

1 **Title**

2 Different management strategies exert distinct influences on microclimate of soil-
3 atmosphere system in tea fields

4

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15

16 **Abstract**

17

18 Agricultural management strategies are crucial in regulating the soil-atmosphere
19 interaction. The crop landscape is influenced by farmers through different field
20 practices, and further impacts the variations of soil temperature, soil moisture, and
21 field microclimate. To examine how different management strategies affect the
22 soil properties and the aforementioned interaction, two observation systems were
23 installed in an organic-certified (ORG) tea field and a conventional (CONV) tea
24 field in northern Taiwan. The results show that the variation of canopy
25 temperature was more significant in CONV while the difference in soil diurnal
26 temperature range was minor. However, the daily loss rate of soil water content in
27 ORG was two times faster than that in CONV ($0.93\% \text{ d}^{-1}$ vs. $0.46\% \text{ d}^{-1}$). These
28 findings suggest that the appropriate management strategies could assist farmers in
29 adapting to environmental fluctuations and provide quantitative references for
30 assessing soil characteristics under different agricultural applications and climatic
31 conditions.

32

33 Keywords: organic; conventional; soil temperature; soil moisture;

34 evapotranspiration (ET); eddy covariance (EC)

35 **Plain Language Summary**

36

37 In agricultural fields, the farmers frequently utilize different field applications,
38 such as pruning, weeding, or soil loosening, to manage their crops. The application
39 of these different agricultural management strategies usually changes the
40 appearance of the crop canopy, and further influences the soil properties and the
41 water conservation in these crop fields. To quantify how field management
42 influences these properties, two sets of micro-meteorological measurement
43 systems were conducted in an organic-certified and a conventional tea field in
44 northern Taiwan. According to the ensemble average of the measurements, the
45 difference in soil temperature was minor but the difference in canopy temperature
46 was significantly larger in conventional field. However, the daily loss rate of soil
47 water content in the organic-certified field was faster than that in the
48 conventional field. The variation in soil water content was stronger than that in
49 the conventional field. The findings from this study could sufficiently provide
50 quantitative knowledge for field management in the agricultural fields.

51

52 **Key Points**

53

- 54 1. Field management is crucial in soil-atmosphere interaction through the
55 changes in canopy structure and soil properties.
- 56 2. The difference in soil DTR is minor, but the loss of soil water content is faster
57 in the organic-certified field than conventional field.
- 58 3. High evapotranspiration in the organic-certified tea field corresponds to a
59 high rate of decrease in soil water content.

60

61 1. Introduction

62

63 The long-term interaction between canopy volume and the dynamics of soil
64 parameters (soil temperature, T_s , and soil moisture) has been investigated through
65 modeling and field surveys (Childs and Flint, 1987; Famuwagun, 2016; Flerchinger
66 and Pierson, 1991; Ritter *et al.*, 2005). Canopy coverage obstructs incident solar
67 radiation, causes changes in surface energy balance and evapotranspiration (ET)
68 (Kustas *et al.*, 2018) and alters T_s through canopy shading (Özkan and Gökbülak,
69 2017). The partitions of the surface net radiation, sensible heat flux, and latent
70 heat flux are also influenced by variations in canopy coverage (Baldocchi, 1994).
71 Furthermore, canopy coverage influences soil evaporation because of changes in
72 the canopy structure. In addition, evaporation, combined with infiltration and
73 percolation of rainwater and dew in the soil layer, notably contributes to soil
74 moisture dynamics (Wang and Dickinson, 2012).

75

76 Vegetation canopy regulates the microclimatic factors of above-ground and
77 underground components through energy and water cycles; thus, canopy coverage
78 plays a supportive role in agriculture (Davis *et al.*, 2019; Gao *et al.*, 2019; Kustas *et*
79 *al.*, 2018; Lin, 2007; 2010; Özkan and Gökbülak, 2017). Hirsch *et al.* (2018)
80 discovered that agricultural management can influence the spatial pattern of soil
81 evaporation, whose trend is opposite to that of canopy transpiration on a global
82 scale. Canopy coverage directly influences the ratio of transpiration to evaporation

83 (Lin, 2010; Villalobos *et al.*, 2009) and the dynamics of soil moisture (Lin, 2007).
84 Furthermore, soil moisture is also controlled by ET and ambient temperature
85 through near-surface climate feedback (Berg *et al.*, 2014). High near-surface air
86 temperature might cause an increase in soil moisture due to the less canopy
87 greenness and lower transpiration ability (Zavaleta *et al.*, 2003). A modeling-based
88 study discovered that the effects of the interactions between soil moisture and the
89 atmosphere account for 50% of the effects on T_s , especially in the case of
90 representative concentration pathway 4.5 (RCP4.5) (Diro and Sushama, 2017).

91

92 Unlike in forests, the interactions between soil moisture and the atmosphere
93 on agricultural land are readily influenced by the dominant exchange of radiation
94 and moisture through the canopy layer because the vegetation coverage is lower
95 on such land than that in forests. Canopy shading is a key factor influencing the
96 microclimate of agricultural fields (Bhagat *et al.*, 2016). Famuwagun (2016)
97 demonstrated that the canopy shading in a cocoa field reduced T_s 4 months after
98 plantation by approximately 7.7 °C, which indicated that the canopy shading
99 regulated solar heating over different growth periods. With a decrease in the
100 incident radiation, less energy is available for the evaporation of water and for
101 increasing the ambient temperature. In previous studies, a coffee field with higher
102 canopy shading exhibited a 41% and approximately 2 °C lower soil evaporation
103 rate and ambient temperature, respectively, than did a field with lower canopy
104 shading (Lin, 2007; 2010).

105

106 Research on soil water content mostly focused on the time series of soil
107 moisture (Almagro *et al.*, 2009; Gao *et al.*, 2019; Liang *et al.*, 2014; Lin, 2010;
108 Zheng *et al.*, 2019) but rarely explored its variations in change rate. These studies
109 have reported on the soil moisture dynamics in various conditions. Because of the
110 limitations of topographical or environmental conditions, crop growth in some
111 fields relies only on rainfall and not on irrigation. Therefore, knowledge on the
112 variations in soil water content after every rainfall event is crucial for farmers and
113 scientists during short-term meteorological fluctuations and in different climate
114 scenarios. However, few studies have investigated the variations in soil moisture
115 in terms of change rate or compared various field management strategies. The
116 present study investigated the patterns of T_s , soil moisture, and ET in two
117 neighboring tea fields with different field management strategies to explore the
118 influence of field management strategies on these microclimate parameters.

119

120 **2. Study site and methods**

121

122 2.1. Study site

123

124 On-site measurements were conducted in two nearby tea fields (121.7279°E,
125 24.9645°N, elevation ~600 m above sea level) on a hilly terrain in Pinglin
126 Township, New Taipei City, northern Taiwan, which is a region in which tea

127 cultivation is the leading occupation (Wang and Juang, 2022). The tea fields in the
128 Pinglin region have desirable canopy heights, crown sizes, leaf area density, and
129 corridor width that satisfy the expectations of the farmers. The farmers in this
130 region adopt management strategies based on their long-term local experience,
131 and modification of the canopy structure is the primary approach for applying
132 these strategies. For example, tea farmers frequently shape the tree crown by
133 pruning the branches and leaves to modify the sunshine, ventilation, and water
134 statuses of their field. Therefore, the analysis of the microclimate of the study area
135 by comparing the energy components and soil parameters in nearby fields with
136 similar meteorological and geographical conditions can enhance the fundamental
137 understanding on how field management affects the microclimate.

138

139 The two neighboring tea fields (separated by approximately 100 m)
140 investigated in this study, in which different management strategies are used
141 (Table 1), exhibit similar environmental and geographical parameters, including
142 topographic slope, orientation, fetch area, elevation, and sky openness (Wang and
143 Juang, 2022). One of the fields is an organic-certified field (ORG) in which labor-
144 intensive applications, such as manual weeding and harvesting, are relatively
145 common. By contrast, the other field is a conventional field (CONV) in which
146 farmers typically use herbicide to eliminate weeding and adopt machines for
147 harvesting.

148

149 Because the strategies adopted by the farmers are different for the two fields,
150 their canopy structures are controlled and shaped through field operations. The
151 tea tree crown in ORG was taller and more extensive than that in CONV.
152 Furthermore, the ground surface in ORG was notably covered by weed, whereas
153 the ground surface of CONV was not covered by weed because of the frequent
154 usage of herbicide but was covered with dry leave debris. Research (Wang and
155 Juang, 2022) conducted at this study site indicated that ORG, which had a wider
156 and taller canopy than did CONV, exhibited a higher latent heat flux (25%) and
157 lower sensible heat flux (10%) than did CONV. Furthermore, after the tea buds
158 were harvested, the sensible heat flux increased by 51.5% in CONV but only by
159 9.6% in ORG.

160

161 Although Pinglin is a wet area (the long-term annual rainfall is approximately
162 4,000 mm), the seasonality in rainfall is notable (the rainfall is approximately 200
163 mm during spring but exceeds 1,000 mm during autumn). The rainfall patterns
164 over different seasons were compared according to the accumulative rainfall
165 acquired from five automatic weather stations and one meteorological station of
166 the Central Weather Bureau in Taiwan near the study fields.

167

168 2.2. Physical properties of the soil in the two fields

169

170 Because the two tea fields managed using different strategies were adjacent to
171 each other, the physical properties of the soil layers in these fields were affected
172 by the different farmers' applications in the fields on a long-term basis. For
173 example, the biological activities and root systems in ORG were more likely to
174 cause the soil to loosen than were those of CONV. Measuring soil bulk density is a
175 common method for characterizing soil structural properties (Dexter, 2004; Rabot
176 *et al.*, 2018).

177

178 Soil bulk density was measured from soil samples excavated from the northern,
179 middle, and southern sides of the corridor near the soil moisture sensor. The
180 volume and depth of the sampling core were 98 cm³ and 5 cm, respectively. Before
181 sampling was performed, the bulk debris cover on the soil surface was carefully
182 removed, but the humus in the soil was kept intact. The core was vertically
183 inserted into the soil, after which the soil samples were excavated. The sample
184 tube was then covered using a plastic lid to avoid evaporation. Each soil sample
185 was dried at 105°C for 24 h. The dried soil samples were then weighed, and the
186 bulk density was calculated as the dried soil weight divided by the core volume
187 (Klute, 1986).

188

189 2.3. Soil temperature, canopy temperature, and soil moisture measurement

190

191 In the study region, tea plants are typically planted in rows in parallel

192 corridors, and the landscape has an inhomogeneous appearance. This
193 inhomogeneity was expected to influence the representativeness of the
194 measurements and should be considered when assessing the soil layer (Michot *et*
195 *al.*, 2003). To consider the spatial representativeness of the tea fields, pairs of soil
196 temperature and water content sensors (Drill and Drop, Sentek Inc., Stepney, SA,
197 Australia) were installed on the northern and southern corridors near an eddy-
198 covariance (EC) flux system in each field. The detectors were placed 5 cm below
199 the ground surface to perform measurements from June 2019 to October 2020. The
200 canopy temperature (T_c) were measured at the tree crown by a T-type
201 thermocouple with radiation shield. The data was collected using a data logger
202 (CR1000X, Campbell Scientific, Inc., Logan, UT, USA) at a sampling frequency of 1
203 min^{-1} .

204

205 The measurement data collected from the winter of 2019 to the autumn of
206 2020 were divided among four seasons because the ground surface temperature
207 was sensitive to solar radiation. To quantify how field applications affect the
208 patterns of field temperature, the half-hourly time series of temperature difference
209 between T_c and T_s ($T_c - T_s$) were obtained for further analysis.

210

211 2.4. ET measurement

212

213 ET was estimated using an EC flux system composed of a 10-Hz sonic

214 anemometer (CSAT-3, Campbell Scientific, Inc., Logan, UT, USA), and an open-
215 path CO₂/H₂O gas analyzer (LI-7500, Li-Cor Inc., Lincoln, NE, USA) in each field
216 (Wang and Juang, 2022). The EC equipment was set at heights of 1.5 m (canopy
217 height of 1.0 m) and 1.0 m (canopy height of 0.5 m) in ORG and CONV,
218 respectively. ET data were collected using the CR1000X data logger, and the 30-
219 min mean ET values were calculated using the EddyPro v6.2.2 software (Li-Cor
220 Inc., Lincoln, NE, USA). In addition, the fetch area of the flux measurement was
221 estimated using a R package (FREddyPro v1.0). Although both fields are small
222 (Table 1), over 90% of the flux originated from the fields because the measurement
223 heights were low.

224

225 **3. Results and discussion**

226

227 **3.1. Soil bulk density**

228

229 According to the analysis of physical properties, the soil bulk density was 1.19
230 ± 0.02 g cm⁻³ in CONV and 1.10 ± 0.10 g cm⁻³ in ORG. The lower bulk density in
231 ORG was likely on account of the higher abundance of organisms and weed roots
232 in the soil layer in ORG because no pesticide or herbicide was used in this field. In
233 ORG, the organisms in the soil caused the soil structure to loosen, increased the
234 porosity for air and water, and decreased the soil aggregate stability for root
235 development. The higher variation in soil bulk density in ORG (0.10 g cm⁻³ in

236 ORG and 0.02 g cm^{-3} in CONV) was consistent with these results (Rabot *et al.*,
237 2018). The lower aggregate stability in ORG than in CONV promoted infiltration
238 more effectively in ORG, thereby resulting in less surface runoff in ORG (Rabot *et*
239 *al.*, 2018).

240

241 3.2. Soil temperature, canopy temperature and temperature difference

242

243 T_s in the fields was influenced by canopy coverage and seasonal variation
244 (dependent on incident solar radiation). To quantify the diurnal temperature range
245 (DTR) over different seasons, the ensemble average of the 30-min data in CONV
246 and ORG was converted into the DTR (the difference between each 30-min data
247 point and the first data point) over different seasons (**B1** to **B4** in Figure 1, from
248 the winter of 2019 to the autumn of 2020). In ORG, the DTR over the seasons was
249 highly similar; however, the DTR in CONV was higher during autumn and winter
250 than during other seasons. The results indicated that the DTR in CONV was
251 higher than that in ORG during autumn ($4.69 \text{ }^\circ\text{C}$ in CONV vs. $3.95 \text{ }^\circ\text{C}$ in ORG)
252 (Figure 1 **B4**), and the DTR in CONV was lower than that in ORG during winter
253 ($2.85 \text{ }^\circ\text{C}$ in CONV vs. $3.07 \text{ }^\circ\text{C}$ in ORG) (Figure 1 **B1**). Although the DTR in autumn
254 and winter were noticeable, the ensemble average over all seasons indicated that
255 the DTR in CONV was similar to that in ORG ($2.50 \text{ }^\circ\text{C}$ in CONV vs. $2.46 \text{ }^\circ\text{C}$ in
256 ORG). The T_s difference in ensemble average was not significant (the maximum
257 difference is $0.46 \text{ }^\circ\text{C}$ at 11:00, Figure 2 **A**).

258

259 Compared to the difference of DTR in T_s , the difference of dynamics in T_c was
260 more notable. T_c in CONV was 0.86 °C (46.5%) higher than ORG around noon
261 (9:00-15:00), and 0.36°C (22.3%) lower than ORG during nighttime (21:00-3:00).

262

263 As indicated by the canopy structure, the canopy coverage in ORG was higher
264 than that in CONV (leaf area index, was 4.11 in ORG and 1.04 in CONV on May
265 14, 2020, as reported by Wang and Juang (2022)). An obvious heating effect in
266 CONV occurred around the canopy (0.86 °C) due to its shorter height.

267

268 A previous study has indicated that a higher canopy shading in a coffee field
269 can result in a lower field temperature and more beneficial to microclimate (Lin,
270 2007). The shading effect of a higher canopy coverage attenuates the radiation
271 incident on the ground surface and might increase the shade tolerance of some
272 organisms in the understory layer (Valladares *et al.*, 2016). De Frenne *et al.* (2013)
273 reported that in addition to moderating the microclimate, a dense forest canopy
274 might result in thermophilization lag under the forest canopy. Canopy shading has
275 notable influence on ecophysiological characteristics, and more active abiotic and
276 biotic ecosystem dynamics in higher shading area are observed within the canopy
277 volume (Valladares *et al.*, 2016). Therefore, the canopy coverage in this study
278 showed an obvious influence on the dynamics of T_c .

279

280 3.3. Soil moisture

281

282 From the data shown in Figure 1, there was no correlation pattern between the
283 seasonal accumulative rainfall (**A1** to **A4** in Figure 1) and the consecutive daily soil
284 water content between every rainfall events (**D1** to **D4** in Figure 1). Because
285 Pinglin is a wet region that receives 4,000 mm of rainfall annually and a
286 considerable amount of dew water in the morning, soil water content did not
287 exhibit seasonal variation. The results indicated that the median daily mean soil
288 water content after rainfall was 28.5% in CONV and 30.6% in ORG. Furthermore,
289 after 7 days, the median changed to 24.9% in CONV and 20.7% in ORG (Figure 3
290 A). Overall, the average daily loss rate was 0.46% d⁻¹ in CONV and 0.93% d⁻¹ in
291 ORG.

292

293 A study indicated that the soil water content in organic field was higher than
294 that in conventional field because of the higher capacity of organic field to retain
295 soil water (Lotter *et al.*, 2003). In the present study, similar results were obtained
296 for soil water content after the rainfall event (CONV vs. ORG: 28.5% vs. 30.6%).
297 However, the rate of soil water loss in ORG was higher than that in CONV 7 days
298 after the rainfall event, thereby which resulted in the soil water content being
299 lower in ORG (CONV vs. ORG: 24.9% vs. 20.7%). Lin (2010) found that lower
300 shading in a coffee field resulted in higher soil water loss in the wet and dry
301 seasons. However, in this study, the soil water content between rainfall events was

302 initially 1.2% higher in ORG but then became lower with time (4.2% lower
303 compared with CONV). This pattern indicates that the loss rate of water content
304 was higher in ORG than in CONV.

305

306 During the first 4–5 days after a rainfall event, the daily soil water content
307 decreased more notably in ORG than in CONV (**D1** to **D4** in Figure 1). The daily
308 loss rate was higher on the first 4 days than on the later days (Figure 3 **B**). After
309 the rainfall events, the median of the daily loss rate of soil water content was
310 0.58% d⁻¹ in CONV and 0.77% d⁻¹ in ORG. On the 3rd to 4th day, the daily loss
311 rate in CONV and ORG were 0.42% d⁻¹ and 1.29% d⁻¹, respectively. On the 6th to
312 7th day, the rate in CONV was 0.21% d⁻¹, and the rate in ORG was 0.71% d⁻¹. The
313 daily loss rate from the 1st and 2nd days to the 4th and 5th days in the two fields
314 were significantly different ($p < 0.05$) (Figure 3 **B**). Overall, the soil moisture
315 dynamics in ORG were stronger than those in CONV. In ORG, the daily loss rate
316 of soil water content increased from the beginning to the following rainfall event,
317 but a retard situation occurred on the 4th day. The relatively fast loss of soil water
318 content in ORG was consistent with the low soil bulk density in ORG, which
319 resulted in a higher infiltration rate in ORG than in CONV. Therefore, the soil
320 moisture dynamics in ORG were stronger than those in CONV.

321

322 The distribution of weed roots in ORG increased the soil porosity in ORG and
323 caused an increase in the water holding capacity of the soil during rainfall events.

324 However, the increased porosity of the soil layer facilitated the evaporation of soil
325 water after rainfall (Or *et al.*, 2013). In addition, transpiration in the weeds in
326 ORG resulted in the loss of soil water. Moreover, the ground surface of CONV was
327 covered with leaf debris (formed during tea plant trimming) that caused a decrease
328 in evaporation by blocking direct solar heating. Therefore, the soil water content
329 in ORG increased after rainfall but later decreased at a high rate, and the
330 rainwater holding ability of the soil in CONV was higher than that of the soil in
331 ORG.

332

333 3.4. Evapotranspiration

334

335 The difference in the daily loss rate of soil water content in terms of the ET
336 pattern between the two fields was considerably large. The ET rate was 6.27 mm
337 d⁻¹ in CONV and 8.38 mm d⁻¹ in ORG, which indicated that the ET in ORG was
338 33.8% higher than that in CONV. The most significant difference occurred around
339 noon (from 10:00 to 14:00 LT). The ensemble average and maximum values of the
340 ET in ORG over 30 min were 0.480 and 0.535 mm, respectively, and the
341 corresponding values in CONV were 0.351 and 0.412 mm, respectively. These
342 results were obtained around mid-day and indicated that the ET in ORG was
343 approximately 36.8% higher than that in CONV (Figure 2). The ET patterns in the
344 two fields were significantly different ($p < 0.001$), especially during the day (7:30–
345 17:00). Thus, according to the ET pattern and soil water content, the loss of soil

346 water from the ground surface in ORG was higher than that in CONV, which
347 contributed to the ET in ORG.

348

349 The higher ET in ORG than in CONV was attributable to the taller and wider
350 canopy structure of the tea plants and the weeds covering the ground surface in
351 ORG. Compared to that in ORG, the tea tree canopy in CONV was shorter,
352 thereby limiting the loss of water. The present study did not distinguish between
353 evaporation and transpiration in the tea fields. However, according to field
354 observations in previous studies, the long-term evaporation of soil water in CONV
355 is limited by the leaf debris covering the ground surface (Facelli and Pickett,
356 1991). Transpiration had a notable influence on the ET in ORG because of the
357 higher canopy volume in ORG than in CONV, as indicated by the leaf area index
358 (LAI). By contrast, soil evaporation had a considerably low contribution to the ET
359 in the Pinglin region because the annual rainfall in the region was approximately
360 4000 mm and the landscape was primarily covered with vegetation that
361 contributed to water conservation.

362

363 W. Todd *et al.* (1991) suggested that wider canopy coverage on the ground
364 surface reduced the evaporation in a corn field. Another study reported that a
365 larger shading area in a coffee field decreased the rate of loss of the soil water
366 content (Lin, 2010). The present study indicated that a tea field with a larger
367 canopy coverage exhibits higher ET and superior soil moisture dynamics between

368 rainfall events. Therefore, a larger canopy coverage contributes to enhancing ET,
369 and the canopy volume is higher because of higher LAI (Wang *et al.*, 2014).

370

371 4. Conclusions

372

373 In the tea cultivation industry, the various management strategies adopted by
374 tea farmers according to their expectations typically involve altering canopy
375 structures and the microclimate of the tea field. In this study, we performed a
376 series of measurements and analyses to examine the outcomes of different
377 management strategies in terms of T_c , T_s , soil moisture, and ET in two neighboring
378 tea fields in northern Taiwan. The results indicated that field applications
379 (organic-certified and conventional methods) corresponded to differences in
380 surface heating and soil moisture through the modification of canopy coverage.

381

382 The shorter and narrower canopy coverage in CONV than in ORG resulted in
383 a lower rate of decrease in soil moisture after each rainfall event in CONV (-0.46%
384 d^{-1}) than in ORG ($-0.93\% d^{-1}$). This result was consistent with the ET pattern and
385 indicated that the rate of ET in ORG was $2.11 \text{ mm } d^{-1}$ (33.8%) higher than that in
386 CONV ($6.27 \text{ mm } d^{-1}$ in CONV and $8.38 \text{ mm } d^{-1}$ in ORG) because the canopy and
387 weed in ORG tended to release more soil water through the root system.
388 Furthermore, the higher ET leads to lower canopy temperature in ORG than in
389 CONV ($0.86 \text{ }^\circ\text{C}$ or 46.5%). In addition, the rate of decrease in soil moisture in the

390 two fields changed drastically 3-4 days after rainfall. The loss rate was faster in the
391 first 3-4 days than the later days, and this pattern was more significant in ORG.
392 The lower soil bulk density in ORG can be attributed to the higher rate of
393 decrease in soil moisture. The inverse relationship between bulk density and
394 variations in soil water content in this study is consistent with the concept of least
395 limiting water range (LLWR) introduced by da Silva *et al.* (1994).

396

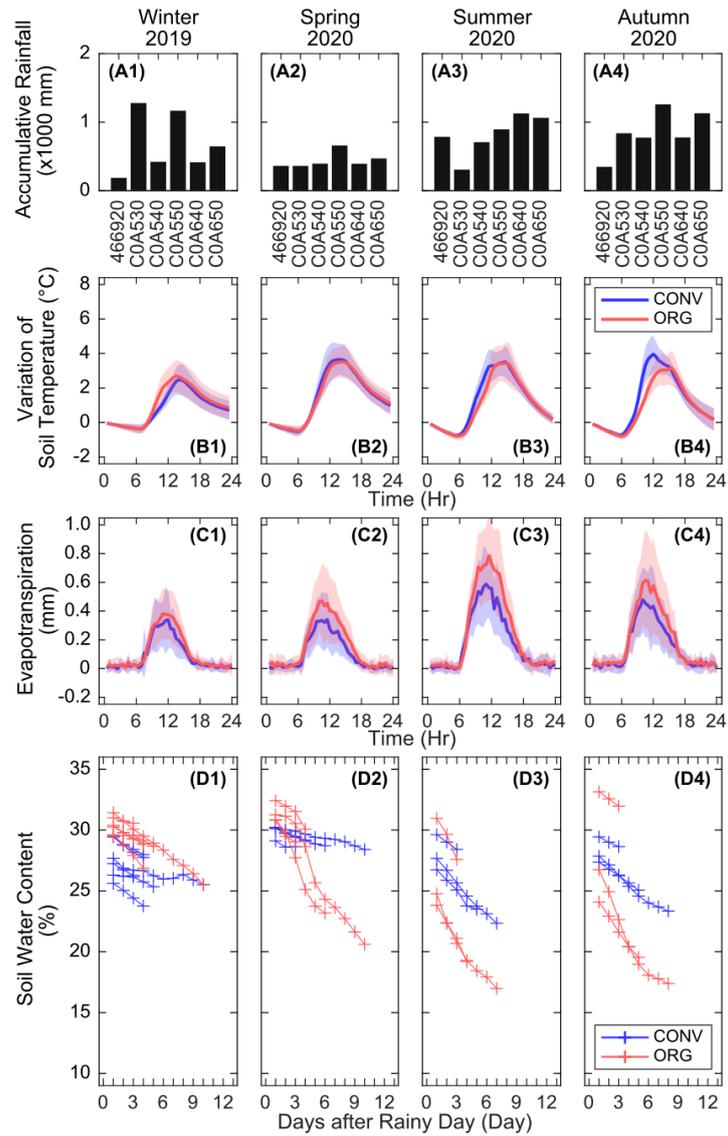
397 The strategies used for soil water management in tea fields can serve as
398 references for water resource management in agricultural land at the regional
399 scale. These strategies can also help farmers determine the extent of trimming and
400 weeding required to offset the influence of rain and drought events (Bhagat *et al.*,
401 2016). Lotter *et al.* (2003) reported that the water holding capacity of soil in
402 organic crop fields is higher than in other fields. The high water holding capacity
403 of soil is crucial for controlling the interactions between soil moisture and the
404 atmosphere (Diro and Sushama, 2017). It dominates the energy budget
405 (Flerchinger *et al.*, 2003) and can effectively retard floods caused by frequent
406 extreme climate fluctuations. Furthermore, T_s and soil moisture are essential
407 parameters that influence the crop yield (Liu *et al.*, 2013), hydrological cycle
408 (Robinson *et al.*, 2008), biological process, and various physical responses (Legates
409 *et al.*, 2011).

410

411 Although the influence of diurnal soil temperature difference on surface

412 temperature is unclear, the results suggest the high correlation between coverage
413 and surface temperature. Canopy coverage or shading in the field can moderate
414 the surface temperature in the long term and mitigate the tradeoffs. Godinho *et al.*
415 (2016) reported that the higher canopy coverage could lower surface temperature.
416 In addition, the existence of cover crops could reduce soil erosion under extreme
417 rainfall (Kaye and Quemada, 2017). Besides the geophysical effects, Schmitzberger
418 *et al.* (2005) reported that ecofriendly agriculture has relatively low economical
419 turnover but provides high biodiversity value. Although ecofriendly agriculture
420 produces relatively low yields (Maeder *et al.*, 2002), the demand for fertilizers and
421 pesticides is considerably lower than that in conventional agriculture
422 (Schmitzberger *et al.*, 2005; Zhang *et al.*, 2018). Furthermore, organic farms have
423 high biodiversity (Maeder *et al.*, 2002) and ecofriendly planting might increase the
424 resilience of crop fields against rigorous climate. The results and data of this field
425 study can serve as background information for numerical models for assessing soil
426 characteristics as the outcomes of different management strategies and different
427 climatic conditions.

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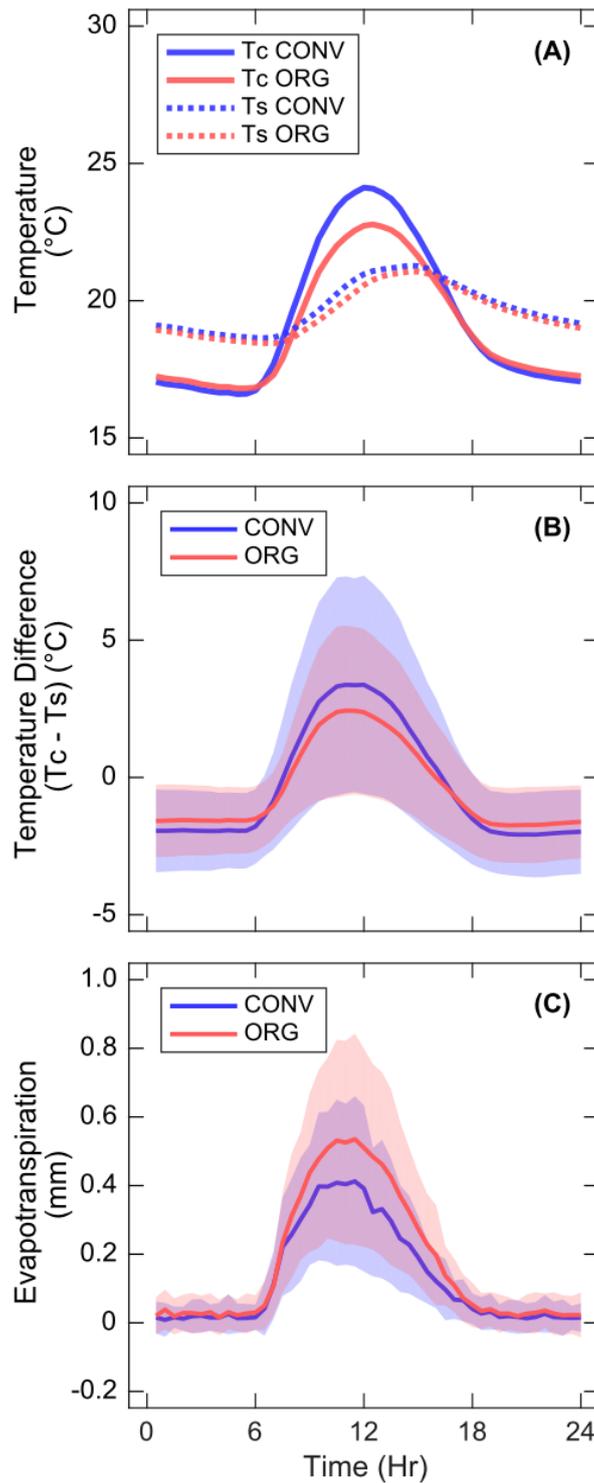


429

430 **Figure 1** Seasonal cumulative rainfall (A1 to A4), soil temperature (B1 to B4), ET
 431 (C1 to C4), and soil water content (D1 to D4) from the summer of 2019 to the
 432 autumn of 2020. Rainfall data were captured at six weather stations (466920:
 433 Taipei, C0A530: Pinglin, C0A540: Sihdu, C0A550: Taiping, C0A640: Shihding,
 434 C0A650: Huoshaoliao) of the Central Weather Bureau.

435

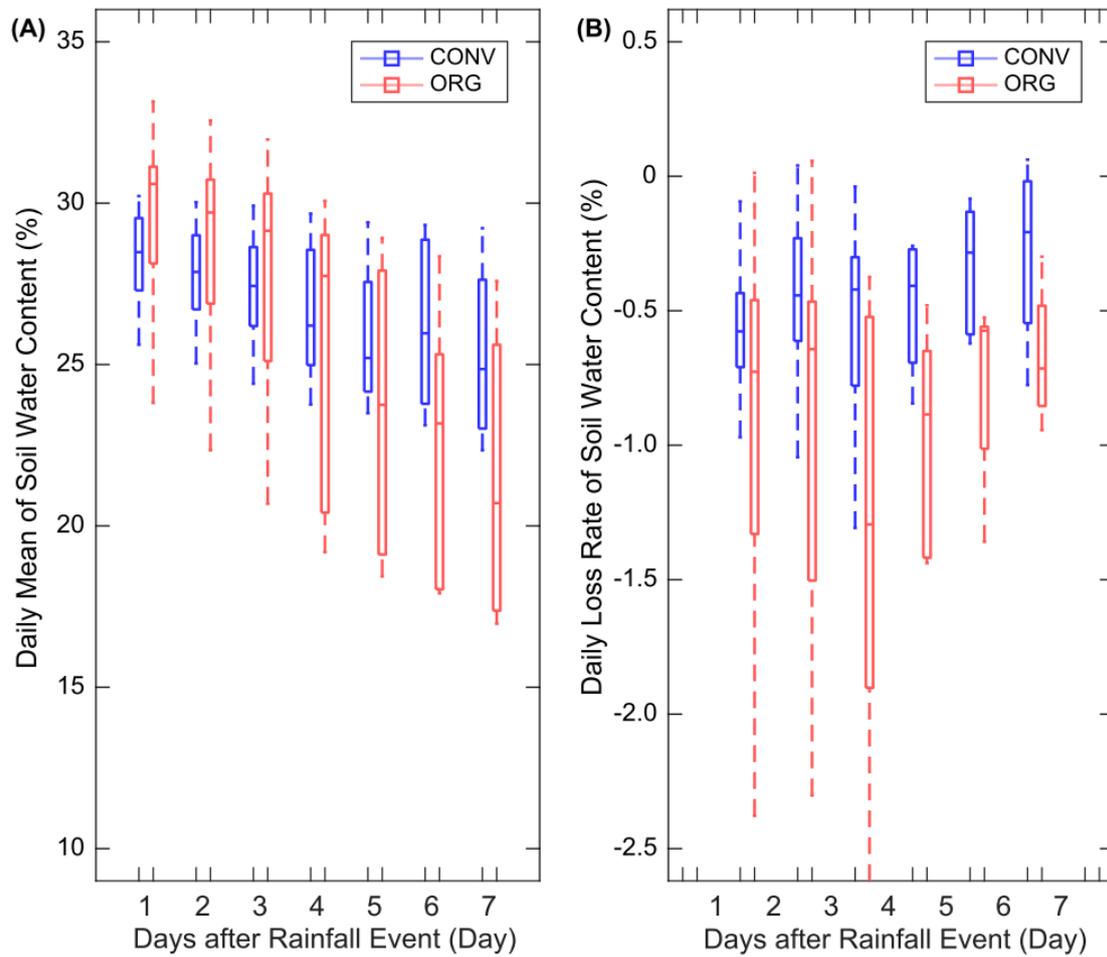
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437

438 **Figure 2** (A) Ensemble average of canopy temperature (T_c) and soil temperature
 439 (T_s), (B) difference between T_c and T_s , and (C) ensemble average values of ET
 440 during the measurement period. The solid lines and dotted lines are the ensemble
 441 averages, and the shadow area represents one standard deviation.

442



443

444 **Figure 3** Daily mean (A) and daily loss rate (B) of soil water content between
 445 rainfall events. The legends in the box plot from the top to the end are the
 446 maximum (upper boundary of the dashed line), third quantile (upper boundary of
 447 the box), median (middle of the box), first quantile (lower boundary of the box),
 448 and minimum (lower boundary of the dashed line) values. The conditions of
 449 capturing rainfall data for daily loss rate were as follows: daily rainfall of less than
 450 0.8 mm; the daily rainfall on the previous day did not exceed 1.2 mm; and the data
 451 for only 2 successive days were excluded.

452

453 **Table 1** Geographical properties, management strategies, and canopy properties of
 454 the two investigated tea fields. The statistical result of FAPAR in 2018 did not pass
 455 the comparison test, and all other comparisons in 2018 and 2020 passed the
 456 Wilcoxon rank sum test.

Properties		CONV	ORG
Geographical Properties	Elevation (m)	575	580
	Slope (%)	33.0	31.7
	Heading (°)	143.1	170.3
	Area (m ²)	1234	1051
Management	Planted species	TTES #13 ¹	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) ²	1.00	1.25
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

¹ TTES: Taiwan Tea Experiment Station.

² Horizontal distance, not including tilt.

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469

470 **Open Research**

471 **Data Availability Statement**

472 The measurement data is available at <https://doi.org/10.1088/1748-9326/ac4361>

473 (Wang and Juang, 2022), and the climate data is available at Central Weather

474 Bureau, Taiwan (https://www.cwb.gov.tw/V8/E/D/Data_Application.html)

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612

Figure 1.

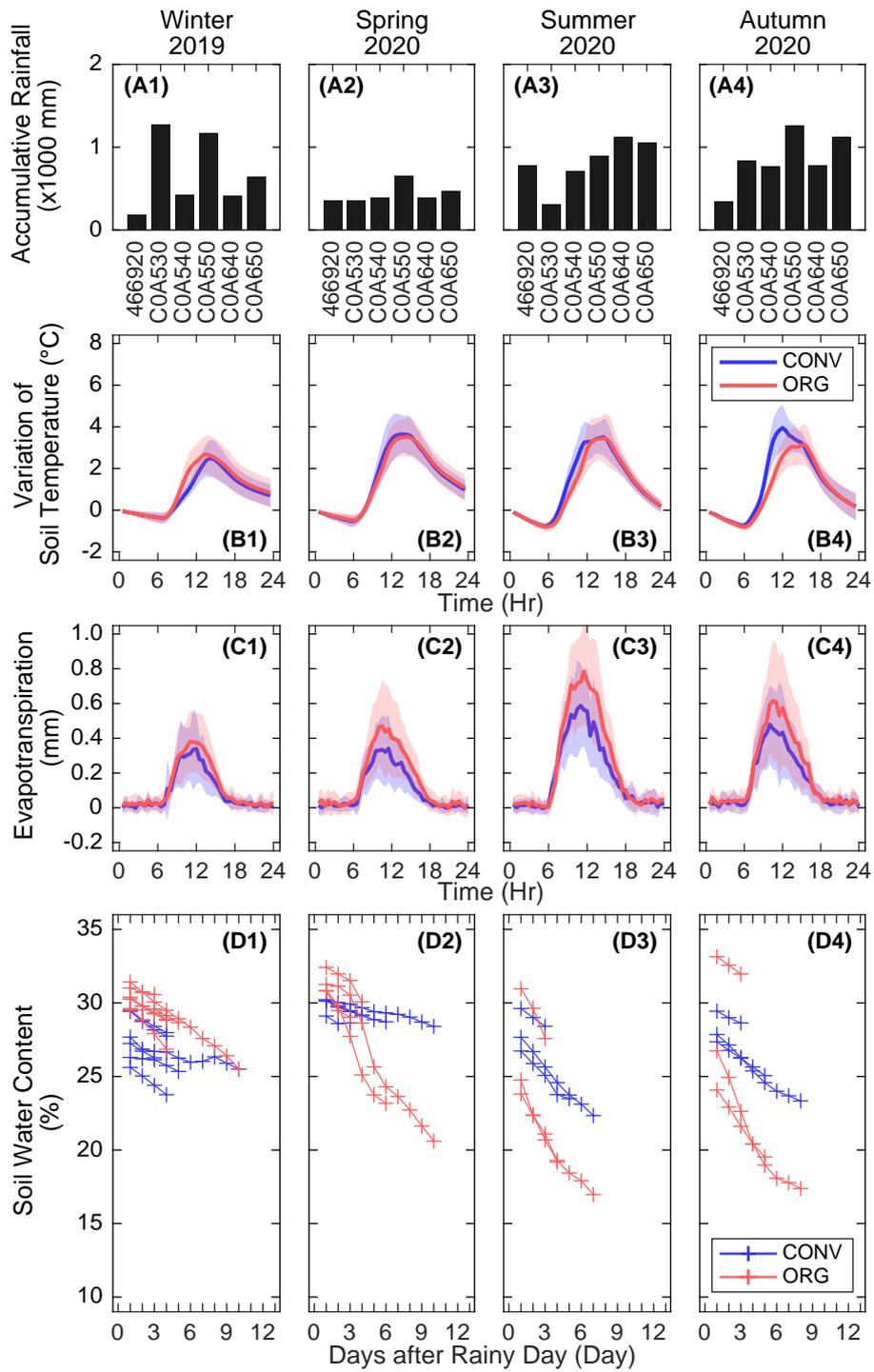


Figure 2.

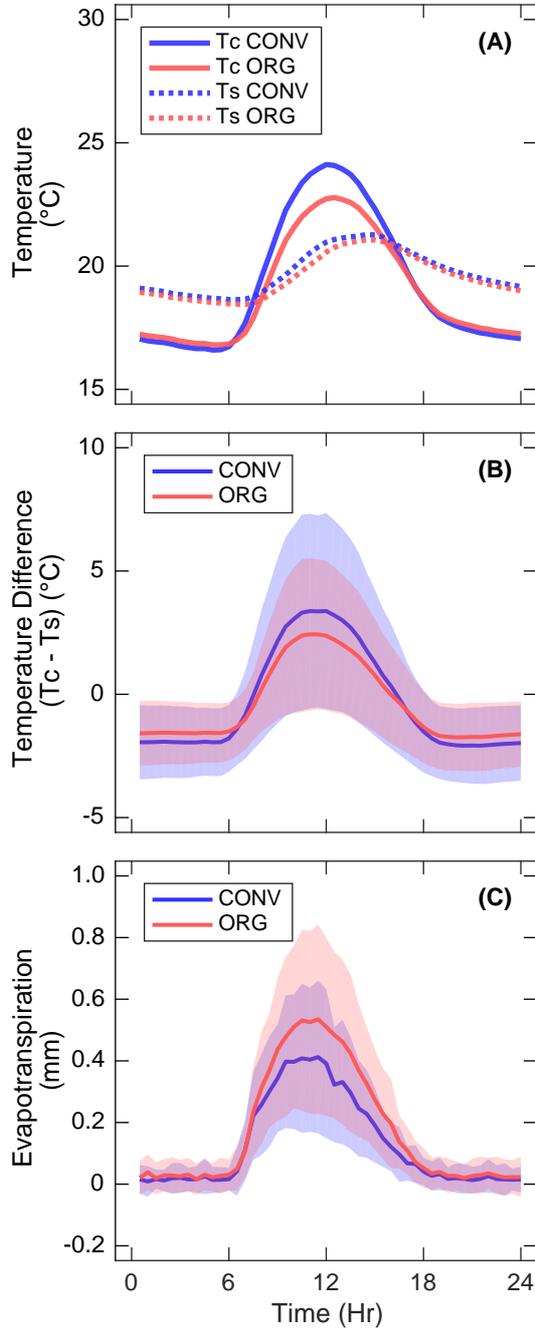


Figure 3.

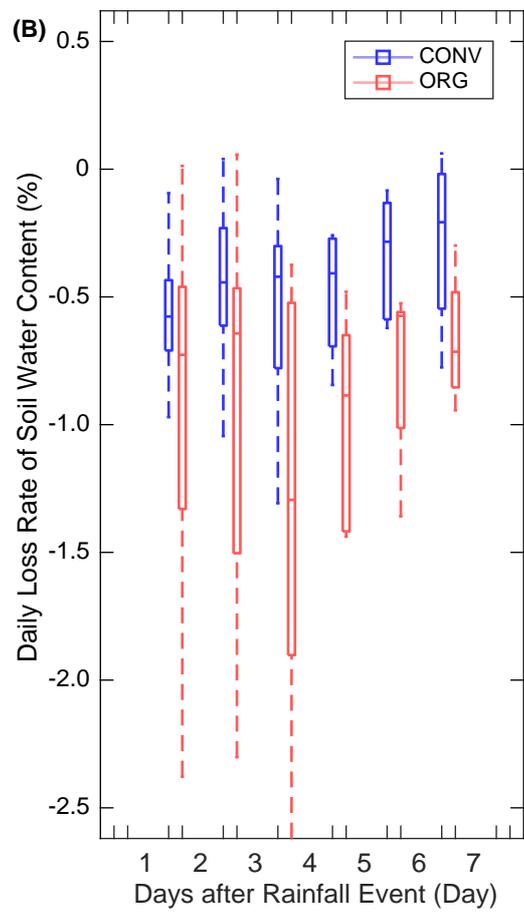
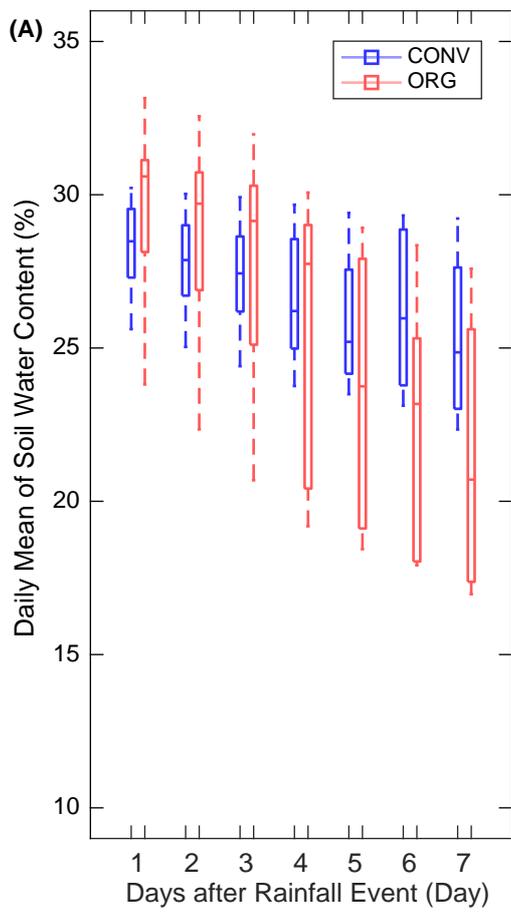


Table 1 Geographical properties, management strategies, and canopy properties of the two investigated tea fields. The statistical result of FAPAR in 2018 did not pass the comparison test, and all other comparisons in 2018 and 2020 passed the Wilcoxon rank sum test.

Properties		CONV	ORG
Geographical properties	Elevation (m)	575	580
	Slope (%)	33.0	31.7
	Heading (°)	143.1	170.3
	Area (m ²)	1234	1051
Management	Planted species	TTES #13 ¹	TTES #12
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² Horizontal distance, not including tilt.