

Energy partitioning and evapotranspiration over a black locust plantation in the Yellow River Delta

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Abstract

Woody plantations play a curtail role in ecological security along coastal zones. Understanding of energy partitioning and evapotranspiration (ET) over black locust plantations can reveal land-atmosphere interaction process and help us to optimize this plantation for land management in the Yellow River Delta. In this study, we investigated energy fluxes, ET in particular, and their related biophysical factors using eddy covariance techniques over a black locust plantation in 2016, 2018, and 2019. Downward longwave radiation offsets 84%–85% of upward longwave radiation, upward shortwave radiation accounted for 12%–13% of downward shortwave radiation, and the ratio of net radiation (R_n) to downward radiation was 18%–19% in the three years. During growing seasons, latent heat flux was the largest components among radiation balance terms; during non-growing seasons, sensible heat flux was a dominant component. ET was mainly controlled by R_n , air temperature, vapor pressure deficit and leaf area index (LAI). Annual ET was smaller than the sum of precipitation and irrigation, and cumulative ET was larger than cumulative precipitation during non-growing seasons. The phenology of black locust influenced the seasonal variation in daily ET, mainly via LAI. ET was larger under sea wind than under land wind, mainly because soil water content at 10-cm depth was greater under sea wind in daytime. Seasonal patterns of daily evaporative fraction, Bowen ratio, crop coefficient, Priestley–Taylor coefficient, surface conductance (g_s), and decoupling coefficient were mainly controlled by LAI, and the threshold value of daily g_s was approximately 8 mm s^{-1} over the studied plantation.

Keywords: Black locust plantation, Yellow River Delta, Eddy covariance, Energy partitioning, Evapotranspiration

1. Introduction

The precise quantification of energy exchange between the land surface and the atmosphere is required by the field of numerical weather predictions and climate modeling, since the land surface thermodynamic and hydrological processes are closely coupled to the atmospheric circulation process (Valayamkunnath et al., 2018; Ward et al., 2014; Odongo et al., 2016). The studies on surface radiation balance and

energy partitioning are promoted by the development of global climate change sciences (Chen et al., 2016). The partitioning of net radiation (R_n) into sensible heat flux (H), latent heat flux (LE), soil heat flux (G), and heat storage in the vegetation plays a critical role in the turbulence flow structure and thermodynamic process of the boundary layer, and hence directly influences the Earth's climate system at local, regional, and ultimately global scales (You et al., 2017; Odongo et al., 2016; Chen et al., 2016). On the other hand, the changes in land cover and climate in turn affect a variety of physical and physiological processes in the vegetation and finally alter the energy exchange between the land surface and the atmosphere (Zhu et al., 2014). Previous studies have demonstrated that the surface albedo is often lower in forests than cropland, grassland, and deserts, and so forests could use more solar radiation (Gao et al., 2018; Yue et al., 2019; Zhu et al., 2014). The forests cover approximately 30% of the total land surface of the Earth (Iida et al., 2006) and distribute from the tropical to frigid zones. Their energy partitioning varies with forest types (Liu et al., 2018; Betts, 2000). Therefore, a better understanding of the energy partitioning in different forest types under various environmental conditions is required to describe complex interactions between the terrestrial biosphere and atmosphere as well as water circulation and global climate change (Zhu et al., 2014).

Evapotranspiration (ET, i.e. LE in an energy unit) is the amount of water into the atmosphere from the land surfaces. ET is the sum of evaporation from bare soil and wet vegetation canopy surface and transpiration out of plant stomas (Valayamkunnath et al., 2018; Iida et al., 2020). The ET consumes about 60% of annual precipitation globally on the land surface (Jung et al., 2010; Odongo et al., 2016), and is the link between hydrological cycle and energy exchange processes. Leaf stomata controls vegetation transpiration and photosynthesis. Therefore, ET is closely coupled to carbon uptake at an ecosystem scale (Aires et al., 2008; Jia et al., 2016). The variations of ET are generally controlled by meteorological factors, vegetation properties and soil water conditions (Gao et al., 2018; Yue et al., 2019; Valayamkunnath et al., 2018). In recent years, reforestation rates have been rapidly increasing in China, and so far forest plantations, critical for ecological protection, account for about 33% of forestland in China (Chen et al., 2014; Ma et al., 2019), which has dramatically shown the role of vegetation in the afforested/reforested areas. Therefore, it is motivated to investigate the ET process related to its control factors determining the mechanisms by which hydrological cycle and energy exchange are

104 regulated for carbon sequestration and other ecosystem processes in plantations.

105 The Yellow River Delta on the north coastline of China covers an area of about
106 $5.4 \times 10^3 \text{ km}^2$, provides the habitats on the East Asian-Australasian Flyway (Liu et al.,
107 2020), has a population over two millions, and supports the largest petroleum industry
108 in China (Zhou et al., 2015). The delta, significantly affected by land-ocean
109 interaction (Kong et al., 2015), is a typical ecologically vulnerable area with low
110 water table (average depth is 1.14 m) and vast saline-alkali soil area ($2.4 \times 10^3 \text{ km}^2$) (Li
111 et al., 2019). Attributed by human intervention and climate change, the delta
112 undergoes intensive conversion from natural wetland to croplands and plantations
113 (Chi et al., 2018). Studies have shown that plantations decrease water table through a
114 large amount of transpiration and control soil saltation through restraining the direct
115 movement of soil water from deeper layers to the soil surface that leaves its salt on the
116 surface and evaporates itself into atmosphere, and finally improving ecological
117 environment and promoting region sustainable development (Minhas et al., 2020).

118 The plantations play a key role in maintaining ecological security. This role needs
119 better understanding through the investigation of land surface processes as impacted
120 by this pivotal ecosystem in the Yellow River Delta. Revealing the maintenance and
121 control mechanisms of the energy partitioning and ET over the plantations in the
122 Yellow River Delta could improve our understanding of land-atmosphere interaction
123 process and provide support for plantation management in the coastal zone
124 of northern China.

125 Black locust (*Robinia pseudoacacia*) is a nectar source and fast-growing timber tree
126 species native to North America (Jiao et al., 2019). More importantly, this species is
127 one of the most ecologically friend species due to its function role in effective erosion
128 reduction, soil improvement and carbon sequestration, and now it is widely used in
129 ecological projects in the northern China (Jiao et al., 2018). As black locust can be
130 grown on the mild saline and alkaline soil (Ma et al., 2013), it is a major tree species
131 for afforestation to improve ecological environment in the saline-alkali land, and the
132 black locust plantations have covered 8000 hm^2 in the Yellow River Delta (Cao et al.,
133 2012). A number of studies have investigated water vapor flux and its control
134 mechanism over black locust plantations on the Loess Plateau, due to the complexity
135 in terrain landform only tree transpiration was measured using the sapflow technique,
136 and energy partitioning could not be analyzed in those studies (Jiao et al., 2018; Jiao
137 et al., 2019; Zhang et al., 2020). Given that the natural environment on the Loess

Plateau is entirely different from that in the coastal zone, it is vital to investigate water vapor and energy fluxes and their dominant influences under global climate change in the Yellow River Delta to fill up the gaps in the previous studies.

Over the past two decades, the eddy covariance (EC) technique has become a standard method for measuring the exchange of water vapor and energy between the land surface and atmosphere (Gao et al., 2017). In this study, we used 3-year energy and water vapor fluxes observed by the EC technique and related biophysical data over a black locust plantation in the Yellow River Delta. Our objectives are to: (1) characterize energy fluxes and ET varied on diurnal and seasonal scales; (2) assess the effects of environmental drivers on energy partitioning and ET; (3) determine the surface parameters characterizing energy partitioning and evapotranspiration.

2. Materials and methods

2.1. Study site

Study site is located at Forest Ecosystem Research Station of the Yellow River Delta in Shandong (37°54'2" N, 118°49'2" E, 3.4 m a.s.l.), Hekou district, Dongying city, China (Fig.1). It is flat and experiences a warm-temperate continental monsoon climate, with a mean annual air temperature of 12.3 °C and a mean annual frost-free period of 210 days. The mean annual precipitation is 574.4 mm with approximately 70% occurring in summer, and the mean annual evaporation is 1962.1 mm (Zhang and Xing, 2009). The soil in this site is a Fluvisol (FAO, 2000) and developed on mixed loess and alluvium, and the volumetric water content of field capacity and wilting humidity are 0.28 cm³ cm⁻³ and 0.10 cm³ cm⁻³, respectively, with bulk density of 1.45 g cm⁻³. The soil is a mild saline-alkali soil, with salt content of 1.53 g kg⁻¹ and pH value of 8.55. The black locust plantation is 35 years old, with stand density of 581 stems ha⁻¹, diameter at breast height of 18.6 cm, and canopy height of approximately 14.5 m. The understory vegetation is mainly Bermuda grass (*Cynodon dactylon*).

(Fig.1)

2.2. Measurements

A 25-m tall tower was constructed in the black locust plantation for mounting turbulent fluxes and meteorological instruments. The details of those instruments are

shown in Table 1. All sensors on the tower are connected to a CR1000 Datalogger (Campbell Scientific Inc., Logan, UT, USA). The data from the measurements of 2016, 2018, and 2019 are used in this study.

The distance of the tower to nearest boundary of the plantation is approximately 450 m. The daily precipitation (P) and groundwater depth (GD) were acquired from Yellow River Delta Ecological Research Station of Coastal Wetland, Chinese Academy of Sciences and nearby national groundwater depth monitoring station (<http://xxzx.mwr.gov.cn/>), respectively.

Based on previous study (Yuan et al., 2014), we divided growing season (GS) into three phenological stages (early growing stage, EG; mid growing stage, MG; and later growing stage, LG). The EG stood for the germination and leaf expansion period; the MG included the vegetative phase, blooming, and fruit ripening stage; and the LG was the leaf senescence period. The start date and end date of each phenological stage is shown in Table 2, and the rest of the year was the non-growing season (NG). The plantation was irrigated once annually at the beginning of the GS.

According to downward shortwave radiation below/above the canopy (S_{db}/S_{da}), leaf area index (LAI) was calculated by inverting the Beer's law equation:

$$S_{db} = S_{da} \exp(-\kappa LAI) \quad (1)$$

Where κ is the extinction coefficient of light attenuation (0.54, Li et al., 2018).

Table 1

2.3. Data processing

The post-processing of turbulent fluxes contains the necessary procedures for quality control and correction. The quality control of turbulent fluxes data includes basic tests, statistical tests, and tests on fulfillment of theoretical requirements (Foken et al., 2004). And the correction of turbulent fluxes data includes the traditional coordination rotation (McMillen, 1988), sonic temperature correction (Schotanus et al., 1983), density fluctuations correction (Webb et al., 1980). For missing flux data due to unacceptable low quality, instrument malfunction, and unfavorable weather conditions, short gaps (≤ 2 h) were filled using a linear interpolation, and long gaps (> 2 h) were filled using the mean diurnal variation (MDV) method described by Falge et al. (2001).

According to the measurements from net radiation sensor above the canopy, net longwave/ shortwave radiation (L_n/S_n), and net radiation (R_n) were expressed as

204 follows:

$$205 \quad L_n = L_d - L_u \quad (2)$$

$$206 \quad S_n = S_d - S_u \quad (3)$$

$$207 \quad R_n = L_n - S_n \quad (4)$$

208 Where L_d/L_u and S_d/S_u represent downward/upward longwave radiation and
209 downward/upward shortwave radiation, respectively.

210 In this study, ET was expressed as follow:

$$211 \quad ET = \dot{Q} / \lambda \quad (5)$$

212 Where λ denotes the latent heat of the vaporization of water (2.45 kJ g⁻¹, [Zhang et al.,](#)
213 [2016](#))

214 The Bowen ratio (β) and evaporative fraction (EF) were expressed as follows:

$$215 \quad \beta = H / \dot{Q} \quad (6)$$

$$216 \quad EF = \dot{Q} / R_n \quad (7)$$

217 The crop coefficient (K_c) was given by [Allen et al. \(1998\)](#) as follows:

$$218 \quad K_c = ET / ET_0 \quad (8)$$

$$219 \quad ET_0 = \frac{0.408 \Delta (R_n - G) + 900 \cdot U \cdot \gamma \cdot VPD / (T_a + 273.3)}{\Delta + \gamma (1 + 0.34 U)} \quad (9)$$

220 Where ET_0 is reference evapotranspiration, T_a signifies air temperature (°C), U
221 represents wind speed (m s⁻¹), VPD stands for the vapor pressure deficit (kPa), Δ is
222 the slope of the water vapor pressure curve (kPa °C⁻¹), and γ signifies the
223 psychrometric constant (kPa °C⁻¹).

224 The Priestley–Taylor coefficient (α) was given by [Priestley and Taylor \(1972\)](#) as
225 follows:

$$226 \quad \alpha = \dot{Q} (\Delta + \gamma) / \Delta (R_n - G) \quad (10)$$

227 The aerodynamic conductance (g_a) and decoupling coefficient (Ω) were estimated
228 according to [Monteith and Unsworth \(1990\)](#), and surface conductance (g_s) was
229 calculated by inverting the Penman–Monteith equation ([Allen et al., 1998](#)):

$$230 \quad g_a = \left(\frac{U}{U_{\dot{Q}}} + 6.2 U_{\dot{Q}}^{-2/3} \right)^{-1} \quad (11)$$

$$231 \quad g_s = \frac{\gamma \cdot \leq \cdot g_a}{\Delta (R_n - G) + \rho_a \cdot c_p \cdot VPD \cdot g_a - \dot{Q} (\Delta + \gamma)} \quad (12)$$

$$232 \quad \Omega = \frac{\Delta + \gamma}{\Delta + \gamma \dot{Q} \dot{Q}} \quad (13)$$

233 Where U_* is friction velocity (m s⁻¹), ρ_a is air density (1.2 kg m⁻³, [Gao et al., 2018](#)),

and c_p is the specific heat of dry air ($1004.7 \text{ J kg}^{-1} \text{ }^\circ\text{C}^{-1}$, Gao et al., 2018).

3. Results

3.1 Biophysical factors

Seasonal variations in biophysical factors in three study years are shown in Fig.2. Daily average air temperature (T_a) ranged from $-12.5 \text{ }^\circ\text{C}$ in winter to $32.0 \text{ }^\circ\text{C}$ in summer, and daily average air relative humidity (H_a) fluctuated around 60% (Fig.2a). Daily average vapor pressure deficit (VPD) increased to the maximum value of $> 2.0 \text{ kPa}$ in early summer, and decreased to the minimum value of $< 0.5 \text{ kPa}$ in winter (Fig.2b). Daily groundwater depth (GD) ranged from 1.4 m to 2.2 m between 12 June 2018 and 31 December 2019 (Fig.2b). Daily average wind speed (U) usually fluctuated above 2.0 m s^{-1} , and the maximum value of U was 8.0 m s^{-1} in this 3-year study (Fig.2c). Annual precipitation (P) was 662.00 mm, 489.30 mm, and 487.50 mm chronologically for three study years. The amount of irrigation (I) water was 80 mm in each year. Soil water content at 10 cm depth (SWC_{10}) closely depended on P and I amounts, and the severe drought occurred in 2019 as soil water content at 40 cm depth (SWC_{40}) was lower than $0.17 \text{ cm}^3 \text{ cm}^{-3}$ (the relative extractable water dropped content was equal to 0.4, Ma et al., 2018) lasted 73 days (Fig.2d). The maximum value of leaf area index (LAI) was $3.08 \text{ m}^2 \text{ m}^{-2}$, $3.14 \text{ m}^2 \text{ m}^{-2}$, and $2.20 \text{ m}^2 \text{ m}^{-2}$ in chronologically for three study years. In the MG of 2018, the canopy of black locust plantation was damaged by a hailstorm (14 August), which resulted in a noticeable drop in LAI (Fig.2e).

(Fig.2)

Table 2

3.2 Energy partitioning

The seasonal variations in daily downward /upward longwave radiation (L_d/L_u) and downward /upward shortwave radiation (S_d/S_u) displayed parabolic trends; the peak value of daily L_d and L_u usually appeared in early August, and that of daily S_d and S_u usually appeared in early June (Fig.3a). In cloudy days, the difference between daily L_d and L_u and that between daily S_d and S_u were small, which resulted that daily net longwave /shortwave radiation (L_n/S_n) were close to 0. The maximum value of daily S_n usually appeared in early June, and daily L_n fluctuated between 0 to -102.7 W m^{-2}

(Fig.3b). The daily albedo increased sharply in winter due to snow cover on the ground, and the general trend of daily albedo had an apparent peak value in the EG (Fig.3c).

(Fig.3)

According to 30-min data, the energy balance closure was stable at our station in this study. The annual energy balance ratios were 0.68–0.69 with the slopes of 0.57, the goodness-of-fit (R^2) values of 0.85–0.86, and the intercepts between 12.05 W m^{-2} and 12.50 W m^{-2} (Table 3).

Table 3

The seasonal course of daily net radiation (R_n) is a parabolic curve, ranging from -18.5 W m^{-2} in winter to 265.4 W m^{-2} in summer (Fig.4a). There was one peak in the seasonal course of daily sensible heat flux (H), appearing at the mid-April (Fig.4b). Daily latent heat flux (LE) was usually smaller than 10.0 W m^{-2} in winter, and greater than 120.0 W m^{-2} after rainy days in summer (Fig.4c). Daily soil heat flux (G) ranged from -19.7 W m^{-2} to 13.7 W m^{-2} , and was usually below 0 in autumn and winter and above 0 in spring and summer (Fig.4d). Diurnal cycle of the monthly average R_n and its components for three study years are shown in Fig.5. The diurnal cycle of monthly average R_n and H showed clear diurnal variations, and peaked at noon. The largest diurnal peaks of R_n and H were 690.76 (May 2019) and 332.21 (April 2016) W m^{-2} , respectively. The diurnal cycle of monthly average LE and G showed clear diurnal variations from March to October in both years, because LE and G in other months was very small. The largest diurnal peaks of LE and G were 239.24 (September 2018) and 123.45 (April 2019) W m^{-2} , respectively.

(Fig.4)

(Fig.5)

Energy partitioning for the three study years is shown in Table 4. Albedo in the GS was similar to that in the NG, and annual albedo was 0.12 or 0.13 in this 3-year study. Both L_d/L_u and $R_n/(S_d+L_d)$ were smaller in the NG than in the GS, annual L_d/L_u was 0.85 or 0.84 and annual $R_n/(S_d+L_d)$ was 0.18–0.19 in this 3-year study. In 2016, 2018, and 2019, H/R_n in the NG was 0.69, 0.66, and 0.61, EF in the GS was 0.44, 0.42, and 0.40, respectively. Annual H/R_n (0.31–0.34) was comparable to annual EF (0.34–0.38) in our study site. The ratio of G to R_n was relatively lower in different periods.

299 **Table 4**

300 A schematic representation of the energy fluxes in the GS, the NG, and the entire year
301 in the black locust plantation is shown in Fig. 6. Average S_d , S_n , L_d , L_u , R_n and LE
302 were larger in the GS than those in the NG. Average H was smaller in the GS than that
303 in the NG. And average G was positive and negative in the GS and NG, respectively.

304 **(Fig.6)**

305 *3.3 Evapotranspiration*

306 Daily evapotranspiration (ET) was usually smaller than 0.50 mm d^{-1} in the NG, and
307 peak values of daily ET appeared after P events, because dews on vegetation surface
308 and water on soil surface easily, as long as energy available, evaporates to the
309 atmosphere (Fig.7). In particular, the reference evapotranspiration (ET_0) was
310 relatively high, and ET was still relatively weak before the EG in the NG. In the EG,
311 the ET increased rapidly, and the ET_0 increased relatively slowly. In the MG, the ET_0
312 decreased slowly in general, and the general trend and day-to-day variation of ET_0
313 was not synchronous with the ET due to drought and P. In the LG, the ET decreased
314 with decreasing ET_0 . Annual ET was 497.16 mm, 503.19 mm, and 479.66 mm, and
315 annual $ET/(P+I)$ was 0.67, 0.86, and 0.85 chronologically for the three study years.
316 And ET/P was 2.67, 1.45, and 2.01 in the NG of 2016, 2018, and 2019, respectively.

317 **(Fig.7)**

318 The major factors controlling seasonal variation in daily ET were R_n , T_a , VPD, and
319 LAI in this study site (Table 5). The effect of T_a on daily ET was mainly indirect, via
320 LAI and VPD, the effect of LAI on daily ET was mainly direct. For R_n , direct effect
321 was smaller than indirect effect, mainly via LAI and VPD, in 2018 and 2019. For
322 VPD, direct effect was greater than indirect effect in 2018 and 2019. In addition, U in
323 2016 and SWC_{10} in 2018 had significant negative and positive correlation with daily
324 ET ($P < 0.01$), respectively.

325 **Table 5**

326 Yellow River Delta is influenced by meso-scale sea-land wind. The wind direction
327 range of 0 to 90° and 180° to 270° was used as typical sea wind and land wind,
328 respectively. Because canopy cover had an important effect on ET and severe drought
329 dramatically decreased ET, only ET and biophysical data in the MG of 2016 were
330 used to analyze the effect of wind direction on ET. As shown in Fig. 8, ET and
331 biophysical factors were affected by sea and land wind. Average λET under sea wind

(80.01 W m⁻²) was greater than that under land wind (67.59 W m⁻²), and average sea and land wind direction was 57.76° and 205.57°, respectively (Fig. 8a and b). Average R_n under sea and land wind was 139.99 W m⁻² and 155.37 W m⁻², respectively (Fig. 8c). After 8:00 h, VPD and T_a under land wind were relatively greater (Fig. 8d and e). Between 8:00 h and 18:00 h, SWC₁₀ under sea wind was relatively greater, and around noon, U under sea wind was relatively greater (Fig. 8f and g).

(Fig.8)

3.4 Surface parameters

Daily EF, K_c, α, g_s, and Ω had similar seasonal course, all of them were relatively smaller in the NG, increased with canopy growth and development and decreased with vegetation senescence in the EG (Fig.9a and c–f). Daily β displayed the opposite course in comparison with the other surface parameters (Fig.9b). Daily β usually decreased sharply and the other surface parameter usually increased dramatically after P events. Average daily EF, K_c, α, g_s, and Ω reached maximum values of 0.42, 0.49, 0.48, 4.43 mm s⁻¹, and 0.14 in the MG of 2016, respectively. Average daily β was 5.94, 5.38, and 5.84 in the NG of 2016, 2018, and 2019, respectively (Table 6).

(Fig.9)

Table 6

The linear relationships were found between daily EF, K_c, α, g_s, and Ω and LAI with goodness-of-fit values of 0.44–0.78 (Fig.10a and c–f). Daily β decreased exponentially with increasing LAI, and goodness-of-fit value was 0.96 (Fig.10b). The exponential relationship was found between daily α and g_s, daily α was insensitive when daily g_s was greater than approximately 8 mm s⁻¹, and the asymptotic value of daily α was 0.66 in this study (Fig.11).

(Fig.10)

(Fig.11)

4. Discussion

4.1 Energy balance

The energy balance closure is usually used to evaluate the performance of the eddy covariance measurements. A comprehensive evaluation of energy balance closure across 22 sites and 50 site-years in FLUXNET showed that slope values ranged from

0.53 to 0.99, intercept values ranged from -32.9 to 36.9 W m^{-2} , goodness-of-fit values ranged from 0.64 to 0.96, and energy balance ratio values ranged from 0.34 to 1.69 (Wilson et al., 2002). Another comprehensive evaluation of energy balance closure across 8 sites and 8 site-years in ChinaFLUX showed that slope values ranged from 0.49 to 0.81, intercept values ranged from 10.8 to 79.8 W m^{-2} , goodness-of-fit values ranged from 0.52 to 0.94, and energy balance ratio values ranged from 0.58 to 1.00 (Li et al., 2005). Our results for energy balance closure in Table 3 are within the ranges in FLUXNET and ChinaFLUX, comparable to the results in a hilly tea plantation, east China (Geng et al., 2020) and a subalpine forest, southwest China (Yan et al., 2017), and better than the results in a young plantation, north China (Ma et al., 2018), indicating that the eddy covariance measurements were reliable in estimating surface energy balance components in the study plantation. The reasons for the energy unbalance may be related to sampling error, instrument bias, neglected energy sinks, high/low frequency loss, advection, and many more complications (Wilson et al., 2002). At our study site, the open canopy with understory vegetation resulted in a patchy underlying surface, which might lead to the observed inconsistency. The energy used for vegetation photosynthesis into biomass and used for heat storage in air below the EC measurement level were excluded in our analysis. The excluded amount might lead to an overestimation of available energy. Moreover, the long- and short-wave radiation transmission at the soil-vegetation interface might be altered by surface cover patchiness, and this phenomenon might alter the allocation of available energy (Ma et al., 2018).

4.2 Energy partitioning

The mean of annual averages of L_d , L_u , S_d , and S_u over the three study years was 327.49 W m^{-2} , 383.82 W m^{-2} , 184.31 W m^{-2} , and 21.90 W m^{-2} in the study plantation (Fig.6). Those means were comparable to a single cropping farmland at the same latitude on the Loess Plateau (Gao et al., 2018). Compared to those over an alpine meadow on the Tibetan Plateau (You et al., 2017), L_d and L_u were relatively greater and S_d and S_u were relatively smaller. Solar altitude mainly controls the diel and seasonal variations in S_d , which is also influenced by aerosols and clouds. And S_u is mainly controlled by S_d and influenced by land cover, in particular snow. Annual average albedo in our study site was smaller than that in an alpine meadow (0.31, You et al., 2017) and a single cropping cropland (0.18, Gao et al., 2018), being consistent with the widely accepted conclusion of albedo often lower in forest than cropland and

398 grassland (Zhu et al., 2014). Daily albedo had a peak in the EG at our site (Fig.3c), we
399 infer that the peak might be caused by the reflection of young leaf fluffs on light.
400 The peak become less obvious with the young leaf growing, during which fluffs
401 gradually fall off. Surface temperature mainly controls the diel and seasonal variations
402 in L_u , and L_d is mainly as influenced by air moisture and temperature. In the GS,
403 humid and warm air resulted in greater L_d/L_u at our site (Table 4). Annual average L_d/L_u
404 in the black locust plantation was comparable to that in a sub-alpine spruce forest
405 on the Tibetan Plateau (0.76, Zhu et al., 2014) and that in a mixed cropping system on
406 the Loess Plateau (0.84, Chen et al., 2016). Similar to previous studies (Zhu et al.,
407 2014; Chen et al., 2016), average $R_n/(S_d+L_d)$ was greater in the GS at our site, mainly
408 because of greater L_d/L_u in the same period. Annual average $R_n/(S_d+L_d)$ at our site was
409 comparable to the croplands on the Loess Plateau (Chen et al., 2016; Gao et al.,
410 2018).

411 As vegetation growth mainly dominated energy partitioning, H/R_n and EF in the GS
412 clearly differed from those in the NG (Table 3). In the NG, 3-year average H/R_n was
413 0.65, indicating that R_n was mainly portioned to H at our site as found in forest,
414 shrubland, grassland and cropland in previous studies (Zhu et al., 2014; Jia et al.,
415 2016; You et al., 2017; Gao et al., 2018). In the GS, EF was greater than H/R_n (Table
416 3), which indicates that LE the greatest component of R_n in the black locust
417 plantation. Similar to some previous studies on forest (Zhu et al., 2014; Ma et al.,
418 2018), EF was smaller than 0.5 in the GS at this site, the limited available water and
419 open canopy might result in this portioning. On an annual scale, EF at our site was
420 0.38, 0.37, and 0.34 in 2016, 2018, and 2019, respectively (Table 4). Those values
421 were greater than those in a sub-alpine forest (0.28, Zhu et al., 2014) and a young
422 plantation (0.15–0.17, Ma et al., 2018), but smaller than 0.66–0.71 for a hilly tea
423 plantation (Geng et al., 2020) and 0.57–0.60 for another sub-alpine forest on the
424 Tibetan Plateau (Yan et al., 2017). Because daily G was usually greater and smaller
425 than 0 in soil temperature increasing and decreasing period, respectively. Annual G/R_n
426 was very small at our site (Table 4) in consistency with previous studies in various
427 ecosystems (Zhu et al., 2014; Jia et al., 2016; You et al., 2017; Gao et al., 2018).

428 In the diurnal cycle of monthly average energy fluxes, LE was a major component of
429 R_n in May–September in 2016 and in August and September in 2018 and 2019. And H
430 was a major component of R_n in other months (Fig. 5). We suspect that different
431 vegetation growth and seasonal distribution of P should be responsible for this

phenomenon. At our site, LE was a little higher than 0 at night, indicating ET occurred at night; H was a little lower than 0 at night, indicating the heat from the atmosphere might be used for ET and offset the heat loss over soil and vegetative surface due to long-wave radiation. Those are similar to previous studies in various ecosystems (Wang et al., 2010; Zhu et al., 2014; Chen et al., 2016; Jia et al., 2016). At our site, G was positive in the daytime and negative at night, respectively (Fig. 5), due to energy into soil in the daytime and out of soil at night, and resulting in relatively small daily G values (Fig.4d). As G was influenced by the shade of vegetation and litter and seasonal variation in R_n , the amplitude of the diurnal cycle of G at our site was between 6.88 (January 2018) and 72.84 (June 2016) $W\ m^{-2}$, comparable to that in a sub-alpine spruce forest (Zhu et al., 2014), and usually smaller than that in cropland, grassland and shrubland (Gao et al., 2018; Jia et al., 2016; Gu et al., 2005), indicating the measurement of G in the high vegetation may be less important than in the low vegetation on a 30-min time scale.

4.3 Evapotranspiration

Annual ET (479.66–503.19 mm) at our site was comparable to that in a sub-alpine forest (Zhu et al., 2014) and an urban-forest ecosystem, north China (Xie et al., 2016), smaller than that in an evergreen broad-leaved forest, south China and a poplar plantation, north China (Xiao et al., 2013), and greater than that in a temperate mixed forest, northeast China (Xiao et al., 2013) and a young plantation (Ma et al., 2018). Annual ET varied in different site must be related to meteorological factors, vegetation properties and soil water conditions. The ratio of annual ET to P and I is a key parameter to quantify the effect of land cover change on regional hydrology (Ma et al., 2018). Annual ET/(P+I) was 0.67–0.86 at our site, being comparable to that in other forest ecosystems (Xiao et al., 2013). And annual ET/(P+I) was smaller than 1 at our site, indicating that the black locust plantation was generally going through the process of salinity eluviation. However, cumulative ET was larger than cumulative P in the NG at our site. This indicates that the NG was a process of salinity cumulation in the black locust plantation. This also suggests that the irrigation was necessary to mitigate the drought and salt stress for black locust growth in the EG. Similar to most terrestrial ecosystems (Gao et al., 2018; Xiao et al., 2013), R_n and T_a were also major meteorological factors controlling daily ET at our site, suggesting that energy induces water vapor loss in the black locust plantation (Sun et al., 2019). As with a coastal salt marsh ecosystem, east China (Huang et al., 2019), VPD was

also a major control on daily ET in the black locust plantation, this is mainly because of relatively higher H_a in the coastal zoon (Fig. 2a), which influences water vapor transport. As leaves transpire water, LAI had significant positive correlation with daily ET at our site, and this was consistent with the result in a single cropping cropland (Gao et al., 2018). Seasonal variation in daily ET_0 was not exactly consistent with that in daily ET (Fig. 7), showing that the seasonal pattern of daily ET in the black locust plantation was related to vegetation phenology, which indicates that the seasonal pattern of daily ET was controlled by the vegetation growth process. And seasonal variation in LAI should be the critical factor of seasonal variation in daily ET during the different phenological stages of black locust. The effect of vegetation phenology on ET was also assessed in a riparian *Tamarix spp.* stand, northwest China (Yuan et al., 2014), and the result was similar to that in our study. However, daily ET did not dramatically decrease after the noticeable drop of LAI in the MG of 2018 (Fig. 2e and 6b). This is mainly because that understory vegetation and soil surface got more radiation, which resulted in higher understory vegetation transpiration and soil evaporation after the canopy of overstory vegetation was damaged by a hailstorm. In the same year, SWC_{10} had significant positive correlation with daily ET, this also because the ratio of understory vegetation transpiration and soil evaporation to total ET may be larger in this year, as top-layer soil water usually is the water source for understory vegetation transpiration and soil evaporation. Therefore, we should pay more attention to the interaction between understory and overstory vegetation in the future. In 2016, U had significant negative effect on daily ET via LAI at our site (Table 5), this is mainly because that general trend of U might be opposite with that of LAI in the GS.

Though annual $ET/(P+I)$ was smaller than 1, drought still occurred in the black locust plantation, as seasonal pattern of P was not uniform at our site (Fig. 2d), and salinity stress would increase while drought. Similar to previous studies (Yue et al., 2019; Ma et al., 2018), drought obviously inhibited daily ET (decreased by approximately 40%) in 2019, which reduced the growth of black locust and resulted in smaller peak value of LAI in the same year. Under the background of climate warming and drought period extending on the North China Plain (Wang et al., 2017), the black locust plantation in the Yellow River Delta may be up against more severe pressure to survive in the future. According to the results reported by Ma et al. (2013), black locust would die while its roots grow into groundwater, because of relatively higher

groundwater salinity content in the Yellow River Delta. As high ground water table of 1.4 to 2.2 m in this study site, the root system of the black locust plantation can survive to 1.4 m depth of soil, and this limitation may weaken the drought resistance of black locust. In addition, the Yellow River Delta is subsiding due to a combination of factors (Liu et al., 2019), which may lead to shallower GD, and hence GD should need more attention in the future.

Wind direction influenced ET in the black locust plantation at our site (i.e. ET under sea wind was larger than that under land wind, Fig. 8a), being consistent with the results in a coastal salt marsh ecosystem (Huang et al., 2019). However, the cause of the phenomenon in the previous studies was different from that in our study. In this previous study, T_a under sea wind was nearly equal to that under land wind, VPD was relatively smaller under sea wind, and solar radiation along with U were relatively larger under sea wind in the daytime, but solar radiation was the dominantly control on ET variation in the daytime, which resulting in larger ET under sea wind (Huang et al., 2019). In our study, R_n , T_a , and VPD were larger under land wind in the daytime, only U and SWC_{10} was larger under sea wind around noon and in the daytime, respectively (Fig. 8b–g). We suspects that ET under sea wind was larger at our site, more likely because of larger SWC_{10} under sea wind in the daytime, indicating that soil water was not sufficient all the time, and also implying that sea wind might usually occur after P events.

4.4 Surface parameters

Seasonal variations in daily EF, β , K_c , α , g_s , and Ω of the black locust plantation were similar to those in previous studies (Gao et al., 2018; Jia et al., 2016; Zhu et al., 2014). Daily EF and β were the important surface parameters of energy partitioning, and daily EF exhibited the opposite pattern from daily β in the MG (Fig. 9a and b). Average daily β in the MG at our site was larger than that in a single cropping cropland and a hilly tea plantation (Gao et al., 2018; Geng et al., 2020), and smaller than that in an alpine meadow (You et al., 2017) and a semi-arid shrubland, northwest China (Jia et al., 2016). Daily K_c is an important surface parameter for planning irrigation system and estimating ET in cropland (Guo et al., 2020), and this parameter has been attracted much attention in natural ecosystems in recent years (Yuan et al., 2014; Yang and Zhou, 2011). Average daily K_c in the MG at our site was smaller than that in a desert-oasis region, northwest China (Zhang et al., 2016), and larger than that in a temperate desert steppe in Inner Mongolia, China (Yang and Zhou, 2011). Daily

534 α , g_s , and Ω are the bulk surface parameters, used to help assess the effect of
535 biophysical factors on ET (Jia et al., 2018). Average daily α in the MG at our site was
536 around 0.50 (Table 6), which reflects available soil water in the root zone of black
537 locust was insufficient. Average daily g_s in the MG in the black locust plantation was
538 smaller than that in a hilly tea plantation and a subalpine forest with larger ET (Yan et
539 al., 2017; Geng et al., 2020), and previous study had proved the higher ET is often
540 associated with larger g_s in various vegetation types (Zhang et al., 2016). Average
541 daily Ω in the MG at our site was relatively smaller (0.12–0.21, Table 6), comparable
542 to that in a young plantation (Ma et al., 2018), and larger than that in a sub-alpine
543 spruce forest (Zhu et al., 2014). The smaller daily Ω indicates that the atmosphere and
544 canopy were coupled, and VPD was an important meteorological factor controlling
545 ET in the black locust plantation (Table 5; Jia et al., 2018).

546 Daily EF, α , g_s , and Ω increased with increasing LAI and daily β decreased with
547 increasing LAI at our site (Fig.10), which is consistent with other studies (Jia et al.,
548 2016; Ma et al., 2018). Daily K_c increased linearly with increasing LAI at our site,
549 which agreed with the same parameter of a riparian *Tamarix spp.* stand (Yuan et al.,
550 2014), indicating that ET was mainly contributed by transpiration through leaves as
551 quantified by LAI without a threshold, and implying that smaller LAI might be a
552 reason for relatively smaller ET in the black locust plantation. And daily K_c usually
553 increased exponentially with increasing LAI in cropland with larger LAI associated
554 with higher ET (Zhang et al., 2016). Abiotic factors (e.g., soil moisture and VPD) also
555 influenced surface parameters (Jia et al., 2016), and this implies that the day-to-day
556 fluctuations and general trends of seasonal variations in surface parameters were
557 mainly controlled by abiotic factors and LAI, respectively, at our site. The effects of
558 LAI on surface parameters illustrate that vegetation growth played a key role in
559 energy partitioning, ET estimating, and land surface development in the black locust
560 plantation.

561 The logarithmic curve between g_s and α at our site is consistent with other results
562 from various ecosystems (Jia et al., 2016; Ma et al., 2018; Gao et al., 2018), indicating
563 that strong physiological and phenological regulation of energy partitioning and ET in
564 the black locust plantation. At our site, daily g_s increased with increasing daily g_s until
565 the threshold daily g_s (ca. 8 mm s⁻¹; Fig.11), which indicates ET was strongly
566 influenced by g_s when daily g_s was smaller than 8 mm s⁻¹. A theoretical study on a
567 fully developed canopy indicated that α was insensitive to g_s when g_s was larger than

16 mm s⁻¹ (McNaughton and Spriggs, 1986; Gao et al., 2018). The asymptotic value of daily α at our site was 0.66 (Fig.11), which was smaller than the results in many ecosystems with larger LAI and higher ET (Gao et al., 2018; Yan et al., 2017; Geng et al., 2020). The smaller asymptotic value of daily α and the daily g_s threshold found in our study were possibly due to the open canopy coupled with drought and salinity stress in the black locust plantation.

5. Conclusion

This study investigated 3-year observation of energy partitioning and ET over a black locust plantation in the Yellow River Delta. At our site, L_d offset 84%–85% of L_u , S_u accounted for 12%–13% of S_d , and the ratio of R_n to downward radiation was 18%–19%. In the GS, LE was the largest component of R_n ; in the NG, H was the dominant component of R_n in the black locust plantation. The seasonal variation in daily ET were mainly controlled by R_n , T_a , VPD and LAI in this study. The black locust plantation was generally going through the process of salinity eluviation, and spring irrigation was necessary to mitigate the drought and salt stress for black locust growth in the EG. The phenology of black locust influenced the seasonal variation in daily ET, mainly via LAI. And ET under sea wind was larger than that under land wind, mainly because SWC_{10} was larger under sea wind in daytime. Seasonal patterns of daily EF, β , K_c , α , g_s and Ω were mainly controlled by LAI, and the threshold value of daily g_s was approximately 8 mm s⁻¹ in the black locust plantation. The open canopy and drought and salinity stress played an important role in energy partitioning, ET and surface development at our site. These results will be a valuable reference for sustainable managements of black locust plantation in the Yellow River Delta.

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775 **Figure Captions**

776 **Fig. 1** The location of study site in the Yellow River Delta (a) and the observation
777 tower (b).

778 **Fig. 2** Seasonal variations in biophysical factors in 2016, 2018 and 2019. Biophysical
779 factors are (a) air temperature (T_a), air relative humidity (H_a), (b) vapor pressure
780 deficit (VPD), (c) wind speed (U), groundwater depth (GD), (d) precipitation (P),
781 irrigation (I) soil water content at 10 cm depth (SWC_{10}) and 40 cm depth (SWC_{40}), (e)
782 leaf area index (LAI). NG: non-growing season, EG: early growing stage, MG: mid
783 growing stage, LG: later growing stage.

784 **Fig. 3** Seasonal variations in (a) downward/upward shortwave radiation (S_d/S_u),
785 downward/upward longwave radiation (L_d/L_u), (b) net shortwave/longwave radiation
786 (S_n/L_n), and (c) albedo in 2016, 2018 and 2019.

787 **Fig. 4** Seasonal variations in (a) net radiation (R_n), (b) sensible heat flux (H), (c) latent
788 heat flux (LE), and (d) soil heat flux (G) in 2016, 2018 and 2019.

789 **Fig. 5** Diurnal cycle of the monthly average R_n and its components in 2016, 2018 and
790 2019.

791 **Fig. 6** Schematic representation of the energy fluxes ($W\ m^{-2}$) in the growing season,
792 the non-growing season, and the entire year in the black locust plantation.

793 **Fig. 7** Seasonal variations in (a) reference evapotranspiration (ET_0), and (b)
794 evapotranspiration (ET) in 2016, 2018 and 2019.

795 **Fig. 8** Diurnal cycle of average (a) ET , (c) R_n , (d) T_a , (e) VPD, (f) SWC_{10} and (g) U
796 under (b) sea ($0-90^\circ$) and land ($180-270^\circ$) wind conditions in the mid growing
797 season, 2016.

798 **Fig. 9** Seasonal variations in daily (a) evaporative fraction (EF), (b) Bowen ratio (β),
799 (c) crop coefficient (K_c), (d) Priestley–Taylor coefficient (α), (e) surface conductance
800 (g_s), and decoupling coefficient (Ω) in 2016, 2018 and 2019. Data for rainy days are
801 not shown.

802 **Fig. 10** Relationships between LAI and (a) daily EF, (b) β , (c) K_c , (d) α , (e) g_s and (f)
803 Ω in the growing season at our site. The dependent variables were bin-averaged into
804 $0.2\ m^2\ m^{-2}$ LAI increments. *Represents a significance level of $p < 0.01$.

805 **Fig. 11** Relationship between daily α and g_s in the growing season at our site. When g_s
806 $< 7\ mm\ s^{-1}$, the dependent variables were bin-averaged into $0.5\ mm\ s^{-1}\ g_s$ increments;
807 when $7\ mm\ s^{-1} < g_s < 11\ mm\ s^{-1}$, the dependent variables were bin-averaged into $2\ mm$
808 $s^{-1}\ g_s$ increments; when $g_s > 11\ mm\ s^{-1}$, the dependent variables were bin-averaged

809 into $10 \text{ mm s}^{-1} \text{ g}_s$ increments. *Represents a significance level of $p < 0.01$.

810

811 **Table 1.** List of measured items and instruments in the black locust plantation.

Observations	Height/depth (m)	Model, manufacturer	Accuracy	Data logging
Latent (LE)/ sensible heat flux (H), friction velocity (U_*)	19.5	IRGASON,Campbell Scientific Inc., Logan, UT, USA	$\pm 2\%$	30 min avg. ^a
Air temperature (T_a)/ relative humidity (H_a)	18	HMP45C, Vaisala Co., Ltd., Helsinki, Finland	$\pm 0.2\text{ }^\circ\text{C}/3\%$	30 min avg.
Downward (S_d)/upward shortwave radiation (S_u), downward (L_d) /upward (L_u) longwave radiation	1.5; 18	CNR4, Kipp & Zonen B.V., Delft, Netherlands	$<1\%$	30 min avg.
Wind speed (U)/direction (WD)	18	034B, Met One Instruments Inc., Grants Pass, OR, USA	$\pm 1\%/4^\circ$	30 min avg.
Soil water content (SWC) ^b	0.1; 0.4	CS650, Campbell Scientific Inc.	$\pm 1\%$	30 min inst. ^c
Soil heat flux (G) ^d	0.1	HFP01SC, Hukseflux B.V., Delft, Netherlands	$\pm 2\%$	30 min avg.

812 ^a 30 min interval average of samples taken at 0.1s sampling interval.

813 ^b calibrated by oven drying method.

814 ^c instantaneous value of 10 s sampling interval at 30 min record interval.

815 ^d included soil heat storage above the plate.

816 **Table 2.** Start date and end date of each phenological stage in the growing season in
817 the black locust plantation.

Year	Period	Start Date	End Date
2016	Early growing stage	6 April	10 June
	Mid growing stage	11 June	20 September
	Later growing stage	21 September	14 November
2018	Early growing stage	11 April	1 June
	Mid growing stage	2 June	20 September
	Later growing stage	21 September	19 November
2019	Early growing stage	15 April	2 June
	Mid growing stage	3 June	20 September
	Later growing stage	21 September	19 November

818

819 **Table 3.** Characteristics of energy balance and annual ratio of $\Sigma(\text{LE}+\text{H})/\Sigma(\text{R}_n-\text{G})$ in 2016, 2018, and 2019. LE: latent heat flux; H: sensible heat
820 flux; R_n : net radiation; G: soil heat flux.

Year	Slope	Intercept (W m^{-2})	Data number	R^2	Annual ratio
2016	0.57	12.05	15707	0.85	0.68
2018	0.57	12.50	12633	0.86	0.69
2019	0.57	12.11	14881	0.86	0.68

821

822 **Table 4.** Energy partitioning in the growing season, the non-growing season, and the entire year for 2016, 2018, and 2019. L_d : downward
823 longwave radiation; L_u : upward longwave radiation; S_d : downward shortwave radiation; EF: evaporative fraction.

Year	Period	Albedo (S_u/S_d)	L_d/L_u	$R_n/(S_d+L_d)$	H/R_n	EF(LE/R_n)	G/R_n
2016	Growing season	0.12	0.88	0.22	0.20	0.44	0.009
	Non-growing season	0.12	0.80	0.13	0.69	0.15	-0.064
	Entire year	0.12	0.85	0.18	0.31	0.38	-0.007
2018	Growing season	0.12	0.87	0.23	0.23	0.42	0.008
	Non-growing season	0.14	0.82	0.13	0.66	0.16	-0.049
	Entire year	0.13	0.85	0.19	0.33	0.37	-0.005
2019	Growing season	0.11	0.87	0.23	0.26	0.40	0.009
	Non-growing season	0.12	0.81	0.14	0.61	0.16	-0.038
	Entire year	0.12	0.84	0.19	0.34	0.34	-0.003

Table 5. Path analysis between daily ET and net radiation (R_n), wind speed (U), air temperature (T_a), vapor pressure deficit (VPD), soil water content at 10 cm depth (SWC_{10}), and leaf area index (LAI) in the black locust plantation.

Year	Variable	Correlation coefficient	Direct effect	Indirect effect					
				R_n	U	T_a	VPD	SWC_{10}	LAI
2016	R_n	0.72*	0.39		0.00	-0.08	0.12	-0.07	0.35
	U	-0.17*	0.04	-0.03		0.04	0.01	0.01	-0.25
	T_a	0.73*	-0.15	0.19	-0.01		0.06	-0.07	0.70
	VPD	0.53*	0.19	0.25	0.00	-0.05		-0.04	0.17
	SWC_{10}	-0.10	0.29	-0.09	0.00	0.03	-0.03		-0.31
	LAI	0.75*	0.79	0.17	-0.01	-0.13	0.04	-0.11	
2018	R_n	0.67*	0.14		0.00	0.12	0.20	0.04	0.16
	U	-0.05	0.02	0.01		-0.03	0.00	0.01	-0.05
	T_a	0.72*	0.19	0.10	0.00		0.16	0.05	0.23
	VPD	0.61*	0.32	0.09	0.00	0.09		0.02	0.10
	SWC_{10}	0.33*	0.24	0.03	0.00	0.04	0.02		0.01
	LAI	0.62*	0.30	0.08	0.00	0.15	0.10	0.01	
2019	R_n	0.70*	0.27		0.00	0.02	0.25	0.00	0.16
	U	-0.09	0.02	-0.02		-0.01	-0.03	0.04	-0.09
	T_a	0.76*	0.04	0.15	0.00		0.22	-0.02	0.38
	VPD	0.73*	0.41	0.17	0.00	0.02		-0.02	0.15
	SWC_{10}	0.01	0.19	0.00	0.00	0.00	-0.04		-0.15
	LAI	0.65*	0.46	0.09	0.00	0.03	0.14	-0.06	

*Represents a significance level of $p < 0.01$.

829

830 **Table 6.** Average daily EF, Bowen ratio (β), crop coefficient (K_c), Priestley–Taylor coefficient (α), surface conductance (g_s), and decoupling831 coefficient (Ω) in early, mid and later growing stage and average daily EF, β , K_c , α , g_s , and Ω during the non-growing season in 2016, 2018, and

832 2019.

Year	Period	EF	β	K_c	α	g_s (mm s ⁻¹)	Ω
2016	Early growing stage	0.33	1.43	0.37	0.41	2.91	0.09
	Mid growing stage	0.47	0.34	0.62	0.56	6.98	0.21
	Later growing stage	0.41	1.19	0.42	0.42	3.16	0.11
	Non-growing season	0.19	5.94	0.16	0.16	1.08	0.06
2018	Early growing stage	0.33	1.28	0.40	0.41	3.30	0.10
	Mid growing stage	0.42	0.61	0.49	0.48	4.43	0.14
	Later growing stage	0.43	1.07	0.42	0.44	2.93	0.11
	Non-growing season	0.21	5.38	0.17	0.19	1.19	0.07
2019	Early growing stage	0.39	0.83	0.38	0.45	2.68	0.08
	Mid growing stage	0.40	0.66	0.47	0.48	3.71	0.12
	Later growing stage	0.39	1.34	0.34	0.37	2.28	0.07
	Non-growing season	0.19	5.84	0.15	0.16	1.01	0.06

