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A Study of Fitting an Alpine Winter Pasture Evapotranspiration to a Model Based on the Penman-Monteith Equation

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Abstract: To accurately estimate the magnitude and seasonal dynamics of Evapotranspiration (ET) over an important alpine winter pasture in the Northeastern Qinghai-Tibetan Plateau, researchers employed the Food and Agriculture Organization (FAO) Penman Monteith (P-M) Model. The model was also used to investigate changes in the crop coefficient (k_c) which was calculated as the ratio of the measured actual ET (ET_a from the Eddy Covariance (EC) System) to the reference ET (ET_0 from the P-M Model). The results indicated a reference ET of 900 mm year^{-1} from the alpine meadow pasture which was significantly higher than the actual ET (426 mm year^{-1}). In addition, the seasonal dynamics of these two ET values differed. The reference ET peaked from April to July while the actual ET was primarily in growing season. The value of k_c exhibited significant seasonal variations within the range 0.3-1.0 with a mean k_c of 0.55 during the growing season. The correlation analysis of the relationship between daily k_c and its primary environmental factors indicated that the Vapor Pressure Deficit (VPD), net Radiation (R_n) and air Temperature (T_a) were the major influencing factors of the daily k_c. The daily k_c showed a linear increase with R_n and T_a and a linear decrease with the VPD. With respect to the biotic factors, the biomass exhibited a significant positive correlation with k_c. Thus, a daily k_c Model is developed as a function of the VPD, R_n, T_a and biomass. This ET Model was validated using 2005 data and showed a satisfactory consistency between the simulated and measured ET.

Key words: Evapotranspiration, reference evapotranspiration, crop coefficient, k_c, T_a

INTRODUCTION

The hydrologic balance of terrestrial ecosystems are important determinants of ecosystem structure, function and productivity (Burman and Pochop, 1994). Evapotranspiration (ET) which is the second-largest water flux in the terrestrial hydrologic cycle, plays an important role in the maintenance of the water and energy balance of the ground surface (Oki and Kanae, 2006).

In addition, ET processes are closely related to vegetation conditions, the ecophysiological processes of plants, soil environments and micrometeorological characteristics. Thus, ET is a pivotal water exchange process in the Soil Plant Atmosphere Continuum (SPAC). Therefore, accurate ET estimation is not only significant to the regulation and management of hydrologic cycles in ecosystems but also to scientific decisions regarding local ecological construction and production activities in agriculture and animal husbandry (Tyagi *et al*., 2000; Gong *et al*., 2006; Torriani *et al*., 2007). Domestic and international researchers have investigated land surface ET for >200 years and have developed a number of fitting models and observational methods for ecosystem evapotranspiration (Priestley and Taylor, 1972; Monteith and Unsworth, 1990; Frank, 2003; Li *et al*., 2005). Currently, the Eddy Covariance (EC) System is the most extensively used and sophisticated micrometeorological approach. Ecosystem ET may be continuously monitored with the EC System without damage to the soil or vegetation. The Penman equation which utilizes conventional meteorological data is the most influential fitting equation for predicting ET. This equation was proposed in 1948 when Penman proposed an formula for calculating ET from a water surface which considers radiant energy, air saturation deficit, wind speed and other ET-influencing factors. Based on prior research, Monteith modified the Penman equation and proposed the Penman-Monteith (P-M) Model which is a canopy ET

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model that has been extensively applied (Monteith and Unsworth, 1990). In 1990s, the Food and Agriculture Organization (FAO) of the United Nations amended the P-M Model for the estimation of actual ET from farmland and grassland and recommended this modified model as a standard method for calculating ET (Allen *et al*., 1998). In the P-M Model recommended by the FAO (the FAO-P-M Model), a crop coefficient (k_c) has been introduced to correct reference ET values and to accurately estimate actual ET values in specific ecosystems. Studies have reported that k_c is related to various biotic factors such as crop type and growth stage (Williams and Ayars, 2005). For homogeneous vegetation which consists of plants in a particular growth stage, k_c may be regarded as a constant. For example in the FAO-56 Method, k_c values are assigned based on a pasture's growth stage thus k_c values for the initial, mid-season and late-season growth stages are 0.4, 1.05 and 0.85, respectively (Allen *et al*., 1998). Recent studies have demonstrated that k_c exhibits specific variations and is affected by radiant energy, moisture levels and other environmental factors (Lockwood, 1999; Yang and Zhou, 2011). The k_c value is the key to using the FAO-P-M Model to accurately estimate the actual ET of an ecosystem. Thus, the study of the patterns and characteristics of changes in k_c in natural pastureland can improve the accuracy and simplicity of the calculation of the ecological water demand of pasturelands and provide a theoretical foundation for the grazing production of these lands.

The Qinghai-Tibetan plateau which is referred to as "Asia's water tower", plays a pivotal role in the global hydrologic cycle and the global water balance. Alpine meadow which is one of the most extensively distributed types of vegetation in the Qinghai-Tibetan plateau, covers an area of approximately 1,200,000 km^2 (Zheng *et al*., 2000). The alpine pasture in this study is an alpine meadow in the northeast of the Plateau which is also an unique natural landscape and one of the most important grassland resource for grazing (Cui and Graf, 2009). Few studies have explored the ET characteristics of meadow ecosystems (Li *et al*., 2013) as a result, studies on applicable models for accurately and conveniently evaluating ET in the alpine pasture meadow ecosystem also remain scarce.

This study aimed to achieve the following objectives: use the FAO-P-M Model and Eddy Covariance System to explore the dynamics of the actual ET and reference ET changes in the alpine meadow ecosystem of the Qinghai-Tibetan Plateau and derive a suitable k_c-based Model of the alpine meadow ecosystem by determining how k_c values vary with changes in meadow climate and vegetation and by establishing the relationships between k_c and the factors (including both the environmental and biotic factors).

MATERIALS AND METHODS

Study site: The study area is located in the Northeastern of the Qinghai-Tibetan plateau (37°36'N, 101°18'E; 3250 m). The climate in this area is characterized by long, cold and dry winters and short, cool and moist Summers. The annual mean temperature in the study area is -1.7°C; January is the coldest month (-15°C) and July is the warmest month (10°C). The average annual duration of sunshine is 2462.7 h and the total radiation (R_s) received per year ranges from 6000-7000 MJ m^{-2}. The alpine meadow features high vegetation cover composed of short and densely distributed plants. The vegetation primarily consists of meadow species such as *Kobresia humilis*, *K. pygmaea*, *K. Tibetica* and *Stipa aliena*. The meadow land which is primarily used for Winter pasture (January to May and September to December) serves as an important grazing resource in the plateau region. The aboveground biomass of the alpine meadow increases in early May and peaks in August with a multi-year average biomass of approximately 350 g m^{-2}. The study area receives a yearly precipitation of approximately 600 mm. This precipitation is primarily concentrated between May and September and changes in the Soil Water Content (SWC) are subject to precipitation-related effects.

Measurements

Flux measurements: EC observation system was placed in the center of the study area. This area features flat terrain which enables unobscured observation and provides a sufficiently large "fetch" to satisfy the required physical conditions for eddy and meteorological observations. ET was measured using a H_2O/CO_2 infrared gas analyzer (Li-7500, Li-Cor, USA) and a three-dimensional sonic anemometer (CSAT3, CSI, USA) with a sensor placed 2.2 m above the ground. A data-logger (CR5000, Campbell Inc.) was employed to continuously record water vapor flux data and output average values at 15 min intervals. The actual ET (ET_a) was measured by the EC System in this study.

Meteorological measurements: Environmental variables were continuously measured at this site. Air temperature (T_a), humidity and actual vapor pressures were measured at 110 and 220 cm (HMP45C, CSI); soil temperature was measured at 0, 5, 10, 20, 30 and 50 cm depths (thermocouple); solar Radiation (R_s) and net Radiation (R_n) were measured at 150 cm (CNR-1, Kipp and Zonen, Netherlands); a horizontal wind-speed sensor (014A and 034A-L, CSI) was attached at 110 and 220 cm to measure horizontal wind speeds; precipitation was measured at 70 cm (TE525MM, CSI); SWC was measured at 5, 20 and 50 cm depths (TDR soil moisture sensor; CS615, CSI) and the soil heat flux was set at a depth of 2 cm (HFT-3, CSI). The signals were sampled at 10 Hz and 15 min mean data were logged by the data-logger (CR23X, CSI).

Observations of vegetation data: Aboveground biomass in the study area was measured semimonthly during the growing season. A harvesting method was adopted to obtain these measurements. In particular, five 0.5×0.5 m quadrants were randomly selected; within each quadrant, plants were harvested by cutting the plants at ground level and loading the plants into sampling bags. Each sample was numbered, rapidly transported to a laboratory and dried at 65°C until a constant weight was obtained for each sample. These weights were subsequently converted into g/m^2.

The FAO-P-M Model

The calculation of reference ET: The reference crop comprises a well-managed short grass of uniform height (8-15 cm) that completely covers the ground and grows lushly across open ground without experiencing water stress. The reference crop ET refers to the ET of the reference crop under these conditions (Allen *et al*., 1998). In this study, the standardized FAO-P-M Model was used to calculate the actual ET in the lpine meadow ecosystem. This model includes two components reference ET and k_c as indicated in the following Eq. 1:

$$ET_{P\_M} = k_c ET_0 \tag{1}$$

Where:

ET_{P_M} = The actual ET of an ecosystem in the FAO-P-M Model
k_c = The crop coefficient
ET_0 = The reference ET

The reference surface consists of well-watered grass with a height of 12 cm and a fixed surface resistance of 70 sec m^{-1}. The applicable equation is expressed as:

$$ET_0 = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T+273} u(e_s - e_a)}{\Delta + \gamma(1+0.34u)} \tag{2}$$

Where:

Δ = The slope of the saturation vapor pressure curve at the examined temperature
R_n = The net radiation
G = The soil heat flux
γ = The psychrometric constant
T = The mean daily temperature at a height of 2 m
u = The wind speed at a height of 2 m
e_s and e_a = The saturation vapor pressure and actual vapor pressure, respectively
Δ and γ = Calculated as:

$$\Delta = \frac{4098\times\{0.6108\exp[17.27T/(T+237.3)]\}}{(T+237.3)^2} \tag{3}$$

$$\gamma = \frac{c_p \times P}{0.622\lambda} \tag{4}$$

$$\lambda = 2.501 - (2.361\times10^{-3})\times T \tag{5}$$

Where:

C_p = The specific heat at constant pressure which has a fixed value of 1.013×10^{-3} MJ/kg°C
P = The atmospheric pressure
0.662 = The ratio of the molecular weight of water vapor to the molecular weight of dry air
λ = The latent heat of vaporization which represents the energy per unit volume of water required to convert water into steam under ambient temperature and pressure conditions

The study meadow area is located on a plateau zone at an average elevation of 3250 m. Using Eq. 6, the atmospheric pressure (P) can be calculated from this average elevation (H = 3250 m):

$$P = 1013 - 0.1093H \tag{6}$$

The crop coefficient (k_c): The crop coefficient k_c was obtained from the ratio of the reference ET in 2004 to the ET obtained from EC System observations in 2004 and fitted with environmental factors to obtain an empirical equation which was eventually validated by 2005 data. In the FAO-56 approach, the growth of pasture plants was divided into different growth stages (Allen *et al*., 1998). The study area of the current investigation features an alpine climate in this area, plant growth typically begins in late April and the growing season extends from May to September.

Evaluation methods: In this study, the slope, linear correlation coefficient (R^2), Relative Root-Mean-Squared Error (RRMSE), Index of Agreement (IA) and Coefficient of Determination (CD) were utilized to examine the extent of the differences between the observed and calculated values of ET and to statistically analyze the accuracy of the adopted fitting approach from multiple perspectives. The slope and R^2 were calculated by Origin 8.0. RRMSE, IA and CD values were computed as (Alexandris and Kerkides, 2003; Yang and Zhou, 2011).

$$\text{RRMSE} = \sqrt{\frac{\sum_{i=1}^{n}(O_i - E_i)^2}{n} \bullet \frac{1}{\overline{O}^2}} \tag{7}$$

$$\text{IA} = 1 - \frac{\sum_{i=1}^{n}(E_i - O_i)^2}{\sum_{i=1}^{n}(\left|E_i - \overline{O}\right| + \left|O_i - \overline{O}\right|)^2} \tag{8}$$

$$\text{CD} = \frac{\sum_{i=1}^{n}(O_i - \overline{O})^2}{\sum_{i=1}^{n}(E_i - \overline{O})^2} \tag{9}$$

Where:

O_i = ith observed value
E_i = ith simulated or estimated value
n = The number of samples
O = The mean observed value

RESULTS AND DISCUSSION

Seasonal variations in reference ET (ET_0) and actual ET: As indicated in Fig. 1, the reference ET derived from the P-M Model was significantly higher than the actual ET measured by the EC System. The reference ET (ET_0) refers to the reference capacity of moisture diffusion from the ecosystem to the atmosphere under specific environmental conditions thus ET_0 represents the maximum ET. The annual reference ET of the examined alpine meadow was 900.2 mm which was significantly higher than the actual ET of 425.8 mm. These parameters also exhibited significant seasonal variations. ET_0 began to significantly increase in March and attained peak levels from April to July however, it began to decline in August. The total ET_0 during the growing season (from May to September) was 487.1 mm which represented 54% of the annual cumulative ET_0. Conversely, seasonal variations in actual ET (ET_a) in the alpine meadow lagged behind variations in reference ET. The ET_a was concentrated in the growing season between May and September the ET_a was 337.1 mm which represented 79% of the annual cumulative ET_a.

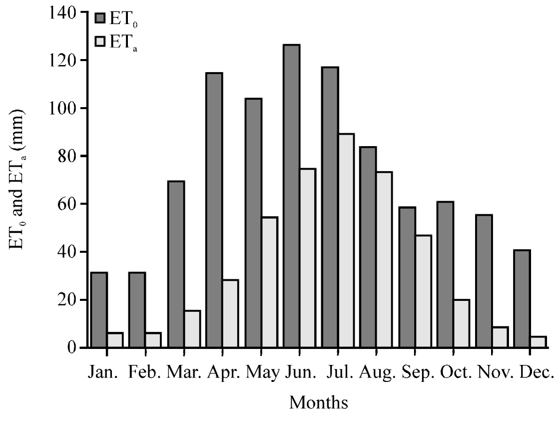

Fig. 1: Annual variations in reference ET (ET_0) and actual ET (ET_a)

According to its definition, the reference ET (ET_0) was only affected by climatic parameters (Allen *et al*., 1998). As shown in Eq. 2, the net radiation (R_n), Vapor Pressure Deficit (VPD, e_s-e_a), air temperature (T_a) and wind speed (u) determined the reference ET. The annual variation of these environmental factors were shown in Fig. 2.

As the maximum of R_n, VPD and u occurred during April to June (Fig. 2), ET_0 reached its maximum value at the similar period (March to June). However, with the canopy development in growing season, the effect of biotic factors will exert increasing influence on the actual ET. Therefore, with the ET_a rapidly increase in growing season, the difference between ET_0 and ET_a became smaller (Fig. 1).

Moreover, the reference ET in growing season (487.1 mm) was lower than the value of precipitation (579.7 mm). The ratio of ET_0 to P was 84% during growing season. This result was similar to a nonirrigated pasture (Sumner and Jacobs, 2005) however, it was much lower than some grassland ecosystems (Wever *et al*., 2002; Li *et al*., 2005). In these grassland, the reference ET was significantly higher than the precipitation in growing season.

Comparing to these grassland (Wever *et al*., 2002; Li *et al*., 2005), the lower ET_0 may be caused by the unique climate in this plateau. The net radiation (R_n) in the Qinghai-Tibetan Plateau was much lower than that for lowland grasslands (Hammerle *et al*., 2008), despiting the high incident solar radiation (R_s), due to the fact that the net long-wave radiation in alpine region is much higher than that for lowland regions (Zhang *et al*., 2010). In this alpine pasture, the R_n was much lower than the R_s and the average R_n and R_s values were 7.7 and 16.6 mol/(m^2 day), respectively (Fig. 2a). The low energy available for water evaporation may limit the reference ET in some extents. Moreover, VPD and T_a were meteorological variables for controlling on water vapour exchange between the atmosphere and vegetation (Baldocchi and Meyers, 1998). Gu *et al*. (2008) indicated that low VPD and T_a due to the frequent precipitation and the altitude were characteristics of the climate in the alpine meadow in Northeast Qinghai-Tibetan plateau. Figure 2b showed the variation of VPD and T_a in this study site. The maximum value of daily mean VPD and T_a were only 1.5 kPa and 14.5°C which were greatly lower than many other grassland with

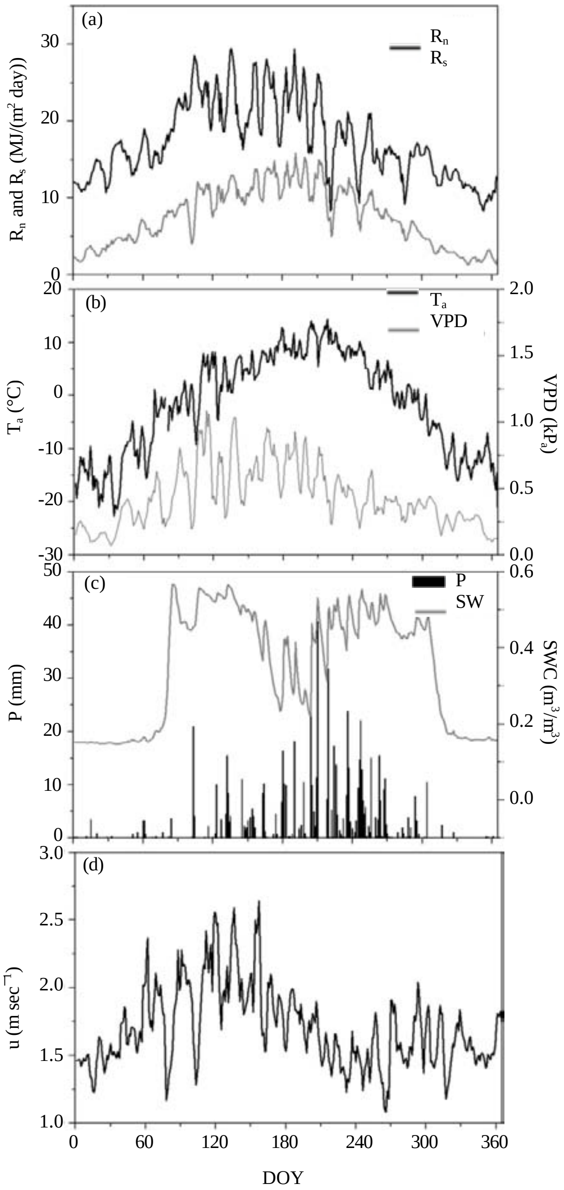

Fig. 2: Temporal variations of a) net radiation (R_n) and solar radiation (R_s); b) daily mean air temperature (T_a) and Vapor Pressure Deficit (VPD); c) daily Precipitation (P) and soil water content at 5 cm depth (SWC) and d) wind speed (u) in the alpine meadow during 2004

the maximum VPD ranged from about 2-5 kPa and with the maximum T_a ranged from about 20-30°C (Kellner, 2001; Hao *et al*., 2007; Dong *et al*., 2011). The low VPD and T_a might imply the weak driving power and are considered as the factors to restrict the reference ET in growing season.

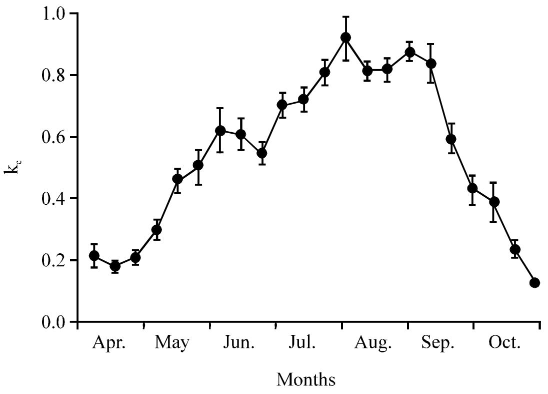

Fig. 3: Seasonal variation in the k_c

The seasonal variation in k_c: Due to the difference between reference ET and actual ET, the correct determination of k_c which is the ratio of daily ET to ET_0 is important for the accurate estimation of the actual ET. In this study, k_c exhibited a gradual rise from mid-April to mid-June and remained at a high level in July and August (Fig. 3). The value of k_c rapidly declined in September and was <0.2 by the end of October. During the growing season which extended from May-September, k_c exhibited a mean value of 0.55 and fluctuated within the range 0.30-0.92. This range is consistent with the range of k_c values reported in FAO-56 (0.30-1.05) (Allen *et al*., 1998) but is significantly higher than the range of k_c values observed for a typical steppe (0.32-0.68) (Miao *et al*., 2009) and temperate desert steppe (0.02-0.50) (Yang and Zhou, 2011) of Inner Mongolia. These results indicated that the k_c for the alpine pasture features more adequate moisture and better plant growth conditions than arid and semi-arid steppe ecosystems.

Factors that impact k_c

The effect of environmental factors on k_c: Previous studies have focused on k_c values related to local climate conditions (Lockwood, 1999; Yang and Zhou, 2011). In this meadow, the Pearson product-moment correlation coefficients for the relationships between k_c and its main environmental factors were computed on a daily scale (Table 1). This computation showed that the VPD and R_n were critical for controlling k_c. T_a also showed a significant relation to k_c, whereas u and SWC at a depth of 5 cm were not significant at the 95% confidence level.

The responses of k_c to changes in VPD, R_n and T_a are illustrated in Fig. 4. To reduce or offset the errors associated with the k_c values, VPD, R_n and T_a were grouped into bins with the following criterion: 0.2 kPa for VPD, 1 MJ/m^2 d for R_n and 2°C for T_a. k_c increased linearly in response to an increase in R_n and T_a and in response to a decrease in VPD (Fig. 4). Zhou and Zhou (2009) also obtained a similar result from a study of a reed marsh.

Table 1: Pearson product-moment correlation coefficients for the relationships between daily k_c and daily average values for environmental variables: SWC at a depth of 5 cm, atmospheric VPD, wind speed (u), R_n and T_a over the alpine meadow on a daily basis for days without rain during the 2004 growing season (n = 106)

	k_c	SWC	VPD	u	R_n	T_a
k_c	1.000					
SWC	-0.168	1.000				
VPD	-0.509**	-0.324*	1.000			
u	-0.175	0.339*	-0.114	1.000		
R_n	0.442**	-0.440**	0.164	-0.309*	1.000	
T_a	0.402*	-0.590**	0.400*	-0.518**	0.429**	1.000

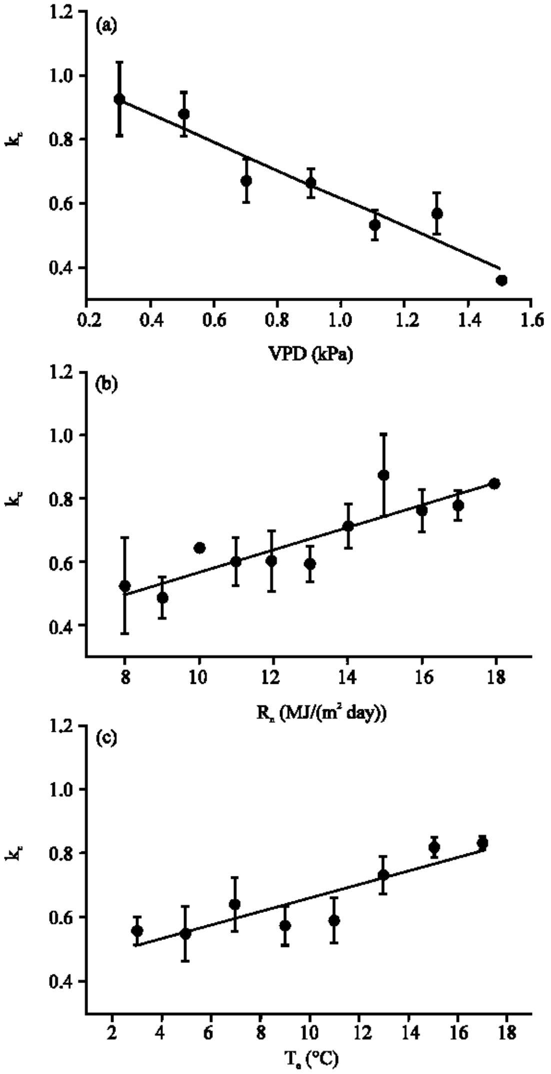

Fig. 4: Linear response of k_c to a) VPD; b) R_n and c) T_a. The daily k_c data were averaged with a bin width of 0.2 kPa for VPD, 1 MJ/(m^2 day) for R_n and 2°C for T_a, respectively. Bars indicate ±SD

However, the result was different from a study in a temperate desert steppe (Yang and Zhou, 2011) which demonstrated that the Soil Water Content (SWC) was the most important factor for determining k_c. In this study, the root-layer (0-10 cm) SWC fluctuated within the range 0.2-0.6 m^3/m^3 (Fig. 1c) which was much better than the SWC at desert steppe in inner Mongolia (0.05-0.15 m^3/m^3). The higher soil moist in this alpine pasture might weaken the SWC impact on k_c.

Daily k_c for the alpine pasture can be expressed by an empirical equation from the correlation and regression analyses of the relationships between k_c and its statistically significant environmental variables:

$$k_c = 0.597\text{-}0.801\text{VPD}+0.026R_n+0.040T_a \quad (10)$$

In this case, based on daily meteorological data and reference ET_0 data during the growing season, the daily actual ET can be calculated by:

$$ET = (0.597\text{-}0.801\text{VPD}+0.026R_n+0.040T_a)\times ET_0 \quad (11)$$

The effects of biotic factors on k_c: In addition to environmental factors, the plant species composition, growth conditions and other biotic factors can significantly affect k_c (Tyagi *et al.*, 2000; Williams *et al.*, 2003; De Medeiros *et al.*, 2005). Biomass directly reflects the growth status of a biological community. In this study, the sampled plants began to grow at the end of April which caused an increase in the biomass that primarily began in early May. The biomass rapidly increased during June and August and attained a peak in late August (with a maximum value of 353.1 g/m^2 in the study year). After August, the biomass rapidly declined as plants gradually died (Fig. 5a).

The linear regression analysis of the relationship between k_c and the biomass demonstrated a significant positive correlation between k_c and the biomass, however the significance of this correlation changed during different growth stages. As indicated in Fig. 5b, the biomass increased and k_c rapidly increased from 0.45-0.93 from May to middle August. After biomass attained its peak, k_c began to decline and decreased to 0.39 in late October. While no significant decrease in k_c was observed from September to October because k_c only decreased from 0.54-0.39 during this period. The following linear equations describe how k_c increases with biomass. May-Middle August:

$$k_c = 0.0019\times\text{biomass}+0.4521 \quad (12)$$

Middle August-October:

$$k_c = 0.0008\times\text{biomass}+0.2514 \quad (13)$$

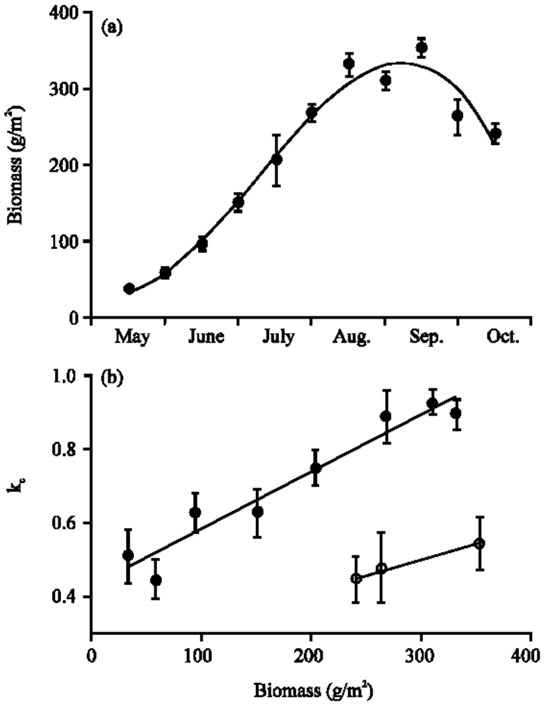

Fig. 5: a) The seasonal variation of biomass in this alpine meadow pasture in 2004 and b) The response of k_c to biomass. The k_c was averaged with a bin width of 50 g/m² for biomass. Bars indicate±SD

Considering both biotic and environmental factors, daily actual ET can be calculated as follows. May-Middle August:

$$ET = (0.596-0.801VPD+0.026R_n+0.040T_a)(0.0019\,biomass+0.4521)\times ET_0 \quad (14)$$

Middle August-October:

$$ET = (0.596-0.801VPD+0.026R_n+0.040T_a)(0.0008\,biomass+0.2514)\times ET_0 \quad (15)$$

Test for modeling evapotranspiration: Equation 15 was validated using the EC data collected during the 2005 growing season. The model performed well during the growing season. The simulated daily ET (ET_{mod}) followed the seasonal trend of the EC measured ET (ET_a) (Fig. 6). The slope (= 0.95) of the regression line between the measured and simulated ET passes through the origin close to 1 with $R^2 = 0.76$, a RRMSE of 0.23 mm day^{-1} and an IA of 0.92.

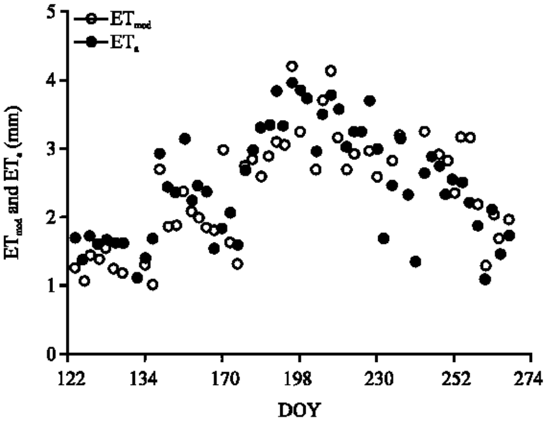

Fig. 6: Seasonal variation in the measured and simulated ET (ET_a and ET_{mod}) for days without rain in 2005 using Eq. 15

Table 2: The validation statistics of the model simulated by the meteorological factors versus the model simulated by the meteorological factors and biotic factors

Variables	Slope	R^2	RRMSE	IA	CD
ET_{mod1}	0.89	0.68	0.28	0.87	0.76
ET_{mod2}	0.95	0.76	0.23	0.93	0.87

Et_{mod1} is simulated by the meteorological factors (VPD, Rn and T_a); ET_{mod2} is simulated by these meteorological factors and biomass

In this study, the abiotic and biotic factors enabled a better estimation of evapotranspiration. RRMSE is a measure of the relative magnitude of residuals; smaller values of RRMSE indicate better model calculation results. The IA can be used to evaluate the correlation between the observed values and the simulated values; the closer IA is to 1, the more closely the fitted values match the observed values. The CD can be used to measure the dispersion of the simulated values from the mean observed values; a CD greater than 0.8 indicates satisfactory simulation results (Cai *et al*., 2007). In Table 2, the slope, R^2, IA and CD of ET_{mod1} are greater and the RRMES is smaller than those of ET_{mod2}. These results indicated that relative to the fitting method that accounts for meteorological variables, the fitting method that comprehensively considers meteorological factors and vegetation conditions can be used to derive simulated ET results that are closer to the actual observed ET results (Table 2).

CONCLUSION

The FAO-Penman-Monteith Model was used to simulate ET over the alpine meadow on the Qinghai-Tibetan plateau. The reference ET was estimated by the FAO-P-M Model and showed difference from the actual ET measured by the EC System. The crop coefficients (k_c) was used to estimate ET_a The average value of k_c during growing season was 0.55 (ranging from

0.30-0.92). VPD, R_n and T_a explained the majority of the daily variation in k_c which showed a linear increase with an increase in R_n and T_a and a linear decrease with an increase in VPD. Researchers also considered the impact of biomass on k_c which showed a significant positive effect on k_c. A daily empirical k_c model driven by VPD, R_n, T_a and biomass was developed to estimate daily actual ET using the FAO-56 k_c approach and the P-M Model for reference ET. This ET model was validated against 2005 growing season data for this meadow and demonstrated a suitable and consistent performance between the simulated and measured ET.

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