AsiaFlux Workshop 2017 and the 15th Anniversary Celebration of ChinaFLUX

Seasonal drought effect on water and carbon fluxes in a subtropical Coniferous Plantation

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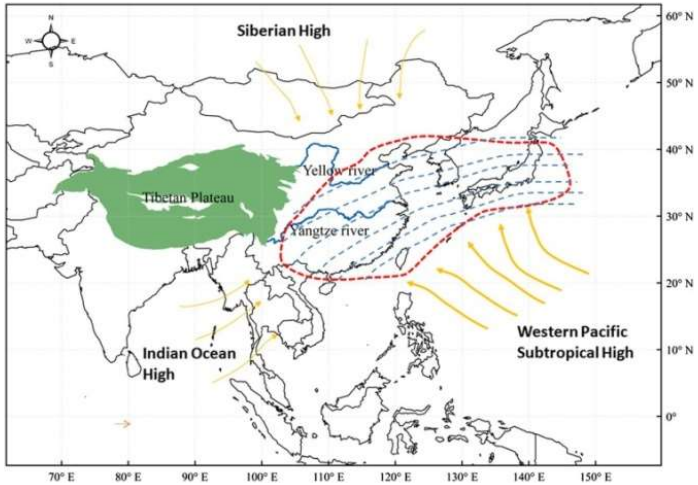
Outline

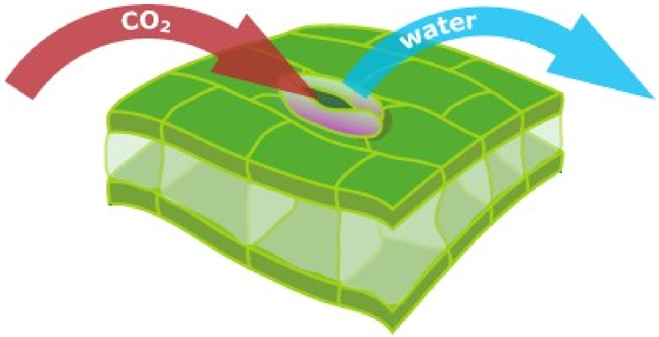
1. Background and Objective
2. Site description and method
3. Seasonal drought effect on variations of carbon and water fluxes
4. Quantify the drought effect on carbon and water fluxes
5. Conclusion

1. Background and Objective



Forest NEP in the East Asian monsoon region accounts for 8% of global NEP (**Yu et al., 2014**);

Seasonal drought generally occurs in vigorous growth period of forests (**Tang et al., 2014**);



The coupling between forest carbon and water fluxes prone suffered to drought stress (**Keenan et al., 2012**).

Variations of carbon and water fluxes

Affecting mechanisms on these fluxes

Seasonal drought

Predict the trend of these fluxes

1. Background and Objective

➢ **Annual trends of forest carbon and water fluxes**

(1) **Models predict**:

Global dimming (Liepert et al., 2004) — ET ⬇ β ⬆

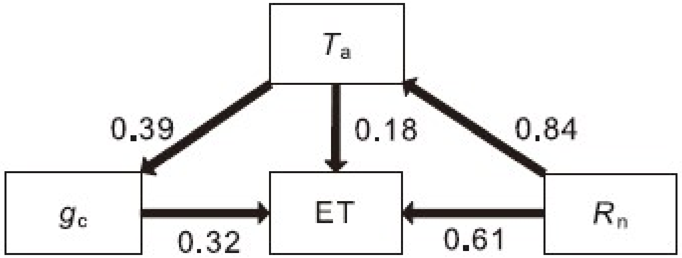
Ecosystem productivity model (Zhang et al., 2013) — NEP CUE ⬇

(2) **Direct observation more than 10 years through eddy covariance :**

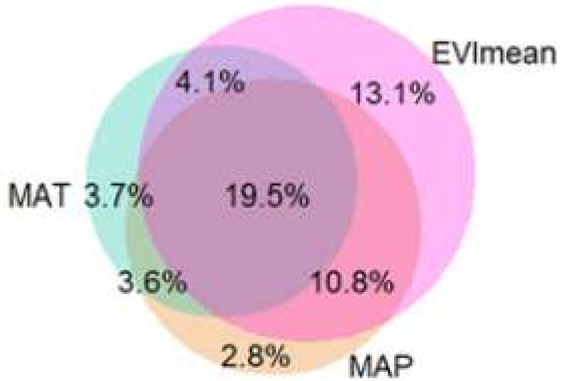
	ET	β	GEP	RE	NEP	CUE
Decrease	3	2	5	2	2	1
Increase	**5**	1	3	5	**4**	**3**
No significant	3	3	4	5	6	8
Total	**11**	**6**	12	12	**12**	**12**

➢ Interactive between environmental and biotic factors, drought effect

(1) Interactive between environmental and biotic factors

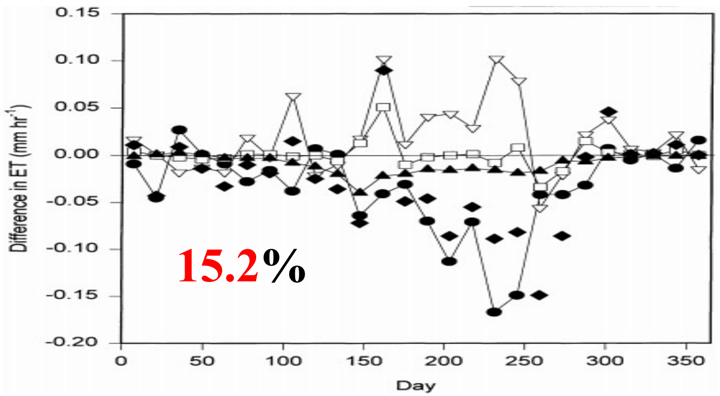


(Huxman et al., 2003)



(Chen et al., 2015)

（2）Seasonal drought enhanced the biotic factor affecting ET



(Wilson and Baldocchi, 2000)

Drought effect on self-regulating mechanisms of trees?

➢ Quantify the contribution of environmental variability and biotic factors

	Advantage	**Disadvantage**
Partial differential equation (Wilson et al.,2000)	Drought effect on ET	Only focused on ET, self-correlation
Look-up Table (Marcolla et al.,2011)	Quantify the contribution for ET and NEP	self-correlation
Homogeneity of Slopes (HOS) model (Tekmariam et al., 2010)	Quantify the contribution for ET and NEP, avoid self-correlation	Long-term observation

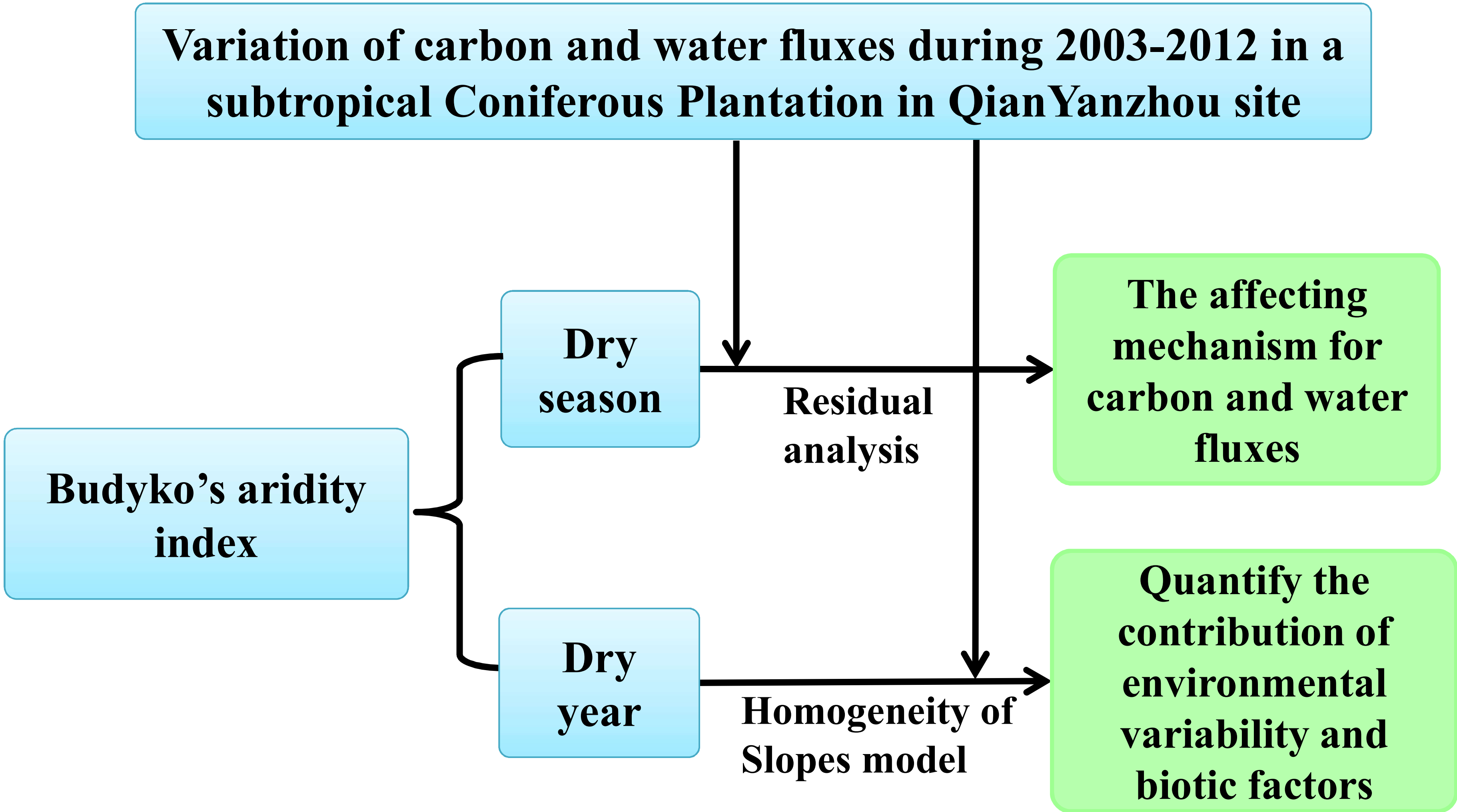
$$\Delta E = \frac{\overline{\partial E}}{\partial G_c}\Delta G_c + \frac{\overline{\partial E}}{\partial D}\Delta D + \frac{\overline{\partial E}}{\partial R_n}\Delta R_n + \frac{\partial E}{\partial \mathrm{Ib}}\Delta \mathrm{Ib}$$

(Wilson et al.,2000)

$$Y_{ij} = a + \sum_{i=1}^{m} b_k X_{ijk} + e_{ij} \qquad Y_{ij} = a + \sum_{i=1}^{m} b_{ik} X_{ijk} + e_{ij}$$

(Tekmariam et al., 2010)

1. Background and Objective



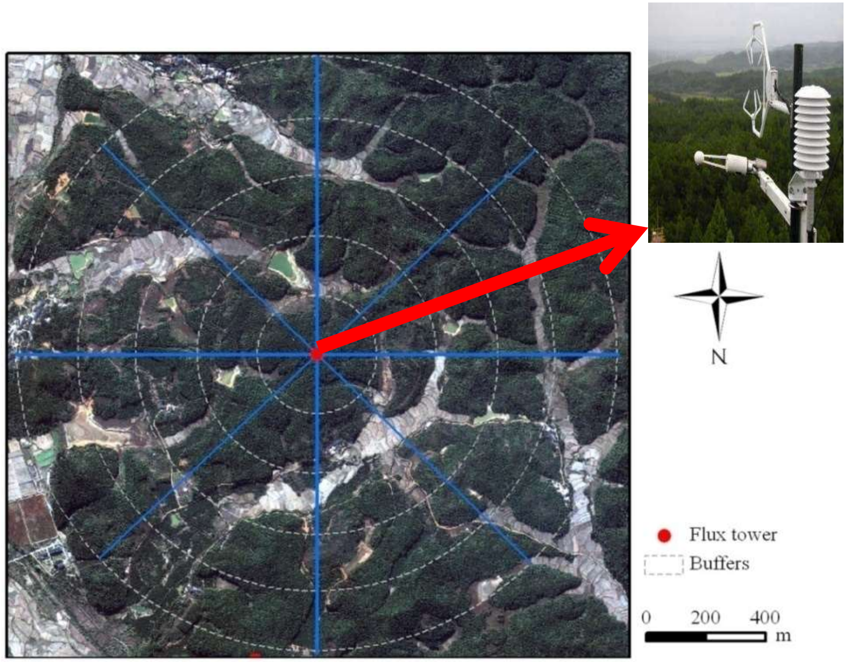
2. Site description and method

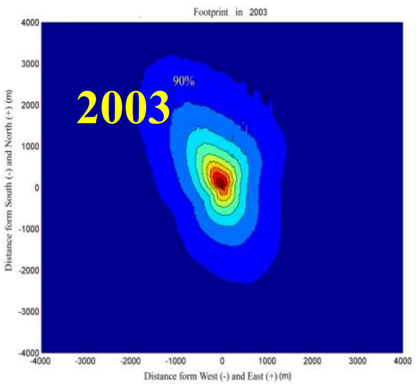
2.1 Site description and Flux observation

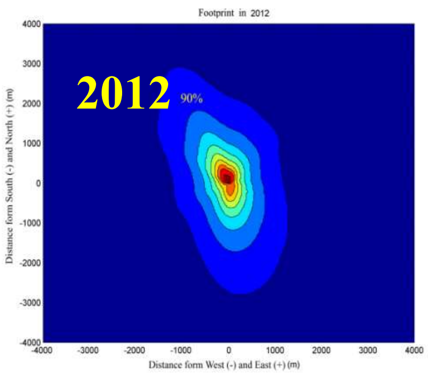
2.2 Dry season and dry year

2.3 Homogeneith-of-slope (HOS) model

2.1 Site description and Flux observation







Zhang and Wen (2015)

Site：Qianyanzhou flux observation site located in Jiangxi province (26° 44′52″N, 115° 03′47″E, elevation: 102 m)；

Climate： Subtropical monsoon climate, with average air temperature and precipitation amount of 17.3 ℃ and1464 mm；

Dominant tree species：

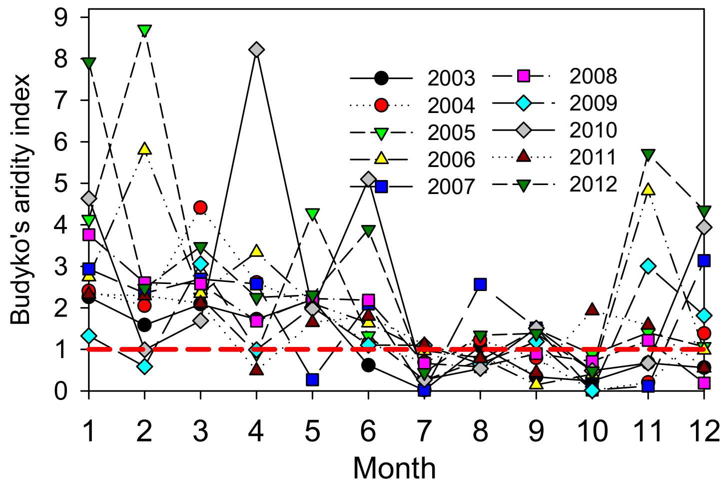
Masson pine (*Pinus massoniana L.*),

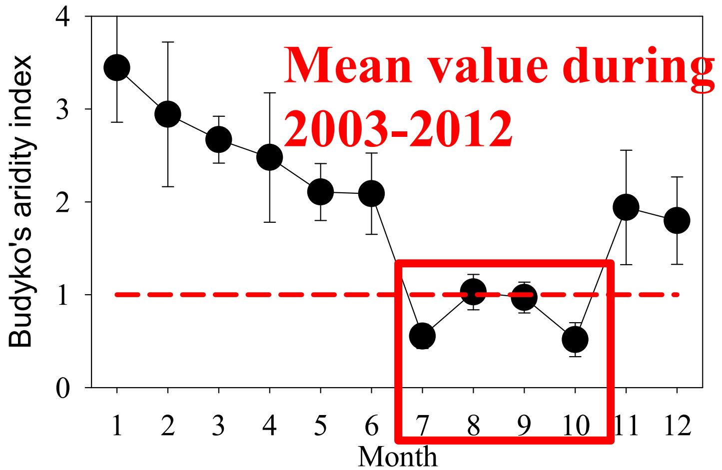
Chinese fir (*Cunninghamia lanceolata L.*)

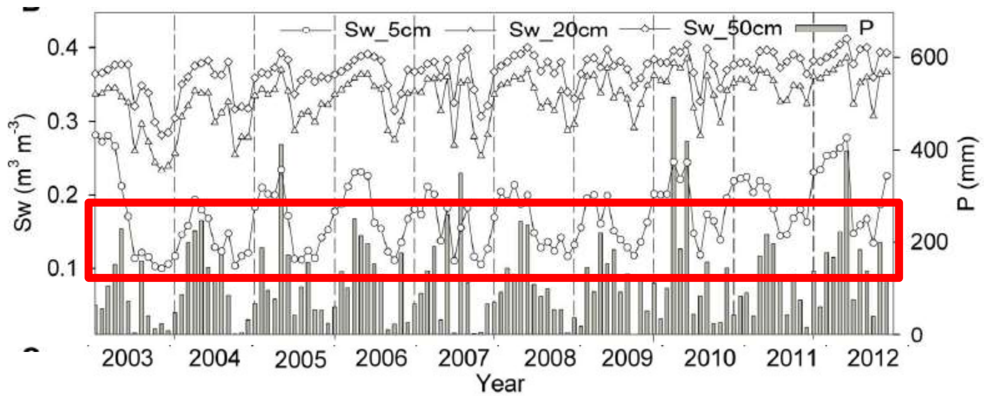
Slash pine (*P. elliottii E.*)

2.2 Dry season and dry year

Dry season







(1) Criterion ：

- **Budyko's aridity index**

＝ P/ P_{ET}

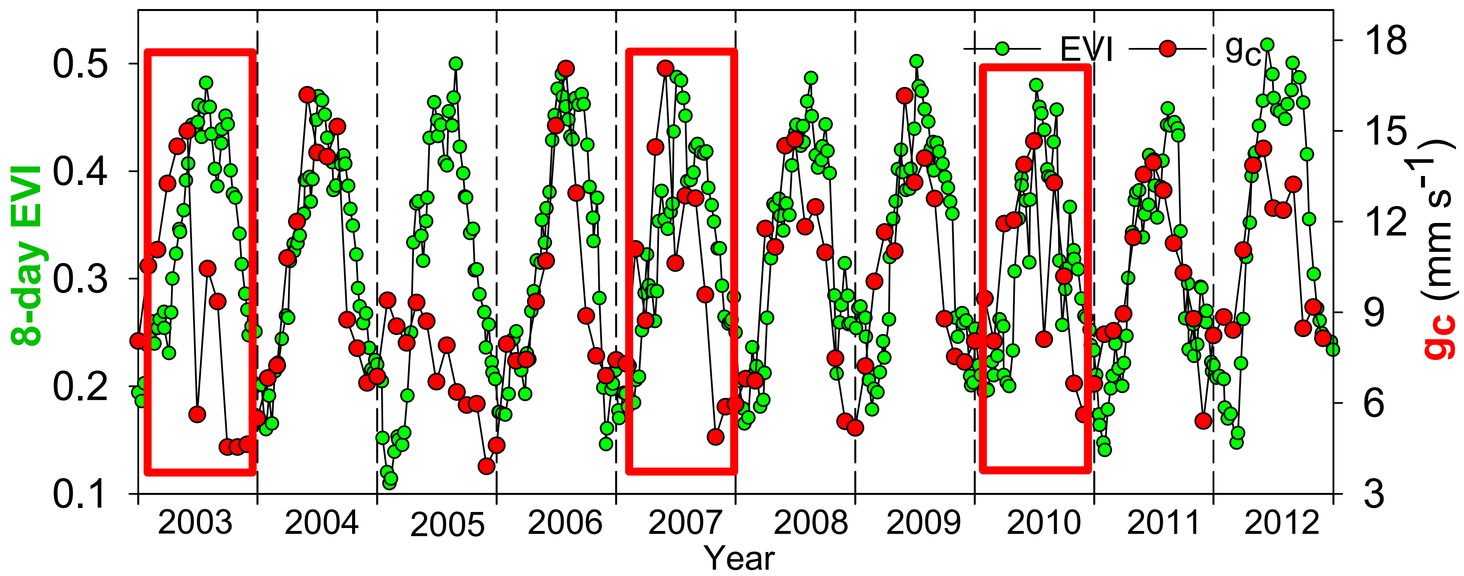
(Budyko, 1974; Ryu et al., 2010; Jassal et al., 2009)

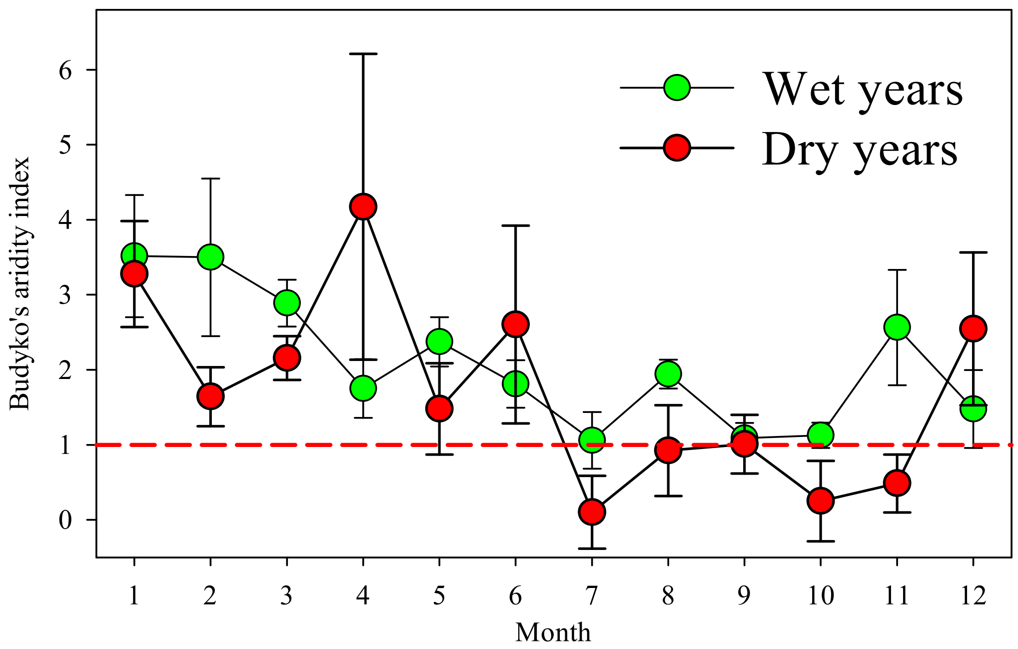
- \> 1 sufficient water supply;
- <=1 drought.

(2) Dry season：

- **Dry season ： July-October during 2003-2012;**

Dry year





(1) Criterion：

- Obviously declined EVI and g_c;
- **Budyko's aridity index <=1**;

(2) Dry year：

- 2003, 2007, and 2010

2.3 Homogeneith-of-slope (HOS) model

Principle of HOS model (Hui et al., 2003)

$$Y_{ij} = a + \sum_{i=1}^{m} b_k X_{ijk} + e_{ij} \qquad (1)$$

$$Y_{ij} = a + \sum_{i=1}^{m} b_{ik} X_{ijk} + e_{ij} \qquad (2)$$

$$SS_T = SS_f + SS_i + SS_s + SS_e \qquad (3)$$

Any **significant change** ($p<0.05$) in the **slope** of the regression between NEP or ET and a given environmental variable among **different years** is usually assumed to indicate **an indirect effect (**changes in ecosystem structure and vegetation physiological processes**)** of an environmental variable.

$$SS_f = \sum_{i=1}^{y}\sum_{j=1}^{n}(\hat{Y}'_{ij} - \hat{Y}_{ij})^2$$

Functional change (SSf)

$$SS_e = \sum_{i=1}^{y}\sum_{j=1}^{n}(Y_{ij} - \hat{Y}'_{ij})^2$$

Error (SSe)

$$SS_i = \sum_{i=1}^{y}\sum_{j=1}^{n}(\hat{Y}_{ij} - \bar{Y}_{.j})^2$$

Interannual environmental Variability (SSi)

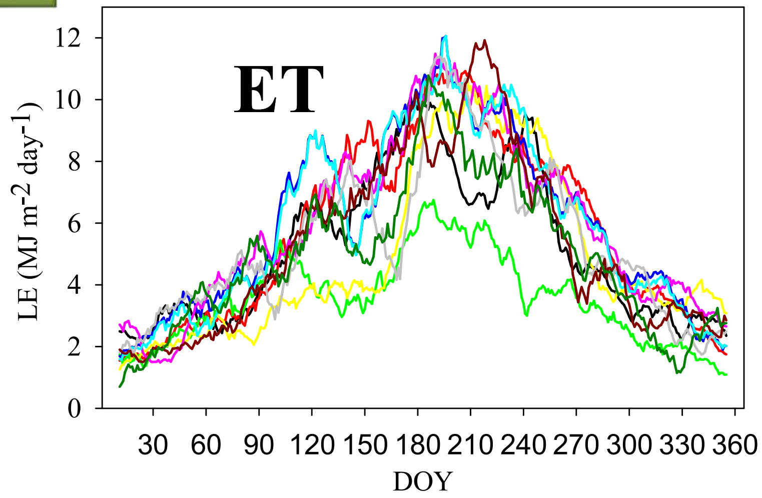
$$SS_s = \sum_{i=1}^{y}\sum_{j=1}^{n}(\bar{Y}_{.j} - \bar{Y})^2$$

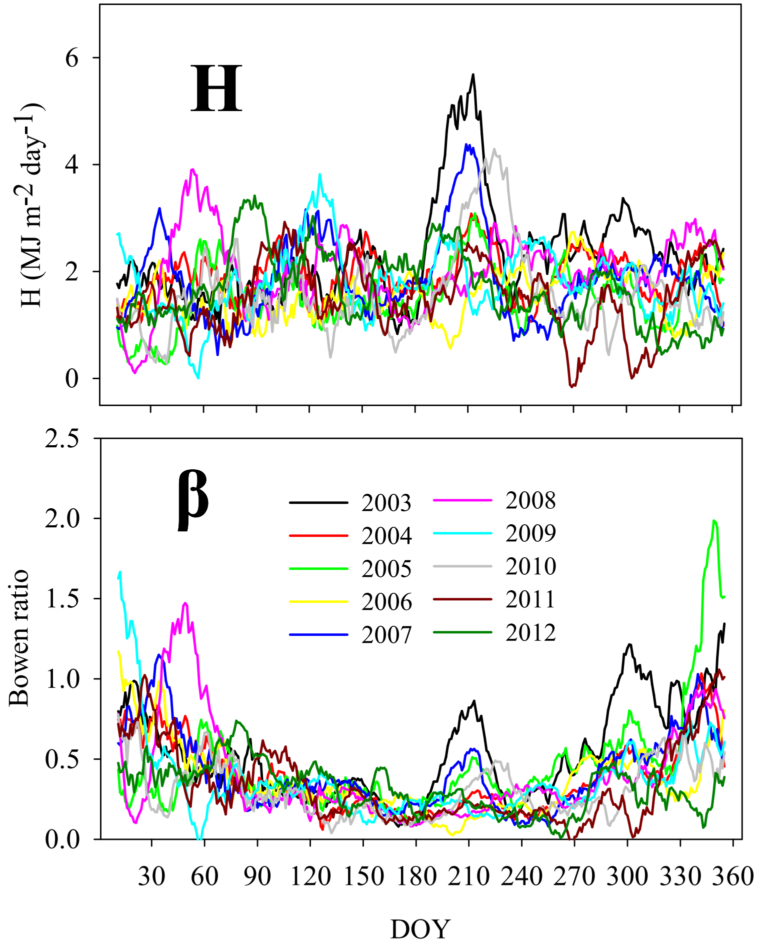
Seasonal environmental Variability(SSs)

To avoid the **autocorrelation effect** between environmental variables and estimated carbon and water fluxes, only the **available daytime** NEP and ET were analyzed.

3. Seasonal drought effect on variations of water and carbon fluxes

Seasonal





(1) **General bimodal curve** was observed for ET, β experienced **U** type;

(2) Seasonal drought decreased ET, but increased H and β;

3. Seasonal drought effect on variations of carbon and water fluxes

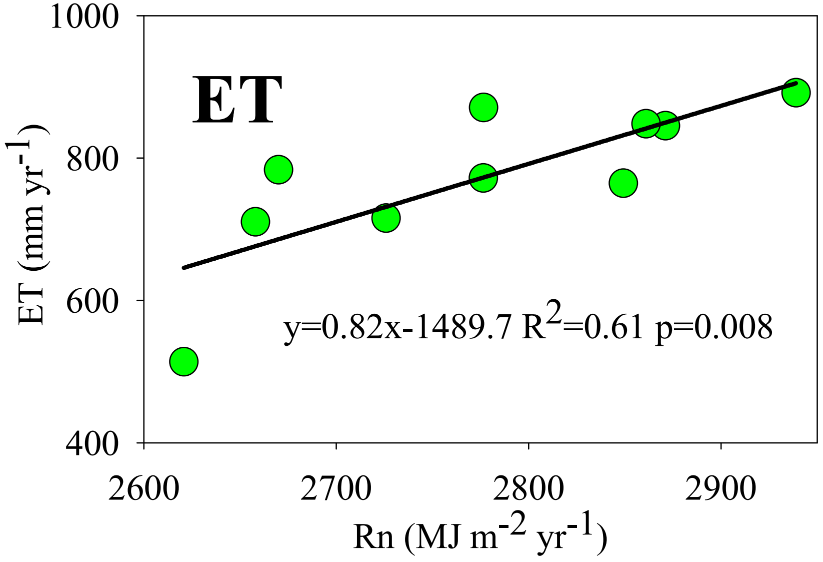
Year	ET	H	β
2003	764.3	845.5	0.45
2004	845	704.4	0.34
2005	513.6	564.7	0.45
2006	710	568.8	0.33
2007	870.5	631.8	0.3
2008	847.9	768.9	0.37
2009	891.5	721.8	0.33
2010	783.3	581.9	0.3
2011	771.5	547.7	0.29
2012	715.2	610.3	0.35
mean	771.3	654.6	0.4
SD	110.1	100.63	0.06
CV	**0.14**	**0.15**	**0.16**

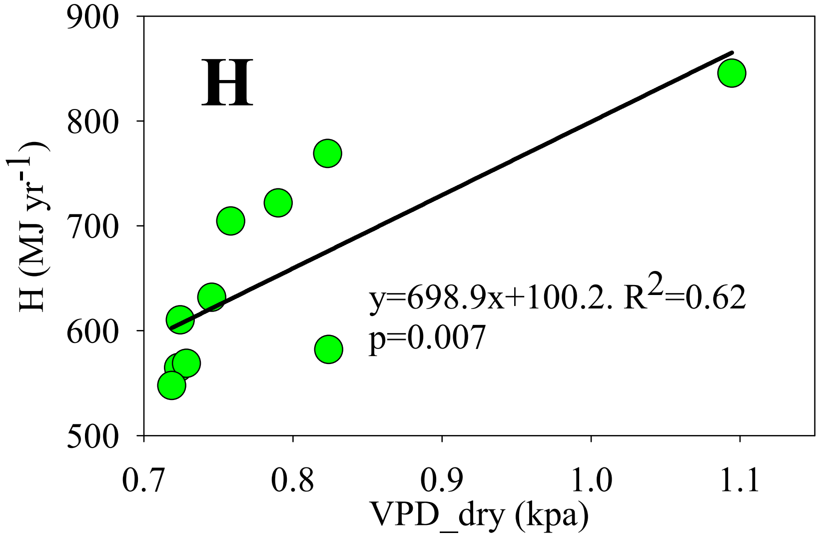
Interannual

(**3**) The **max.** and **min.** annual β was consistent with H.

(**4**) The coefficient of variation (**CV**) was similar in ET, H and **β.**

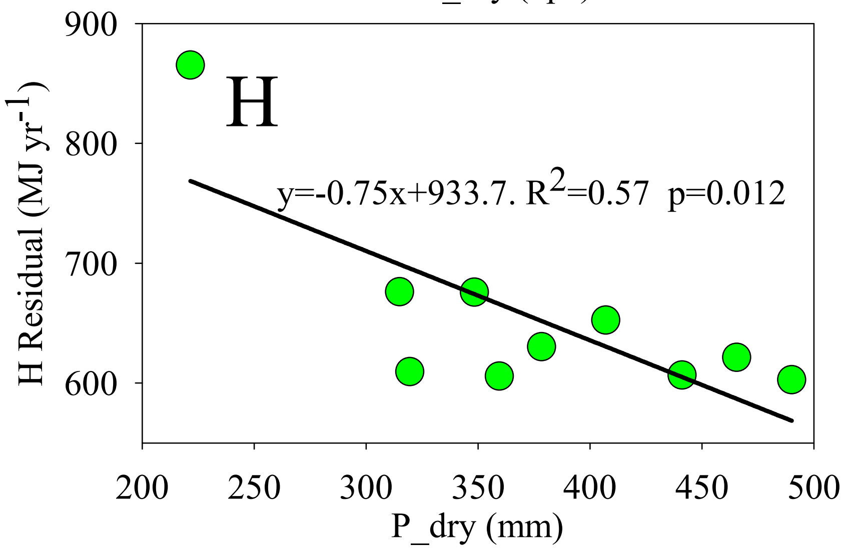
Affecting factor



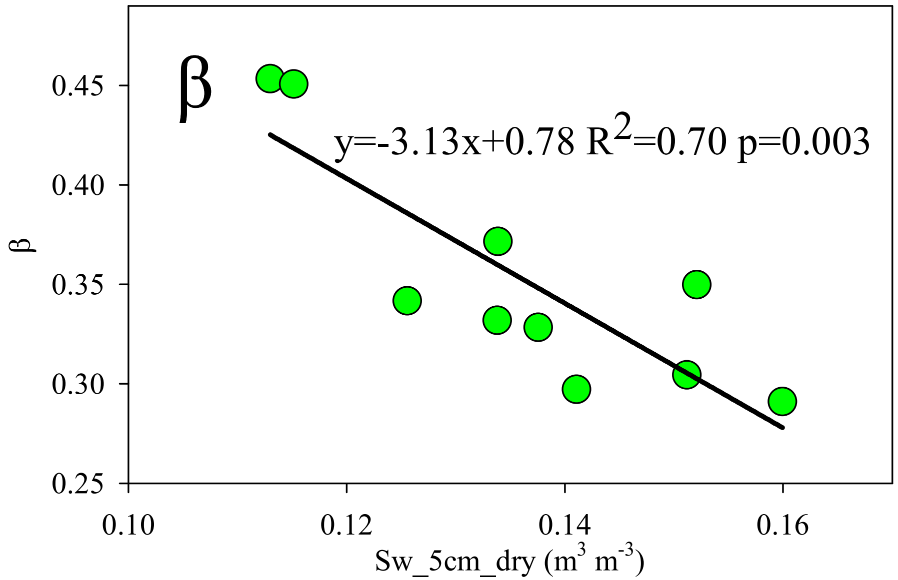


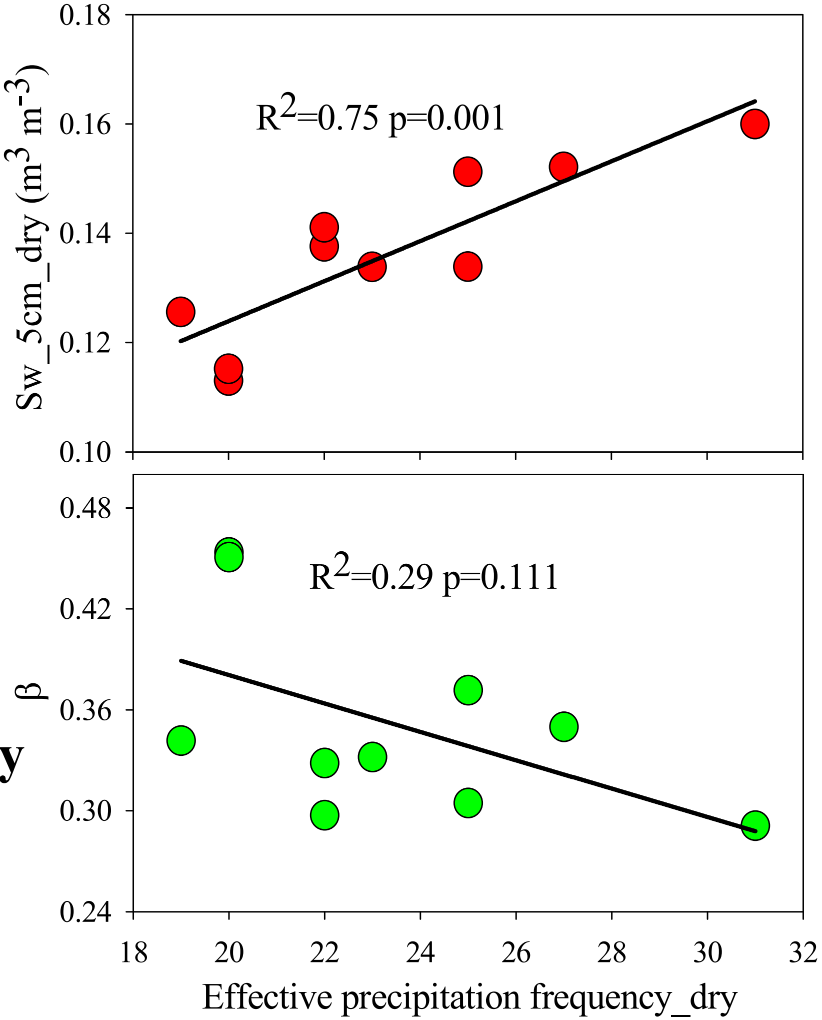
(1) ET was mainly influenced by annual Rn;

(2) H was dominated by VPD_dry (June-October), this residual was mainly influenced by P_dry.



Affecting factor

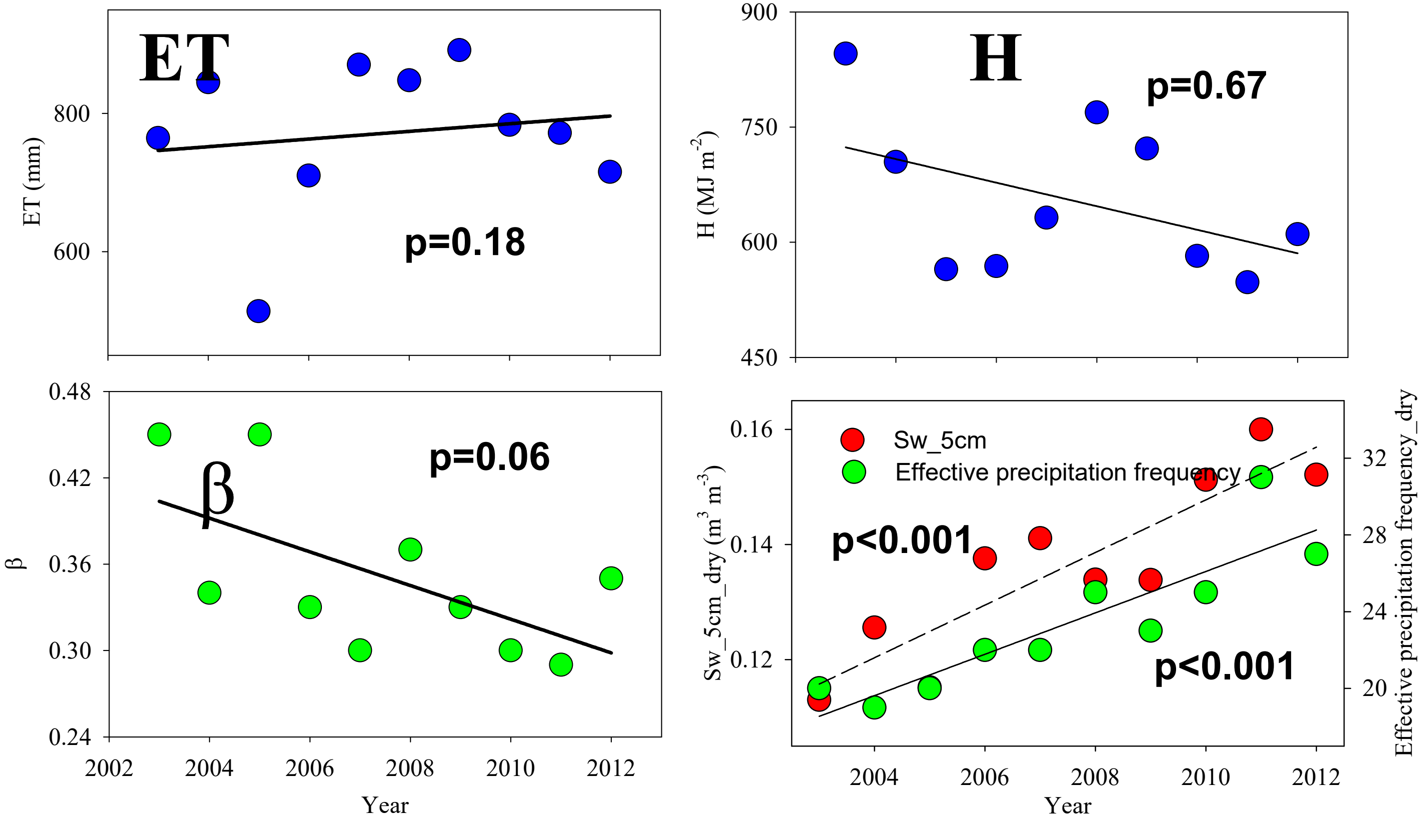




(1) **β** was mainly dominated by SW_5cm_dry;

(2) The **effective precipitation frequency_dry** indirectly affect β through its influence SW_5cm_dry.

Annual trends

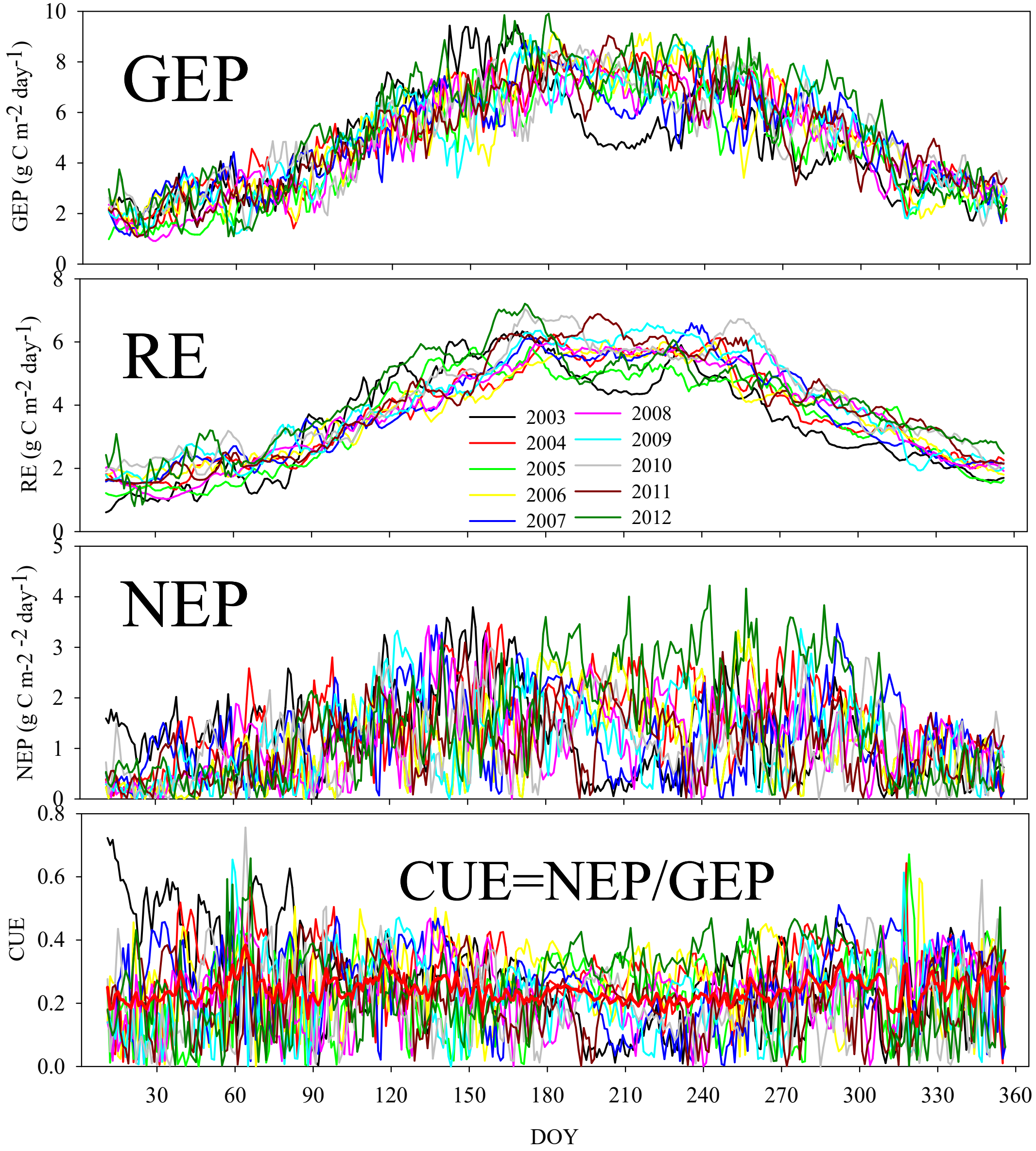


(1) No **significant** annual trends was observed for ET and H， β exhibited **marginally significant decreasing trend**；

(2) SW_5cm_dry and EPF_dry exhibited significant **increasing trend**；

(3) Annual β may decrease further and the **warming effect of available energy** to the surface air may decline. The warming effect may increased for forests, and **offset the carbon fixed ability** due to low albedo (Wickham et al., 2013).

3. Seasonal drought effect on variations of carbon and water fluxes



Seasonal variation

(1) General bimodal curve was observed for GEP, RE and NEP, **no specific curve** was observed for CUE;

(2) NEP **decreased more** than other carbon fluxes in response to seasonal drought;

Interannual variation

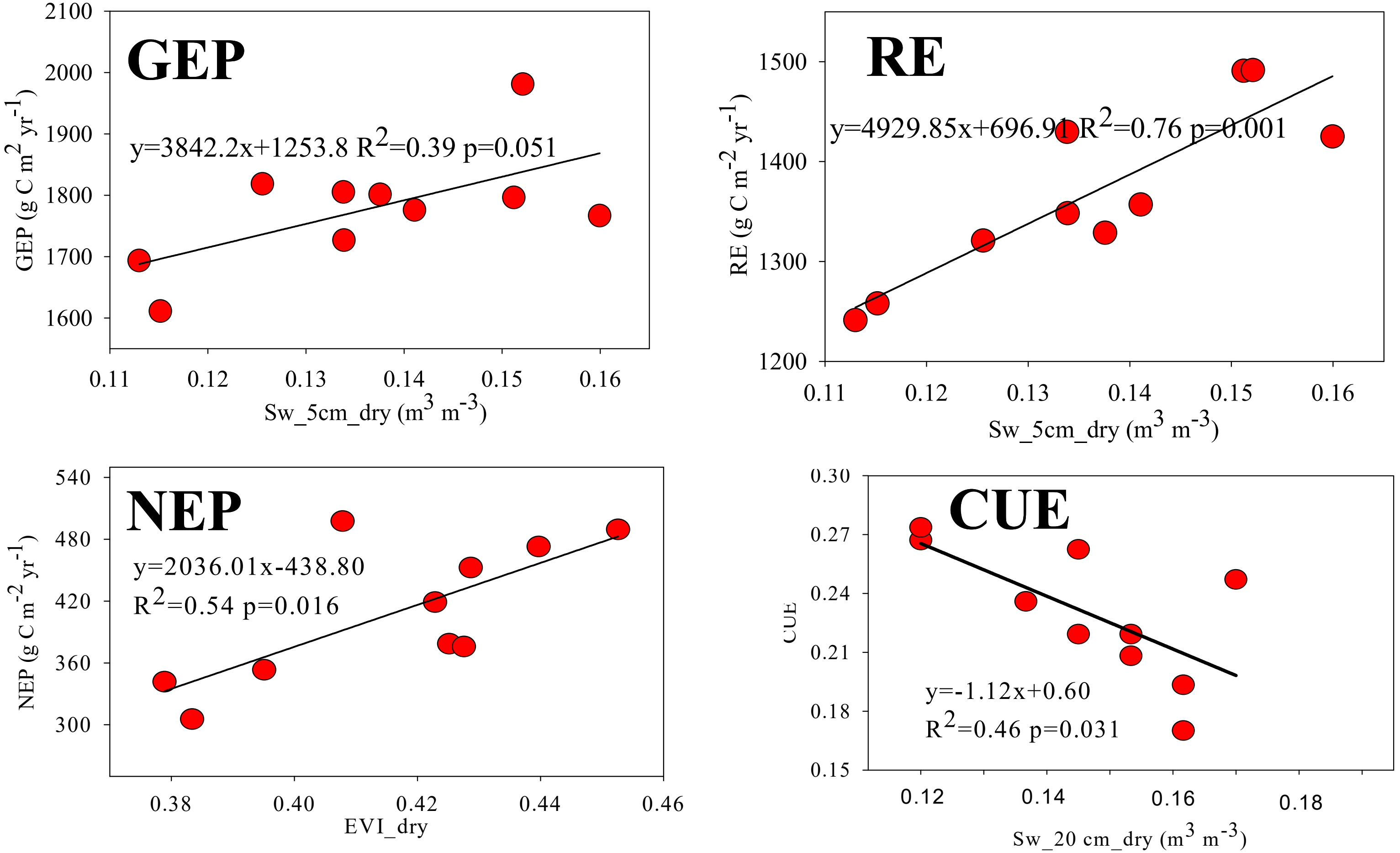
Year	GEP	RE	NEP	CUE
2003	1693.5	1241.1	452.4	0.27
2004	1818.4	1320.9	497.5	0.27
2005	1611	1257.8	353.2	0.22
2006	1801.4	1328.6	472.8	0.26
2007	1775.7	1356.8	418.9	0.24
2008	1726.7	1348.2	378.5	0.22
2009	1805.3	1429.6	375.8	0.21
2010	1796.1	1490.7	305.4	0.17
2011	1766.5	1424.9	341.7	0.19
2012	1980.9	1491.5	489.4	0.25
mean	1777.6	1369	408.6	0.23
SD	95.58	88.11	67.3	0.03
CV	**0.05**	**0.06**	**0.16**	**0.15**

(3) The max. and min. annual **GEP** was consistent with **RE**;

(4) The max. and min. annual **CUE** was consistent with **NEP** ;

(**5**) The annual NEP and CUE experienced higher coefficient of variation (**CV**).

Affecting factor

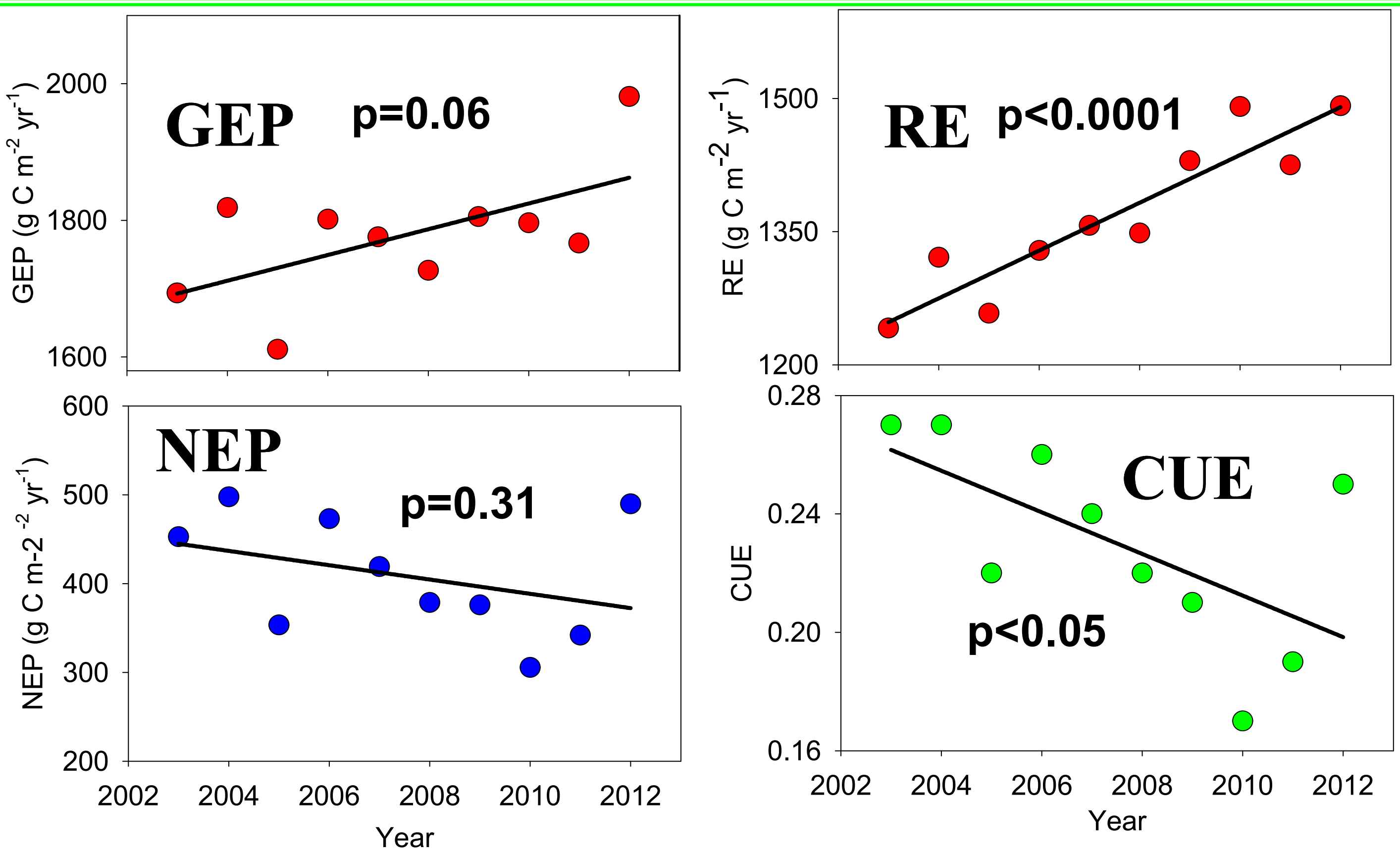


(1) **GEP and RE** mainly dominated by SW_5cm_dry;

(2) **CUE** mainly dominated by **SW_20cm_dry** ;

(3) **NEP was mainly affected by EVI_dry**;

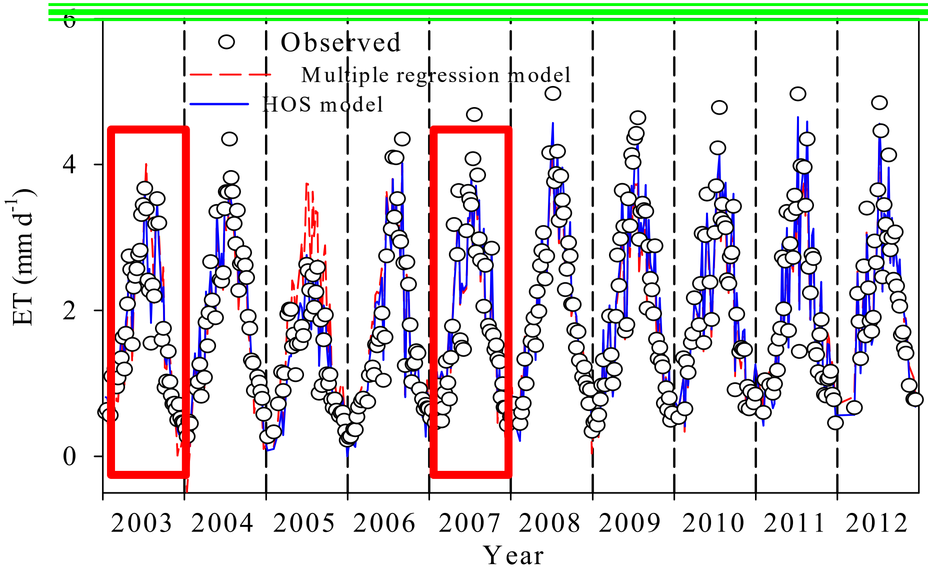
Annual trends

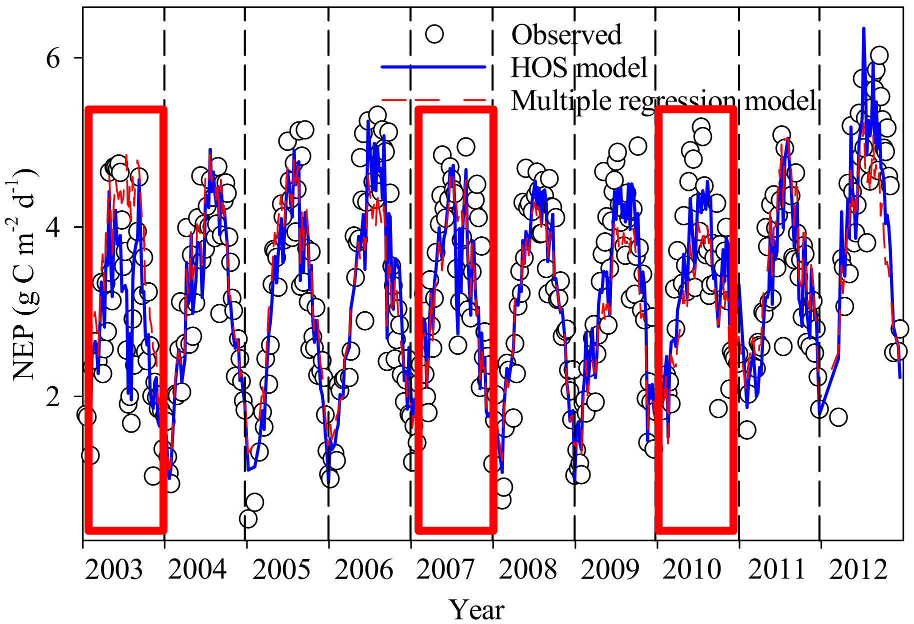


(1) Increased annual trends was observed for GEP (**marginally**) and RE，CUE exhibited **significant decreasing trend**；

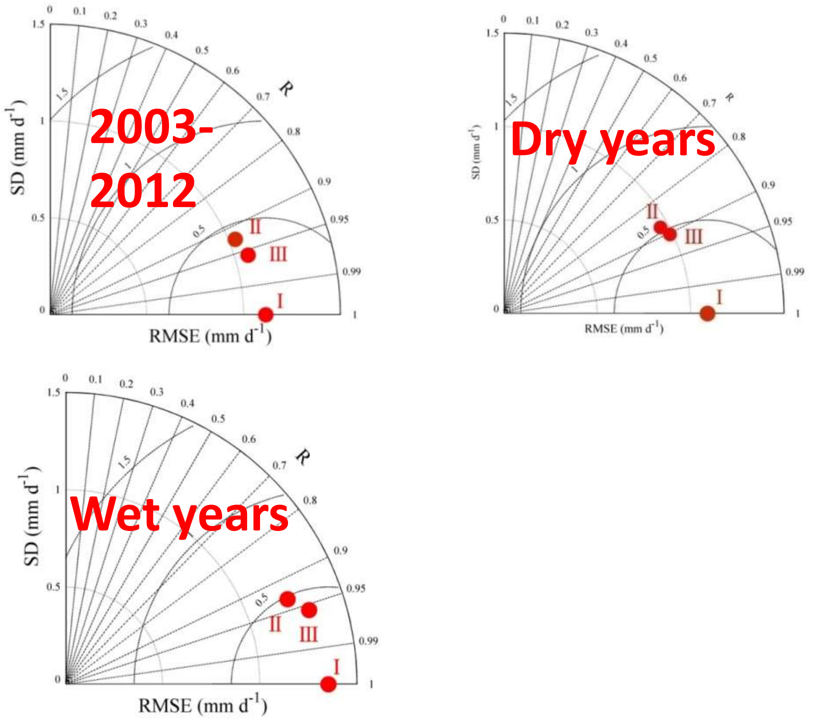
(2) Annual CUE may decrease further as SW_20cm_dry and EPF_dry continue increased, the **carbon fixed efficiency** along with **forest age** may decline further.

4. Quantify the drought effect on carbon and water fluxes





(1) HOS model better matched the seasonal and interannual variation of NEP and ET, as well as the drought effect.



	Seasonal environmental variability (%)	Interannual environmental variability (%)	Functional changes (%)	Error (%)
NEP	60.4	10.6	11.3	17.7
NEP_dry	44.7	7.5	**16.3**	31.5
NEP_wet	72.5	8.4	**3.8**	15.3
ET	71.6	14.1	5.9	8.3
ET_dry	70.5	6.3	**4.7**	18.4
ET_wet	72.2	14.3	**5.5**	8.1

(2) **Environmental variability** rather than **functional changes** dominated the interannual variability of both ET and NEP;

(3) Compared with NEP, ET was more **resistant to drought stress through the self-regulating mechanisms** of this plantation.

- **regulation of leaf stomata, extraction of deep soil water, trophic structure.**

5. Conclusion

(1) Although **no significant trends** was observed for ET and NEP, if the **SW_5cm_dry**, **SW_20cm_dry** and **EPF_dry** continued increased as the past 10 years, the **available energy partitioning** for ET and the **carbon fixed efficiency** may increase and decrease further, respectively.

(2) **Environmental variability** rather than **functional changes** dominant the interannual variation of ET and NEP. The ET was more resistant to drought stress, and can be attribute the severely depressed **carboxylation processes**, and the low concentration of **osmotically active substances** in coniferous trees.

Thanks for your attention !