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Improving ecosystem model by optimizing parameters derived from eddy covariance network: an example of SWH model

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Outline

1

Introduction and Background

ET(evapotranspiration) Models

$$LE_{day} = R_{day} - B(T_s - T_a)^n$$

$$R_n = G + H + LE$$

$$LE = \frac{\Delta \times (R_{net} - G) + \rho \times C_p \times (e_{sat} - e) / r_a}{\Delta + \gamma}$$

Penman (Penman, 1948)

$$LE = \frac{\Delta R_n + c_p \rho VPD / r_a}{\Delta + \gamma + \gamma (r_s / r_a)}$$

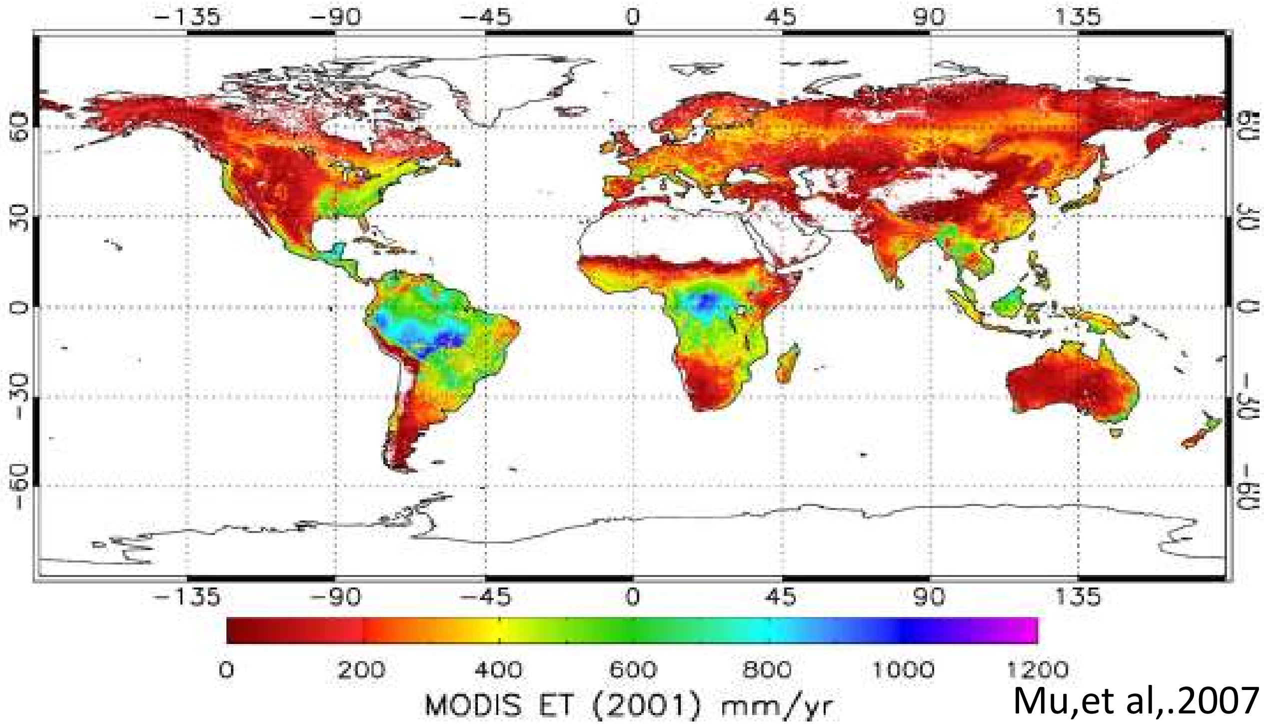
Penman-Monteith (Monteith, 1965

empirical/statistical models

surface energy balance models

physical models

☐ Uncertainties of regional ET estimation:



Mu,et al,.2007

(a)driving variables

such as climate data

(b)model structure

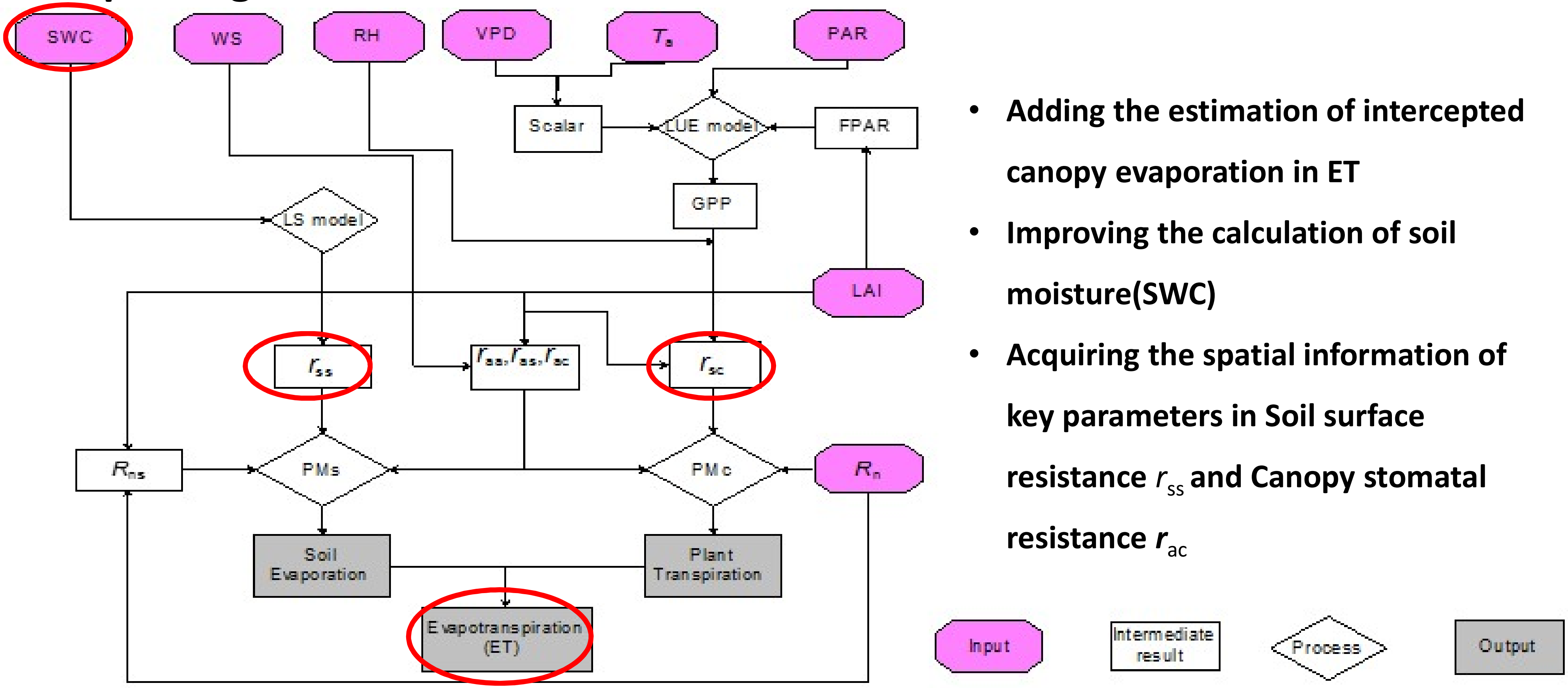
(c) parameters of the

model

2

Methods and materials

☐ Improving SWH model



- **Adding the estimation of intercepted canopy evaporation in ET**
- **Improving the calculation of soil moisture(SWC)**
- **Acquiring the spatial information of key parameters in Soil surface resistance r_{ss} and Canopy stomatal resistance r_{ac}**

[1]Hu, Z.;Yu, G.;Zhou, Y.;Sun, X.;Li, Y.;Shi, P.;Wan g, Y.;Song, X.;Zheng, Z.;Zhang, L.Partitioning of evapotranspiration and its controls in four grassland ecosystems: Application of a two-source model.2009,149,1410-1420.

☐ intercepted canopy evaporation

The evaporation on wet canopy surface can be calculated as[2]:

$$\lambda E_c = \frac{\left(s \times A_c + \rho \times C_p(e_{sat} - e) \times F_c / r\,hrc\right) \times F_{wet}}{s + \frac{P_a \times C_p \times rvc}{\lambda \times \varepsilon \times rhrc}}$$

Details of this model are available in

$$A_c = F_c \times A$$

$$F_{wet} = \begin{cases} 0.0 & RH < 70\% \\ RH^4 & 70\% \le RH \le 100\% \end{cases}$$

[2]Mu, Q. Z.;Zhao, M. S.;Running, S. W.Improvements to a MODIS global terrestrial evapotranspiration algorithm.2011,115,1781-1800.

☐ Soil water content

We estimate soil water content followed by Biome-BGC model.But saturated water content, fild capacity and wilting point in our research are calculated by Community Land Model (CLM), Saturated water content $\boldsymbol{\theta_s}$ is calculated as:

$$\theta_s = (1 - f_{om}) \times \theta_{s,min} + f_{om} \times \theta_{s,min}$$

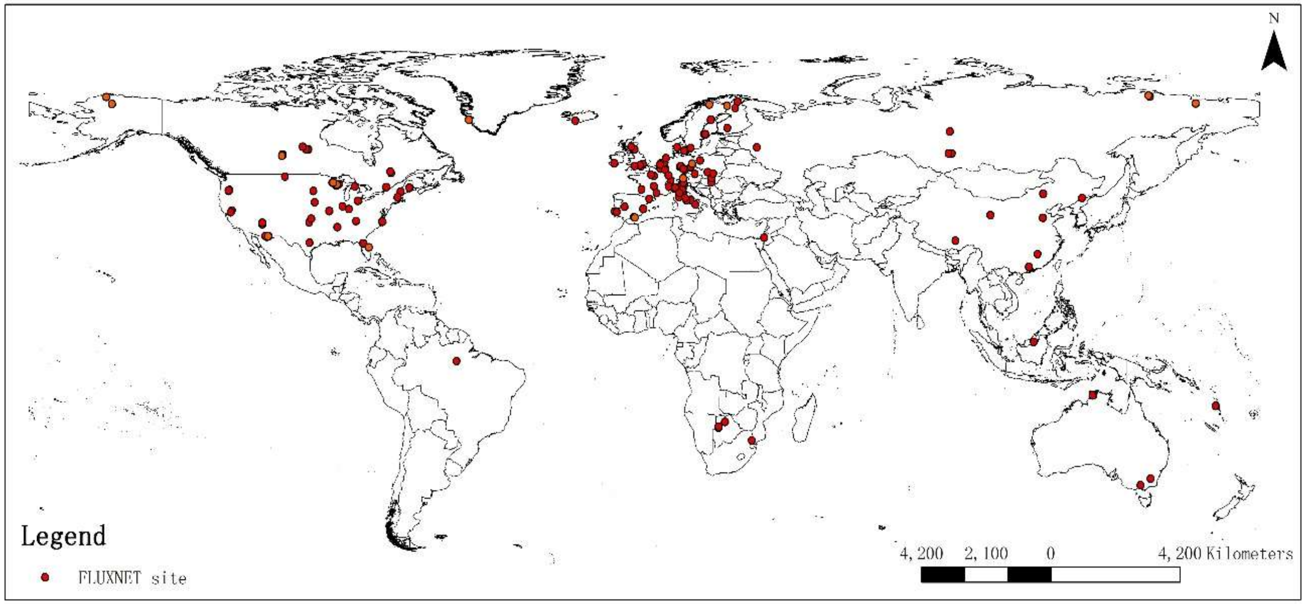
fild capacity $\boldsymbol{\theta_{fc}}$ is:

$$\theta_{fc} = \theta_s \times \left(\frac{0.1}{86400 \times k_{sat}}\right)^{\frac{1}{2 \times B + 3}}$$

wilting point $\boldsymbol{\theta_w}$ is:

$$\theta_w = \left(\frac{\varphi}{\varphi_s}\right)^{\frac{-1}{B}} \times \theta_s$$

☐ Acquiring the spatial information of key parameters



$$a_1 = 21.680 - 0.007 \times \mathrm{P} - 0.586 \times \mathrm{T} \quad (1)$$

$$b_2 = -0.155 + 0.023 \times s_f + 1.559 \times s_r \quad (2)$$

s_f is sand fraction , s_r is soil reference bulk ,P is precipitation and T is temperature

Figure 1. The location of 187 FLUXNET sites

- **Optimized four critical parameters in SWH model (*b_2, b_3, a_1, g_0*) by using measurements of ET and GPP at the 187 sites (Figure 1)around the world. (Monte Carlo simulations)**
- **Established parameter models (Equation(1-2))between the optimal parameters of each sites and annual average of environment variables through linear regression (including meteorological and edaphic variables)**

Results

3

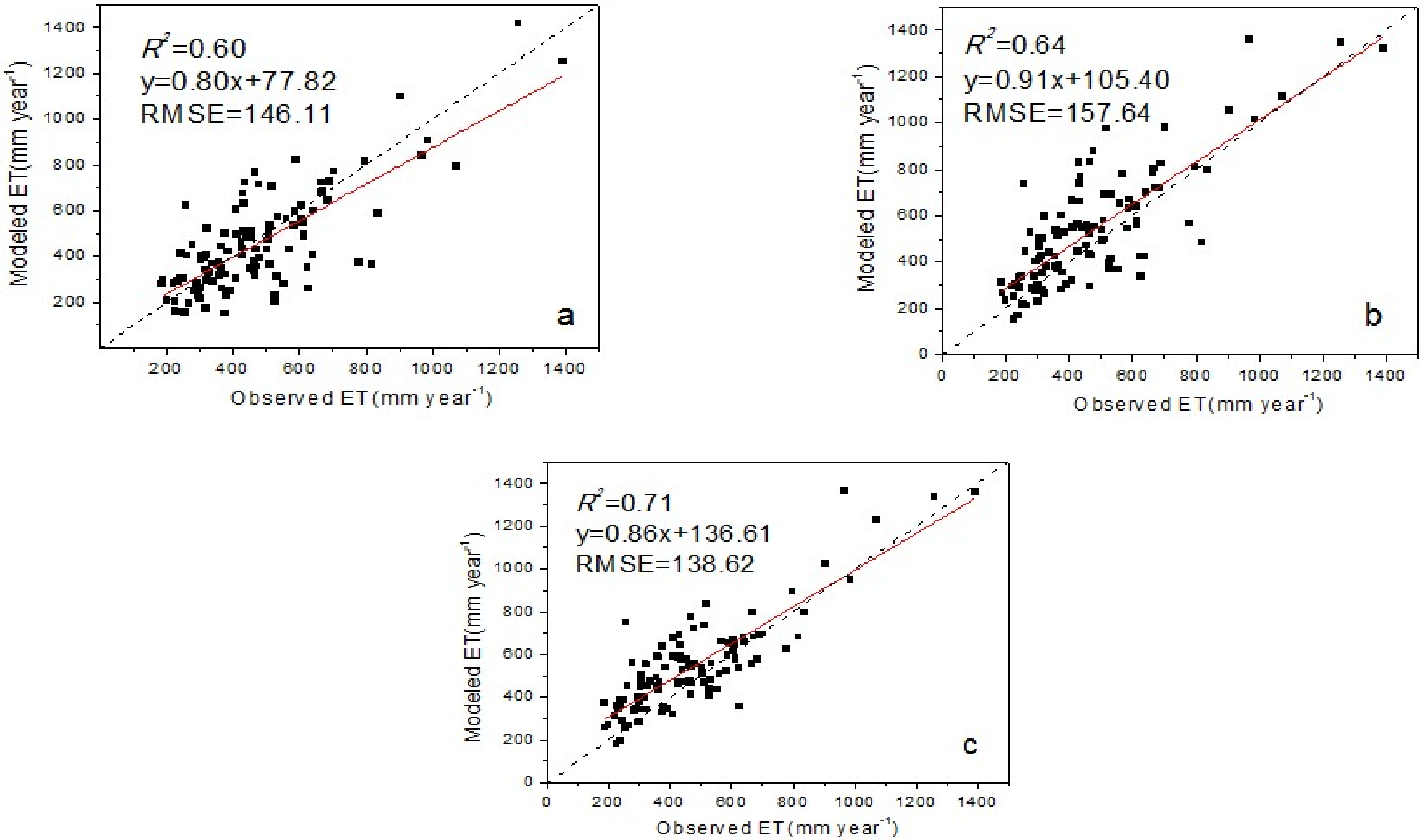
Result of three modes of SWH model

- The **first** mode of SWH model: using parameters in Table.1, run the original SWH model
- The **second** mode of SWH model: using parameters in Table.1, run the modified SWH model
- The **third** mode of SWH model: using parameter models in Equation(1-2), run the modified SWH model

Table 1. Look-up table of optimal parameters for each biome type. The values in parentheses are standard deviations.

Biome	b_2	b_3 (s m^{-1})	a_1	g_0(mol m^{-2} s^{-1})	ε_{max}(mg CO_2 $umol^{-1}$ PPFD)	d (mm)
Cropland	3.8(0.7)	643(234)	7.5(3.8)	0.028(0.025)	0.0022(0.0003)	303(95)
Forest	3.5(0.8)	724(215)	9.0(5.4)	0.005(0.004)	0.0011(0.0003)	244(110)
Grassland*	3.4(0.9)	508(279)	10.3(4.2)	0.017(0.021)	0.0012(0.0005)	188(95)

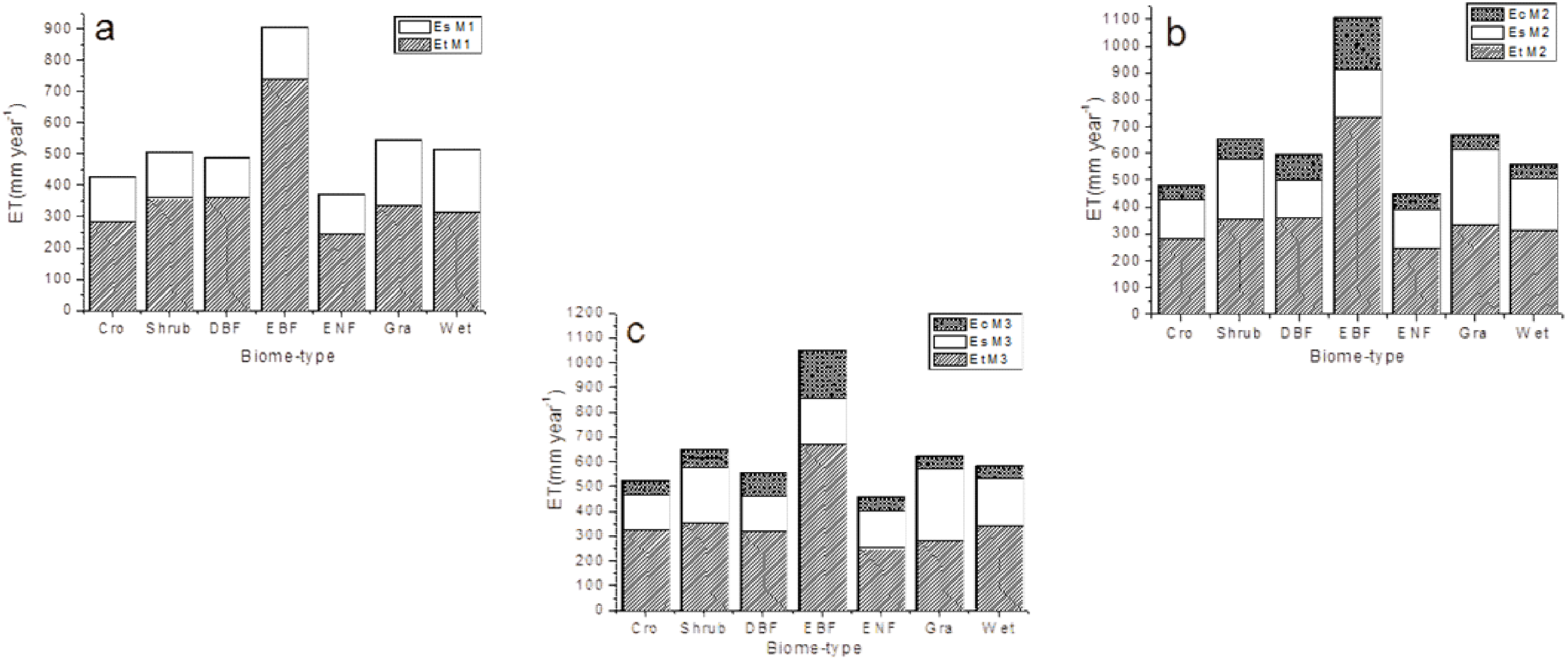
□Performances of three modes of SWH model



□Performances of modeled ET in each biome type

Biome	r(the first mode）	RMSE_ET	r（the second mode）	RMSE_ET	r(the third mode）	RMSE_ET
Crop	0.85	0.66	0.85	0.74	0.79	0.75
Shrub	0.83	4.23	0.85	4.58	0.87	4.59
DBF	0.89	0.65	0.89	0.64	0.88	0.65
EBF	0.66	0.87	0.72	0.78	0.70	0.78
ENF	0.81	0.84	0.82	0.98	0.78	0.96
Grass	0.83	0.68	0.84	0.76	0.76	0.75
MF	0.81	0.84	0.82	0.98	0.77	0.98
Wet	0.78	1.15	0.82	1.11	0.82	1.03

☐ Comparison the three modes of ET partitioning



- **We partitioned ET into its canopy evaporation (E_C)， plant transpiration（E_T）and soil water evaporation (E_S) components and found that E_C accounts for about 12% while E_T and E_S is over 50% and 30%.**

SiteID	mode 1 ET	mode 2 ET	mode 3 ET	measured ET
DX	200.75	370.17	403.79	528.05
SD	370.45	466.02	521.87	779.91
GCT	279.80	367.56	435.38	552.42

- **It is worth noting that we improve the problem underestimating ET at Qinghai-Tibet Plateau prominently**.

4 Conclusion

- **This research revealed that the parameters of canopy stomatal resistance r_{ac} mainly relate to meteorology factors and the parameters soil surface resistance r_{ss} were connected with soil data.**
- **The modified SWH model agrees well with the measurements and the R^2 increases to 71% while RMSE drops to 138.62 mm·year-1**
- **Except for Shrub, the three modes of SWH model performs better in herbaceous ecosystems than in woody ecosystems**
- **We found that E_C accounts for about 12% while E_T and E_S is over 50% and 30%.**

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Thank you for your attention!