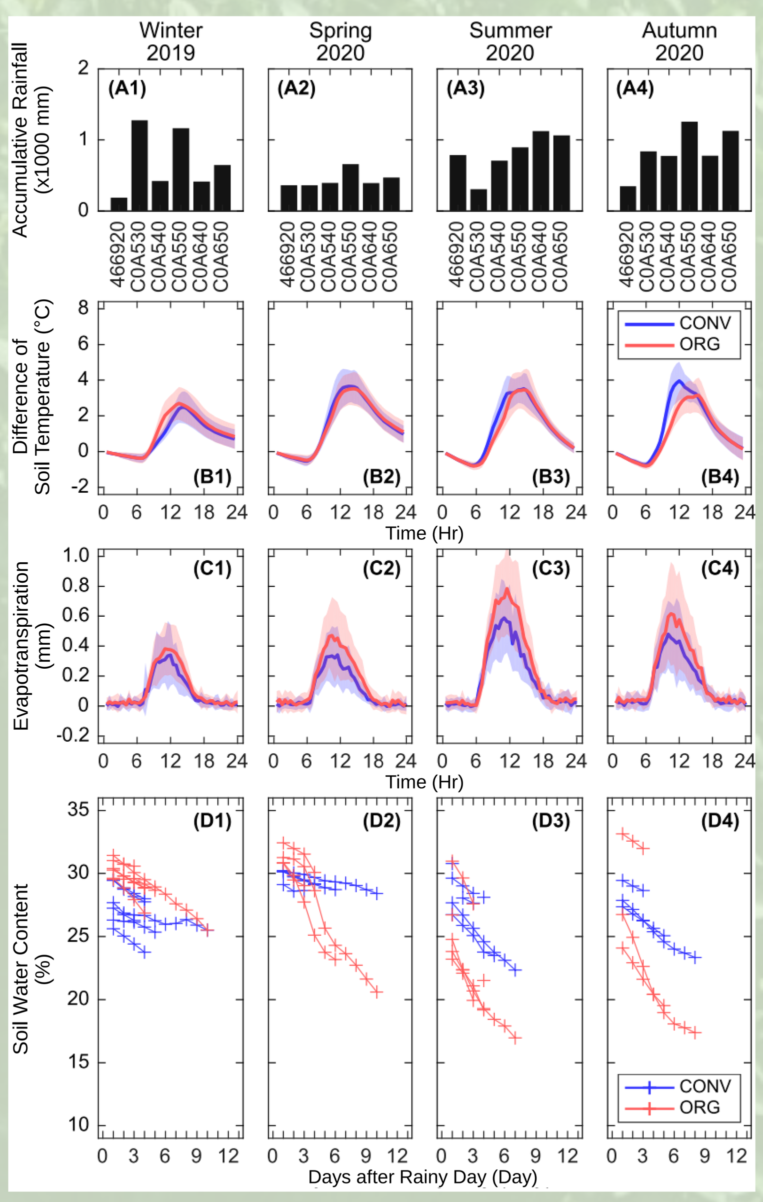
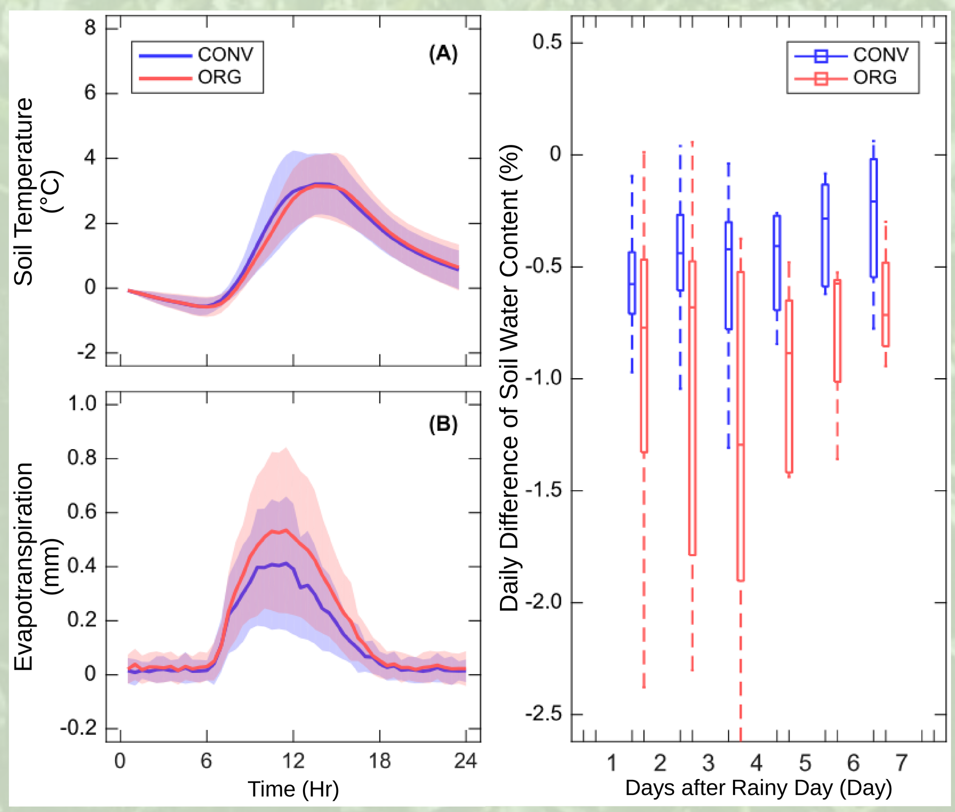


Fig.4 Radiation budget ($NetSW$, $NetLW$, Rn) and energy components (H and LE) around noon at different periods (periods labeled **A1** to **B2**). The statistical results show that $NetLW$ in **A2**, H in **A2** and LE in **A1** in the morning were significantly different (p < 0.05 based on a two-sample t-test or Wilcoxon rank sum test).

Evapotranspiration, Soil Temperature and Soil Water Content



➘Fig.5 Seasonal accumulative rainfall (**A1** to **A4**), soil temperature (**B1** to **B4**), ET (**C1** to **C4**), and soil water content (**D1** to **D4**) from summer 2019 to autumn 2020. Rainfall data is captured from 6 different weather stations (466920: Taipei 台北, C0A530: Pinglin坪林, C0A540: Sihdu四堵, C0A550: Taiping 泰平, C0A640: Shihding 石碇, C0A650: Huoshaoliao火燒寮) from Central Weather Bureau.



🡩Fig.6 The soil temperature and evapotranspiration during the measuring period (left). The daily difference in soil water content between rainfall events (right). The legends in the box-plot from the top to the end are maximum (upper boundary of the dashed line), 3rd quantile (upper boundary of the box), median (middle of the box), 1st quantile (lower boundary of the box), and minimum (lower boundary of the dashed line).

Conclusion

Canopy coverage performs a significant role in partitioning the surface energy budget, regulating the soil temperature, and balancing the ET and soil water content in the landscape scale. Therefore, managing the crop canopy in the agricultural field could be a key in regulating regional micrometeorology and mitigating the possible climate change. This study could offer helpful information for study on the heat stress for workers in the crop fields, for water conservation in agriculture, and for reducing the uncertainties in climate model from micro to regional scales. On the other hand, it may provide a reference to design the ecofriendly agricultural policy.