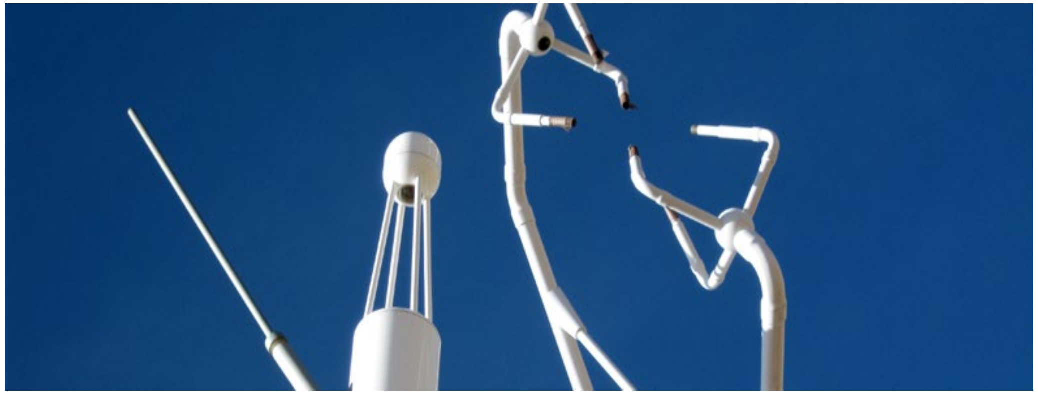
第19届ChinaFLUX通量培训

蒙古高原通量观测



邵长亮
中国农科院资源区划所
2024.8.21 呼伦贝尔

提　纲

1 蒙古高原通量观测网

2 主要进展-通量

3 主要进展-通量塔群

4 主要进展-极端气候

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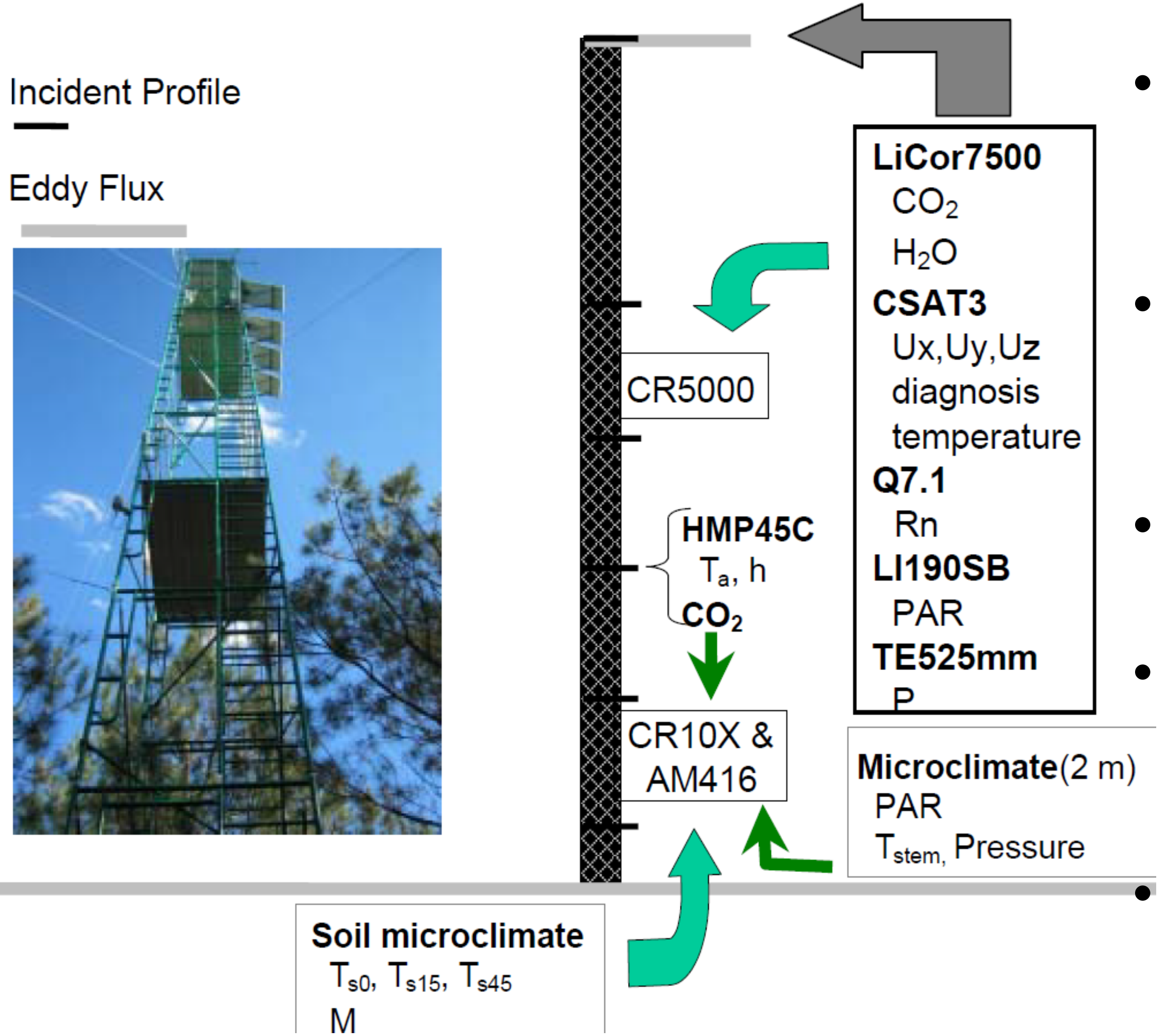
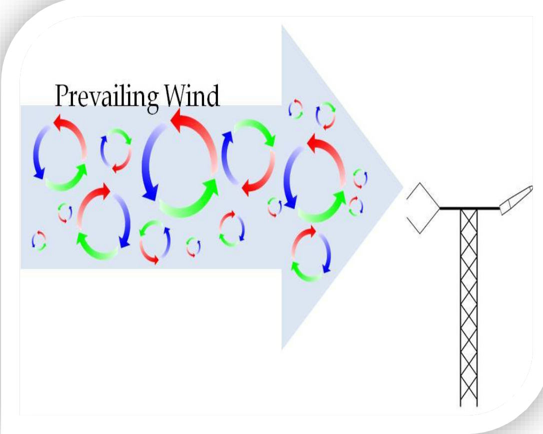
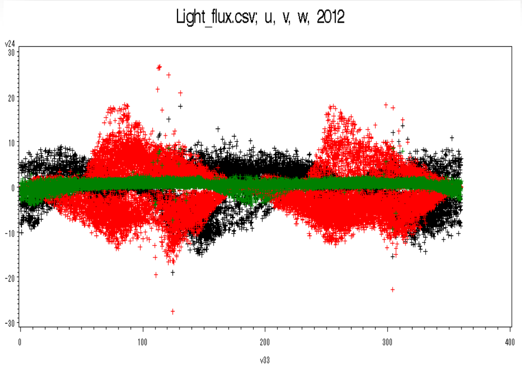
涡度相关通量观测系统-通量塔



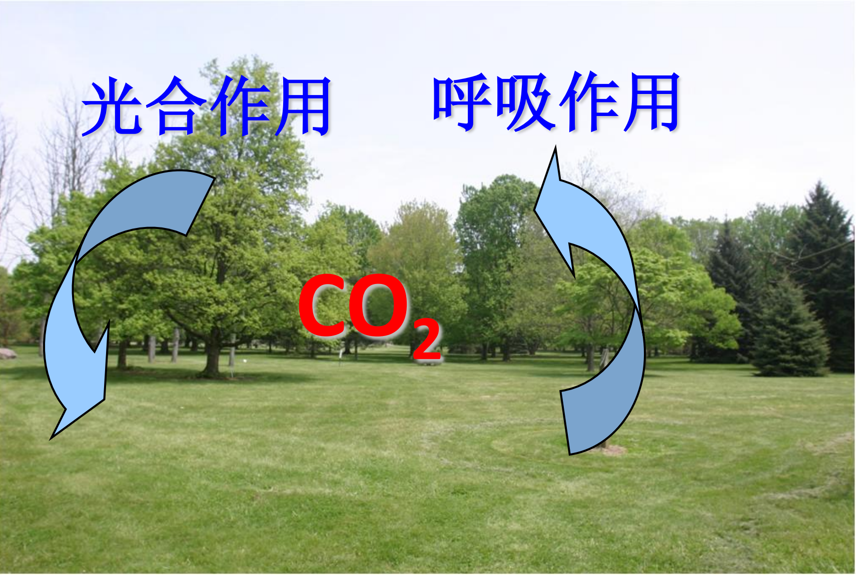
- 利用垂直风速和CO_2/H_2O浓度变化来量化气体交换
- 观测要求为下垫面平坦、足够大
- 仪器反应非常快（10hz）
- 测量生态系统气体通量最直接、最可靠的方法
- 非破坏性、极端气候下



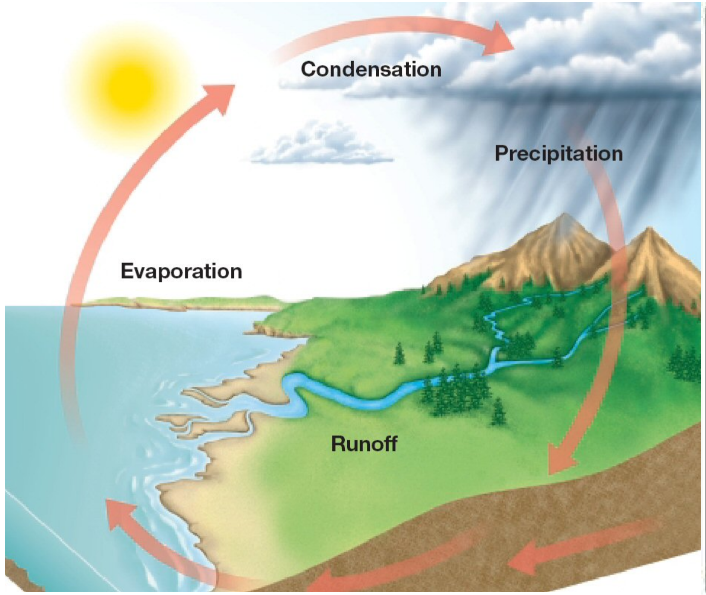


涡度相关通量观测系统-通量塔

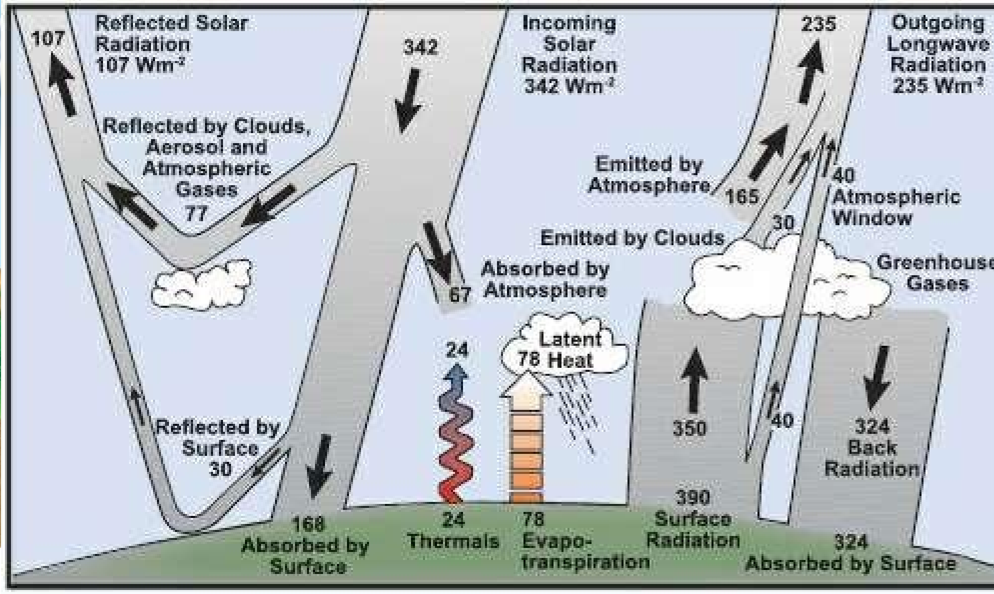
碳收支



水收支



能量收支

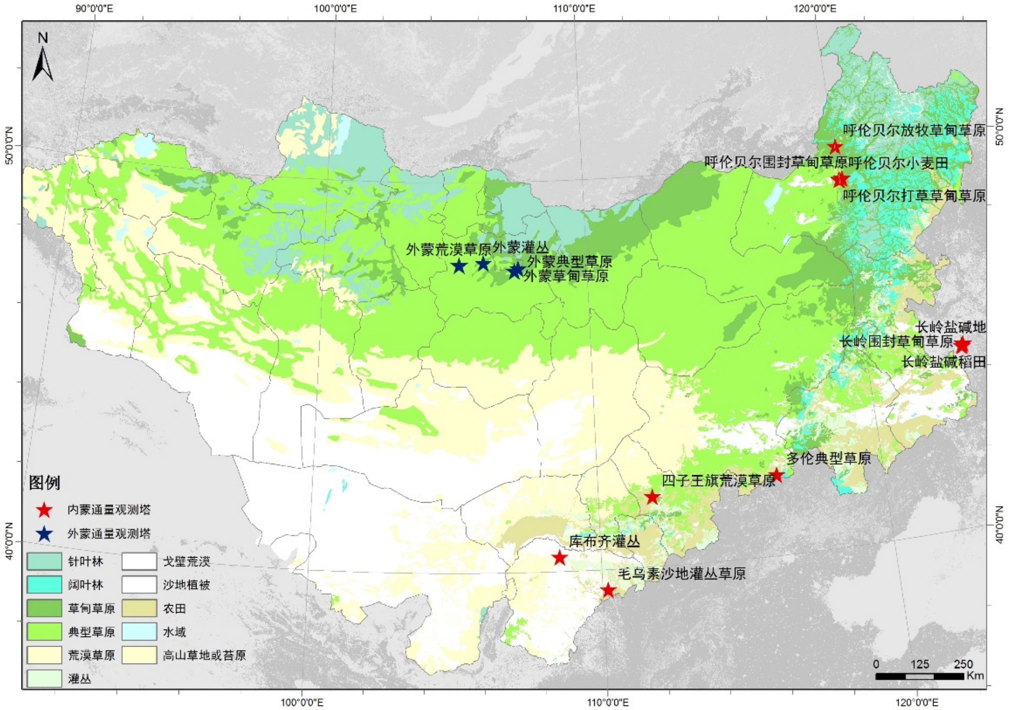


蒙古高原通量网

构建了蒙古高原大型草原通量观测平台

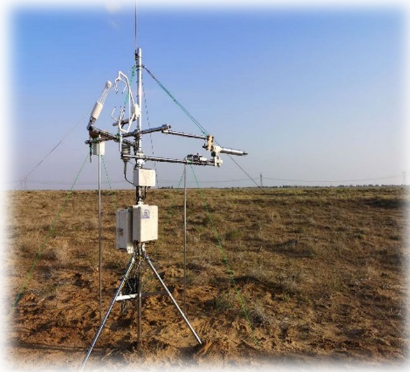
2017年到中国农科院后新建涡度通量塔8套，共运行16套

- 蒙古国2012年至今维护运行4套（草甸、典型、荒漠、灌木）
- 内蒙古呼伦贝尔草甸草原4套（围封、放牧、刈割、农田）
- 吉林长岭3套（围封、刈割、稻田）
- 内蒙古通辽站1套（灌木）
- 内蒙古锡林郭勒典型草原2套（围封、放牧）
- 内蒙古四子王旗站1套（放牧）
- 内蒙古巴彦淖尔站1套（灌木），黄河上游



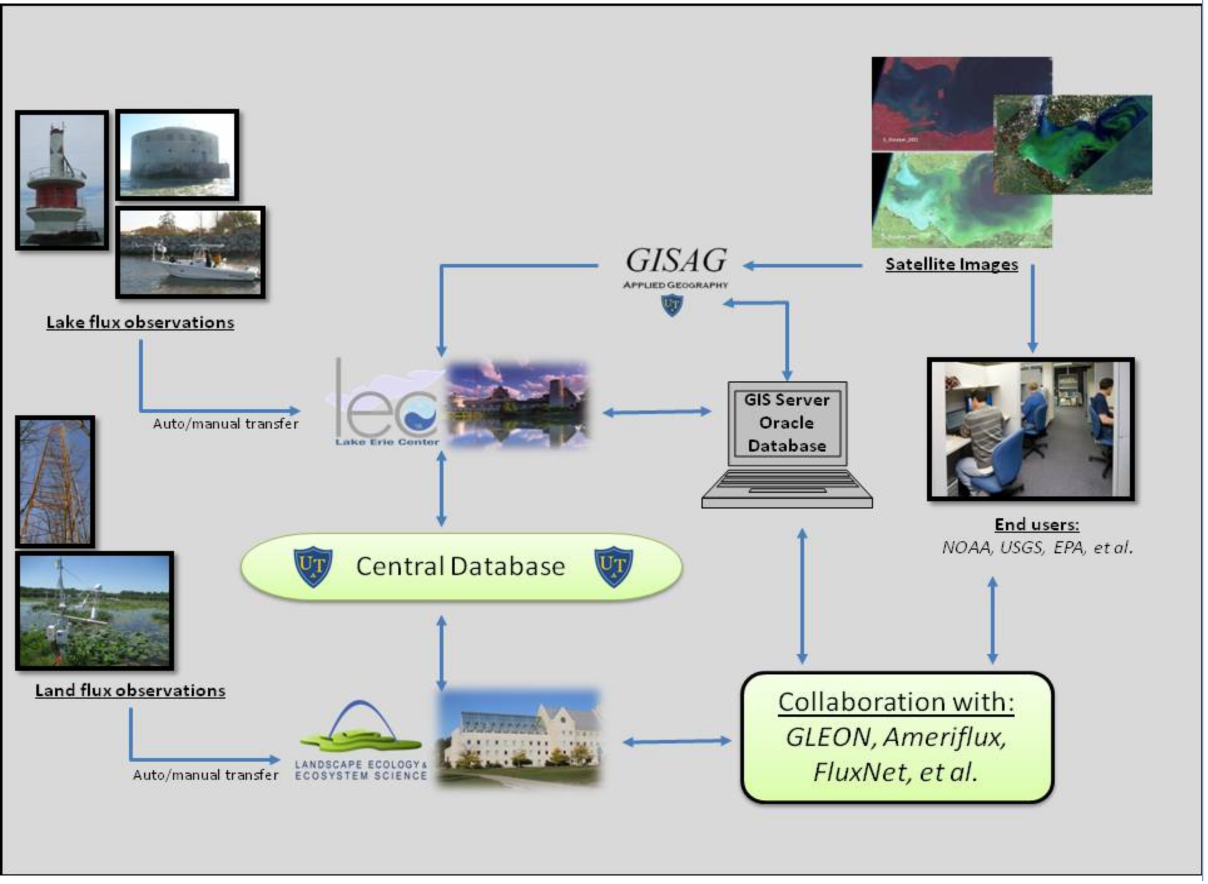


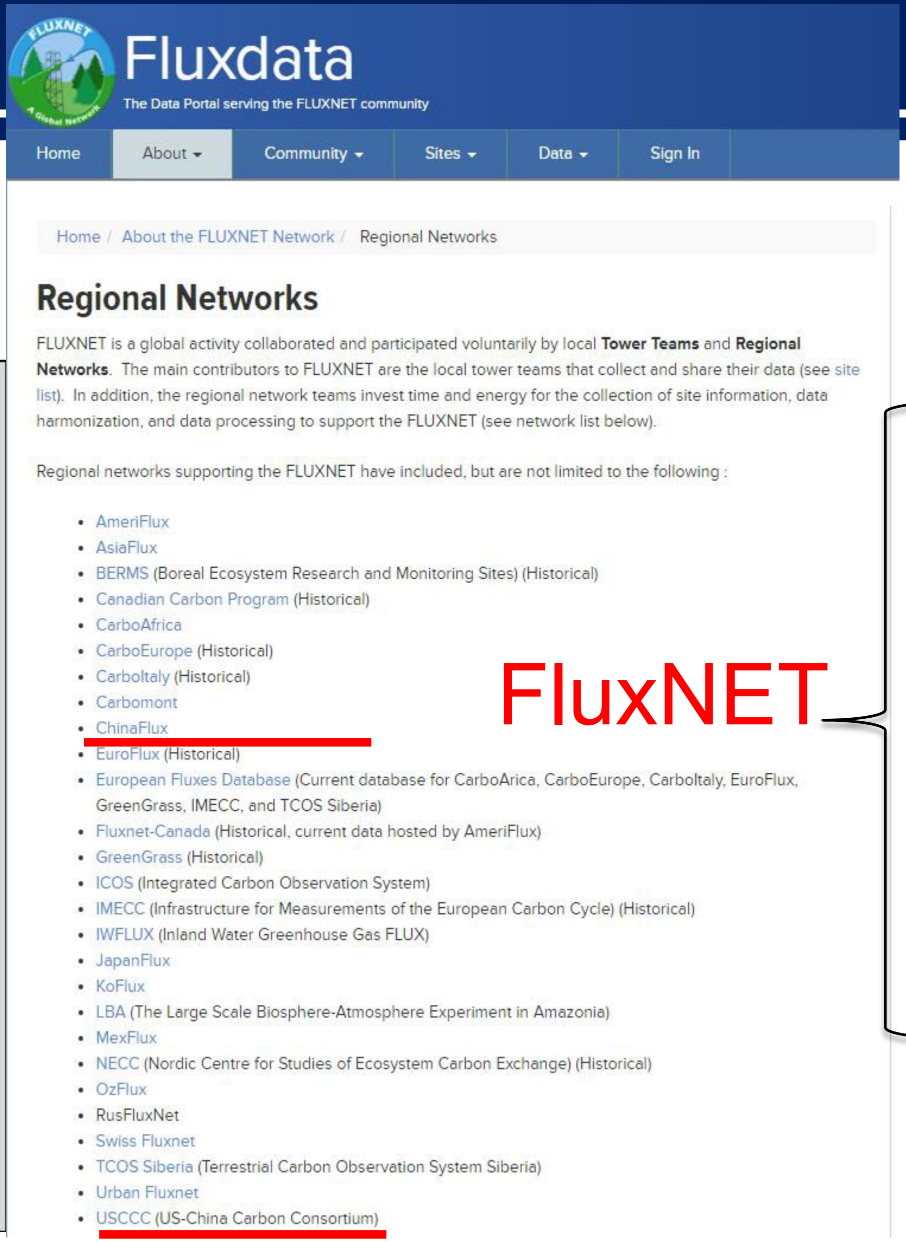


通量观测网络

The Framework





Fluxdata

The Data Portal serving the FLUXNET community

Home | About | Community | Sites | Data | Sign In

Home / About the FLUXNET Network / Regional Networks

Regional Networks

FLUXNET is a global activity collaborated and participated voluntarily by local **Tower Teams** and **Regional Networks**. The main contributors to FLUXNET are the local tower teams that collect and share their data (see site list). In addition, the regional network teams invest time and energy for the collection of site information, data harmonization, and data processing to support the FLUXNET (see network list below).

Regional networks supporting the FLUXNET have included, but are not limited to the following :

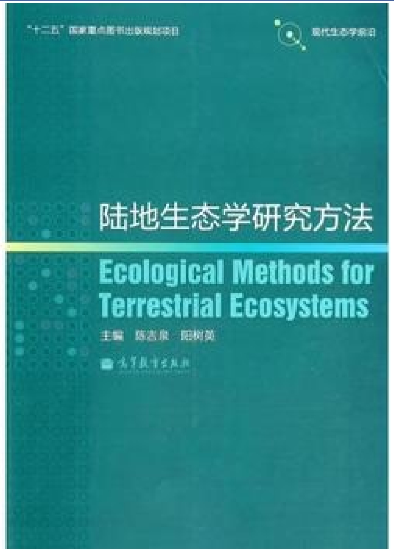
- AmeriFlux
- AsiaFlux
- BERMS (Boreal Ecosystem Research and Monitoring Sites) (Historical)
- Canadian Carbon Program (Historical)
- CarboAfrica
- CarboEurope (Historical)
- CarboItaly (Historical)
- Carbomont
- ChinaFlux
- EuroFlux (Historical)
- European Fluxes Database (Current database for CarboArica, CarboEurope, CarboItaly, EuroFlux, GreenGrass, IMECC, and TCOS Siberia)
- Fluxnet-Canada (Historical, current data hosted by AmeriFlux)
- GreenGrass (Historical)
- ICOS (Integrated Carbon Observation System)
- IMECC (Infrastructure for Measurements of the European Carbon Cycle) (Historical)
- IWFLUX (Inland Water Greenhouse Gas FLUX)
- JapanFlux
- KoFlux
- LBA (The Large Scale Biosphere-Atmosphere Experiment in Amazonia)
- MexFlux
- NECC (Nordic Centre for Studies of Ecosystem Carbon Exchange) (Historical)
- OzFlux
- RusFluxNet
- Swiss Fluxnet
- TCOS Siberia (Terrestrial Carbon Observation System Siberia)
- Urban Fluxnet
- USCCC (US-China Carbon Consortium)

FluxNET

- AsiaFlux
- AmeriFlux
- CarboEurope
- ChinaFlux
- USCCC

常用通量数据处理方法及运算过程

软件	TK2	Alteddy	ECPack	Eddysoft	EdiRE	eth-flux	TUDD	EC_Processor
仪器	CSAT3,USA-1,HS,R2,R3,ATI-K,NUW,Young;6262,7000,7500,KH2O,ADC OP-2	R2,R3,WMPro,CSAT3,USA-1;6262,7500,KH2O	R2,R3,CSAT3,KDTR90/TR61,7500,KH2O,Lyman-a	R2,R3,Young;6262,7000,7500,ADC OP-2	Any	R2,R3,HS;6262,7500,FM-100,MonitorLabs,Scintrex LMA3	R2,R3,HS,USA-1;6262,7000	R2,R3,CSAT3;6262,7000,7500
数据准备	剔异常值;块平均;时间延迟常数/自动校正	剔异常值;块平均;filter去趋势;时间延迟常数/自动校正	剔异常值；linear去趋势；时间延迟常数校正	剔异常值;块平均;去趋势;时间延迟常数/自动校正	剔异常值；filter/linear去趋势；块平均;时间延迟常数/自动校正	剔异常值；块平均；去趋势;时间延迟常数/自动校正	剔异常值；块平均；闭路时间延迟校正	剔异常值；块平均；去趋势;时间延迟常数/自动校正
坐标旋转	平面拟合/2轴转换	2轴转换	平面拟合/2轴/3轴转换	平面拟合/2轴/3轴转换	平面拟合/2轴/3轴转换	2轴/3轴转换	3轴转换	平面拟合 /2轴转换
Buoyancy	Schotanus et al(1983) Liu(2006)	Schotanus et al(1983)	Schotanus et al(1983)	Schotanus et al(1983) Liu et al(2006)	Schotanus et al(1983) Liu et al(2006)	-	Schotanus et al(1983) Liu et al(2006)	Schotanus et al(1983) Liu et al(2006)
氧气校正	Tanner et al(1993)	Tanner et al(1993)	Tanner et al(1993)	-	-	-	-	
高频损失	Moore(1986)	Moore(1986)	Moore(1986)		Moore(1986)		Moore(1986)	
WPL校正	Webb et al(1980)	Webb et al(1980)	Webb et al(1980)	Webb et al(1980)	Webb et al(1980)	Webb et al(1980)	Webb et al(1980)	Webb et al(1980)
计算	λ(T); cp(cp,dry,q)	λ(T); cp=cons	λ(T); cp=cons	λ(T); cp=cons	λ(T); cp(cp,dry,q)	λ(T); cp=cons	λ(T); cp=cons	λ(T); cp=cons
质量控制	稳态测定,湍流特征	不确定因子	统计误差	稳态测定,湍流特征,风区鉴定	稳态测定,湍流特征,风区鉴定	稳态测定,湍流特征	夜间关键u*	稳态测定，湍流特征，u*



《陆地生态学研究方法》陈吉泉等，2014

邵长亮等译，2016

常用通量数据处理方法及运算过程

www.nature.com/scientificdata/

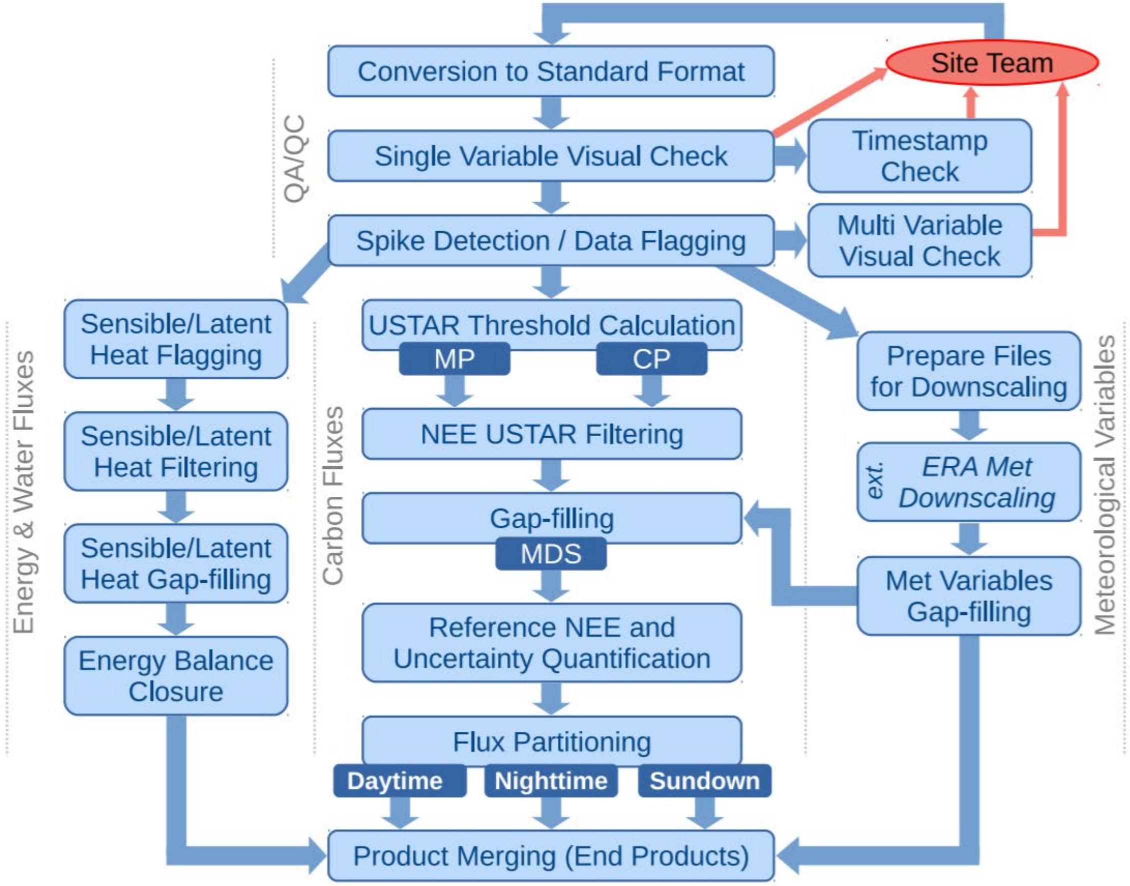


Fig. 2 The logic of the data processing steps for FLUXNET2015 (details about the different steps and meaning of abbreviations in the text).

Pastorello & 160 coauthors

The FLUXNET2015 dataset and the ONEFlux processing pipeline for eddy covariance data. Sci Data 7, 225 (2020). https://doi.org/10.1038/s41597-020-0534-3

2020年发表，已经被引用900次

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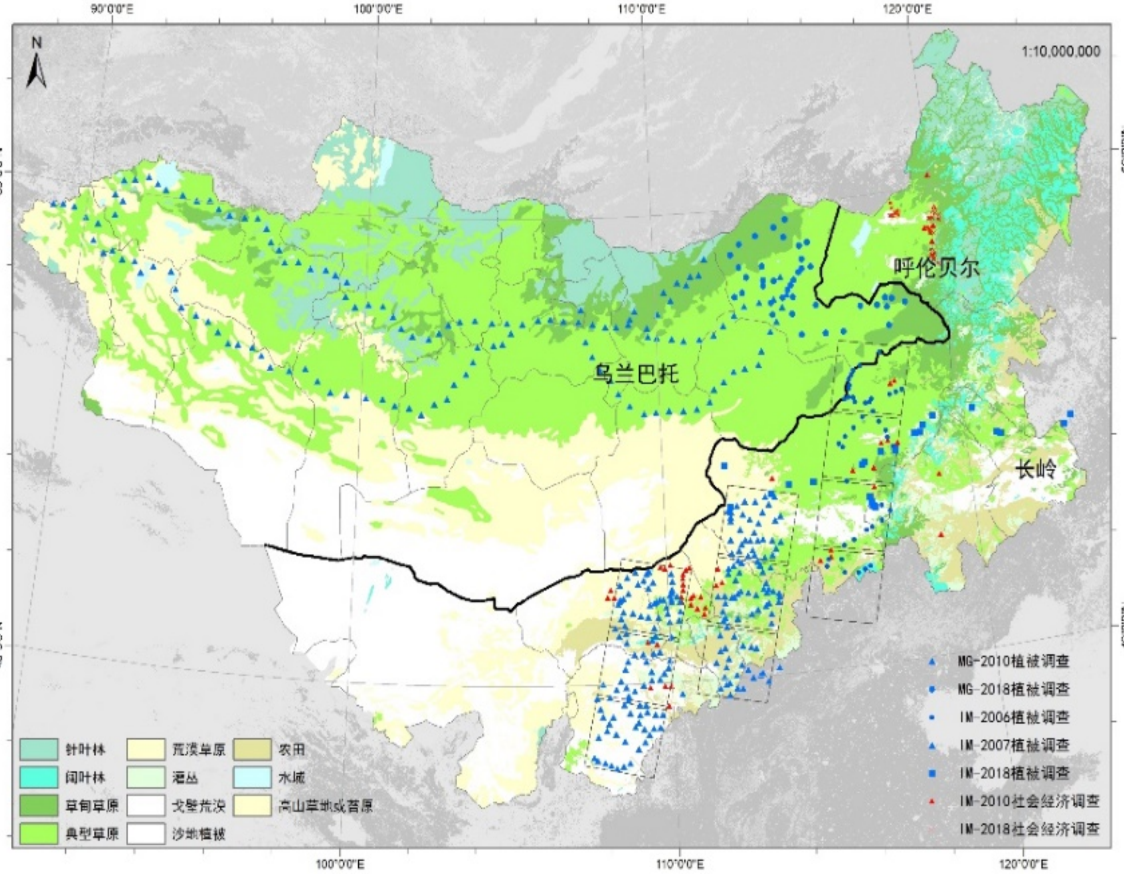
蒙古高原通量研究-总体思路

气候变化和人类活动对草原碳水和能量收支影响及其机理

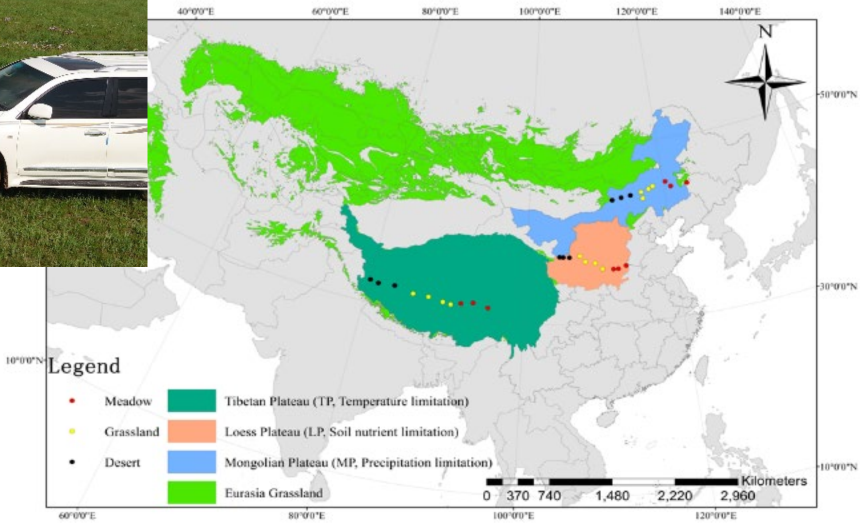


- 我国生态安全屏障
- 研究“热点”区域

3期NASA项目

领队样带实验10次

赴蒙古国实验7次

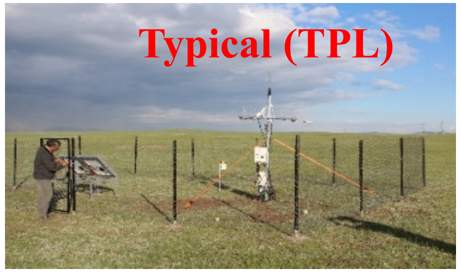


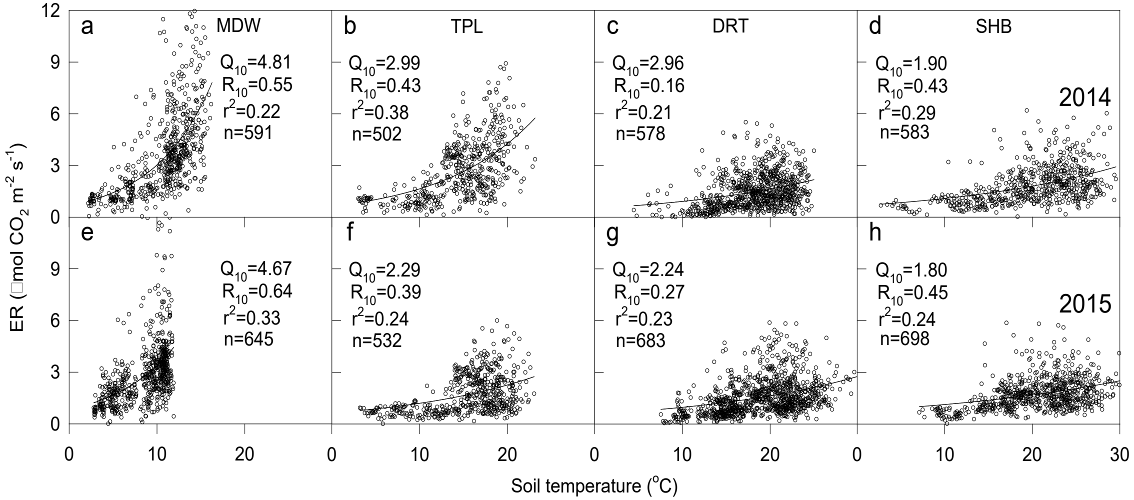
1. 碳收支-不同草地类型

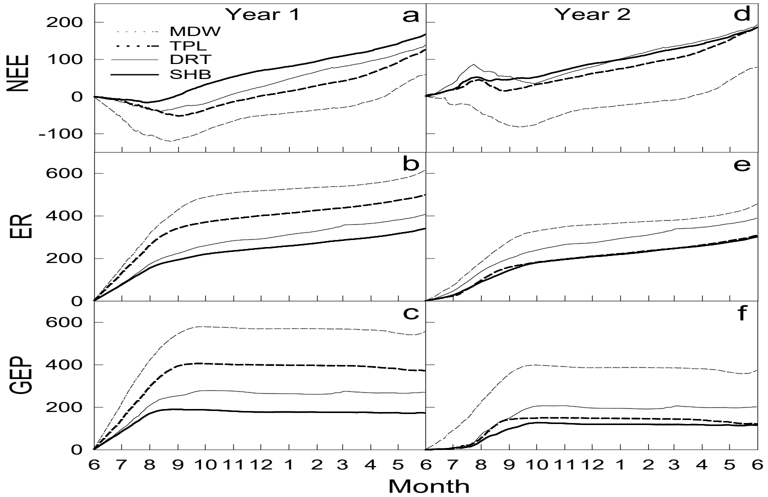
定量了不同草原代表性类型生态系统碳收支

- 草甸草原退化为灌木CO_2释放量可增加高达2.6倍
- 草甸、典型、荒漠草原和灌木年尺度均为碳释放分别为69, 157, 166和177g C m^{-2} yr^{-1}

(Shao et al, 2017, ER)



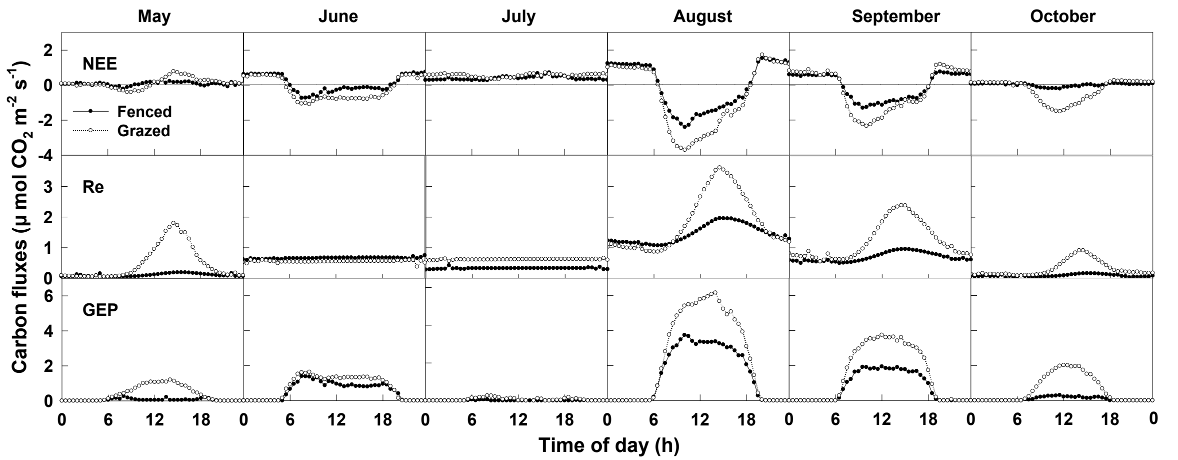


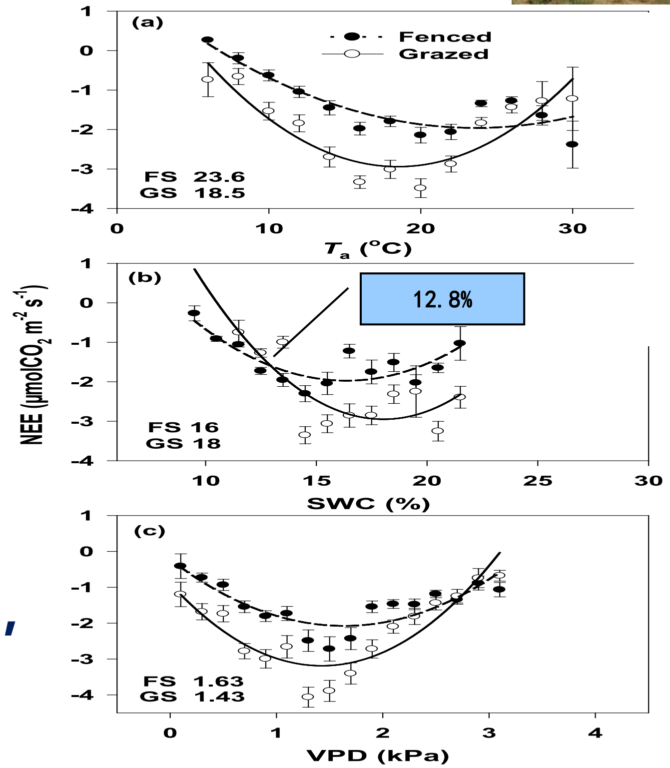


1. 碳收支-人类活动的影响

放牧影响

- 非干旱年份的放牧可增加碳吸收30g C m^{-2}
- 报道了关键生物物理调节阈值 (Shao et al, 2013ERL; 2017EA)





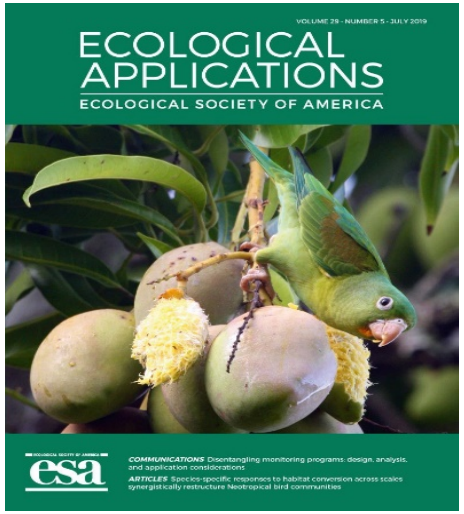
- ➢创新了通量研究的方法(PEC)
- ➢多位学者开展了类似研究（如： Zhang T. et al, 2015； Zhang L. et al，2015 ）

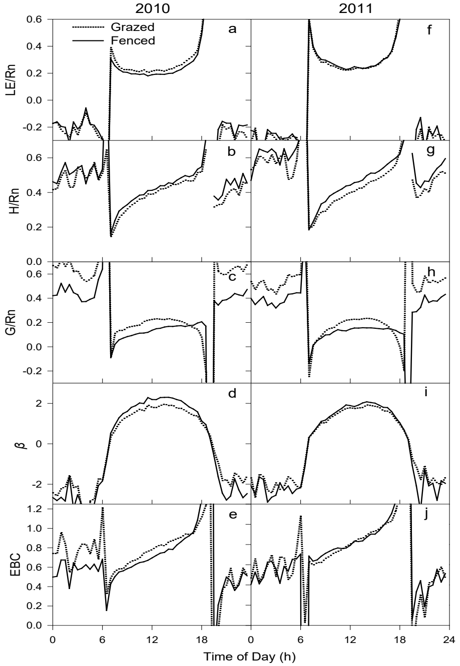
2. 水收支-人类活动的影响

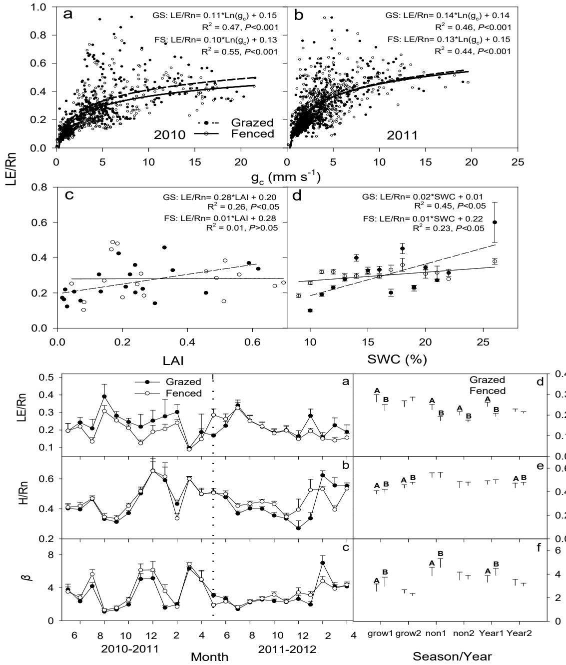
放牧影响草原水分散失机理

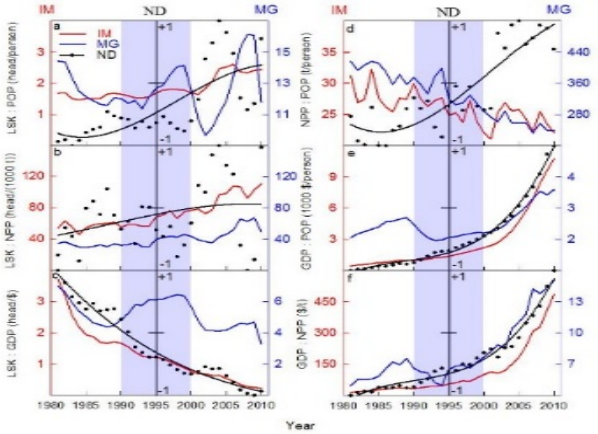
- 放牧增加非干旱年份草原水分散失
- 但减少干旱年份水分散失，原因为蒸腾减少

（Ecological Applications，Shao et al 2017）

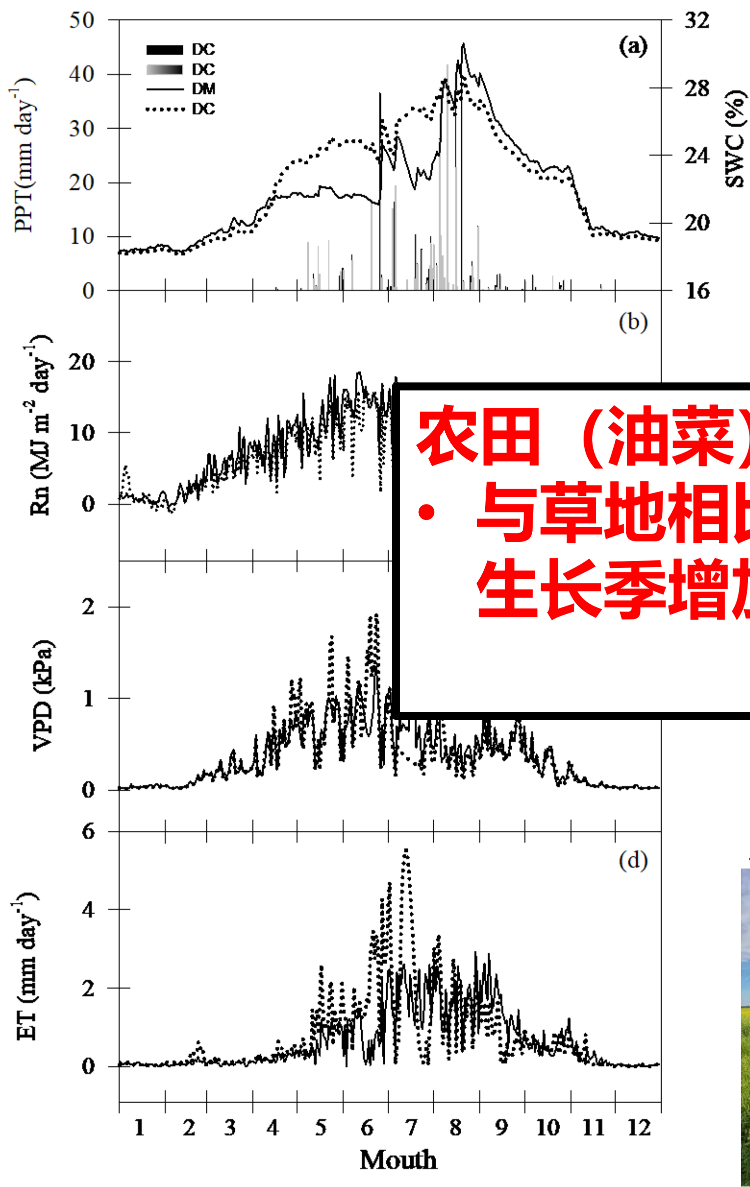


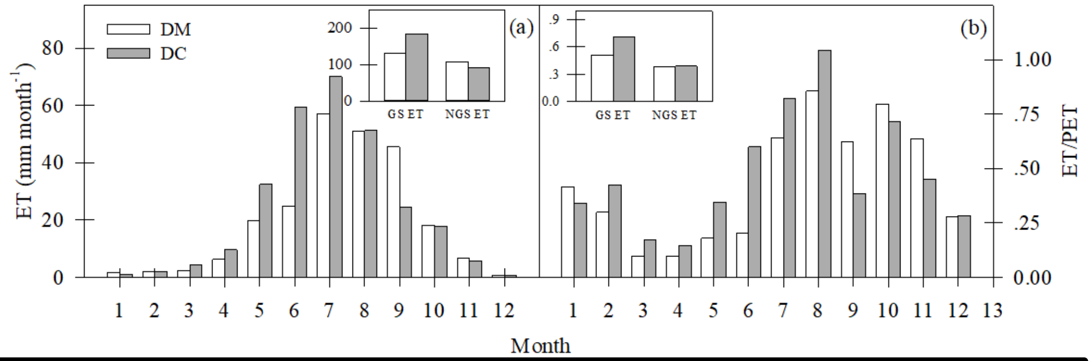






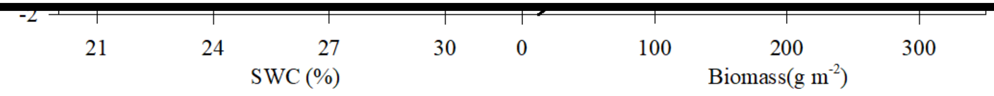
2. 水收支-开垦

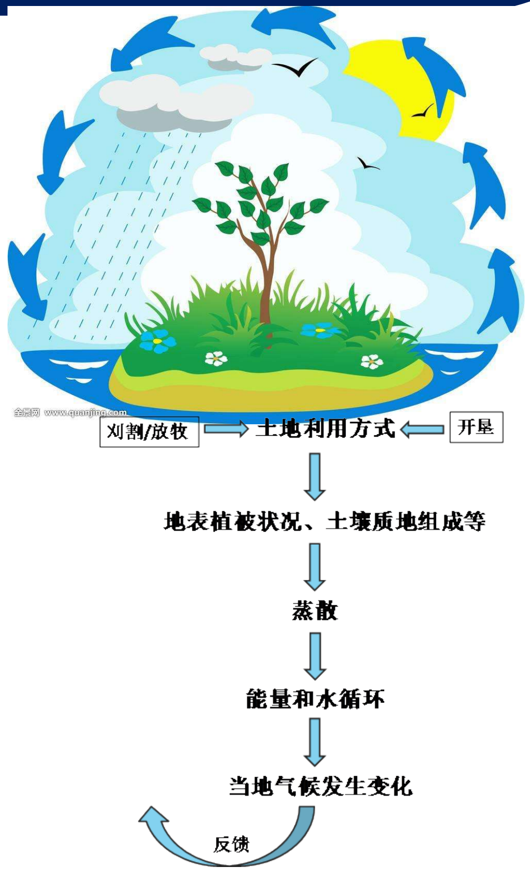




农田（油菜） & 草地

- 与草地相比，开垦后的农田蒸发散增加了16%，生长季增加了38%








Materials and Methods

Hulunbuir Inner Mongolia

Agro-pastoral region

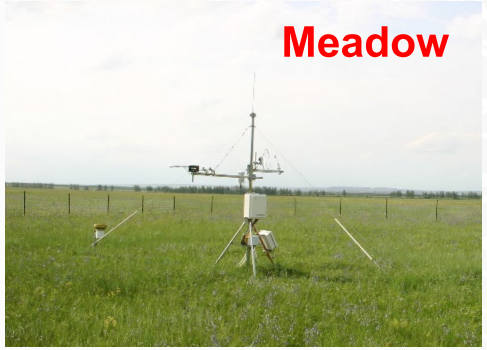
Total grassland area 11,266,700 ha

Total area of cultivated land 1,793,900 ha (2018 year)

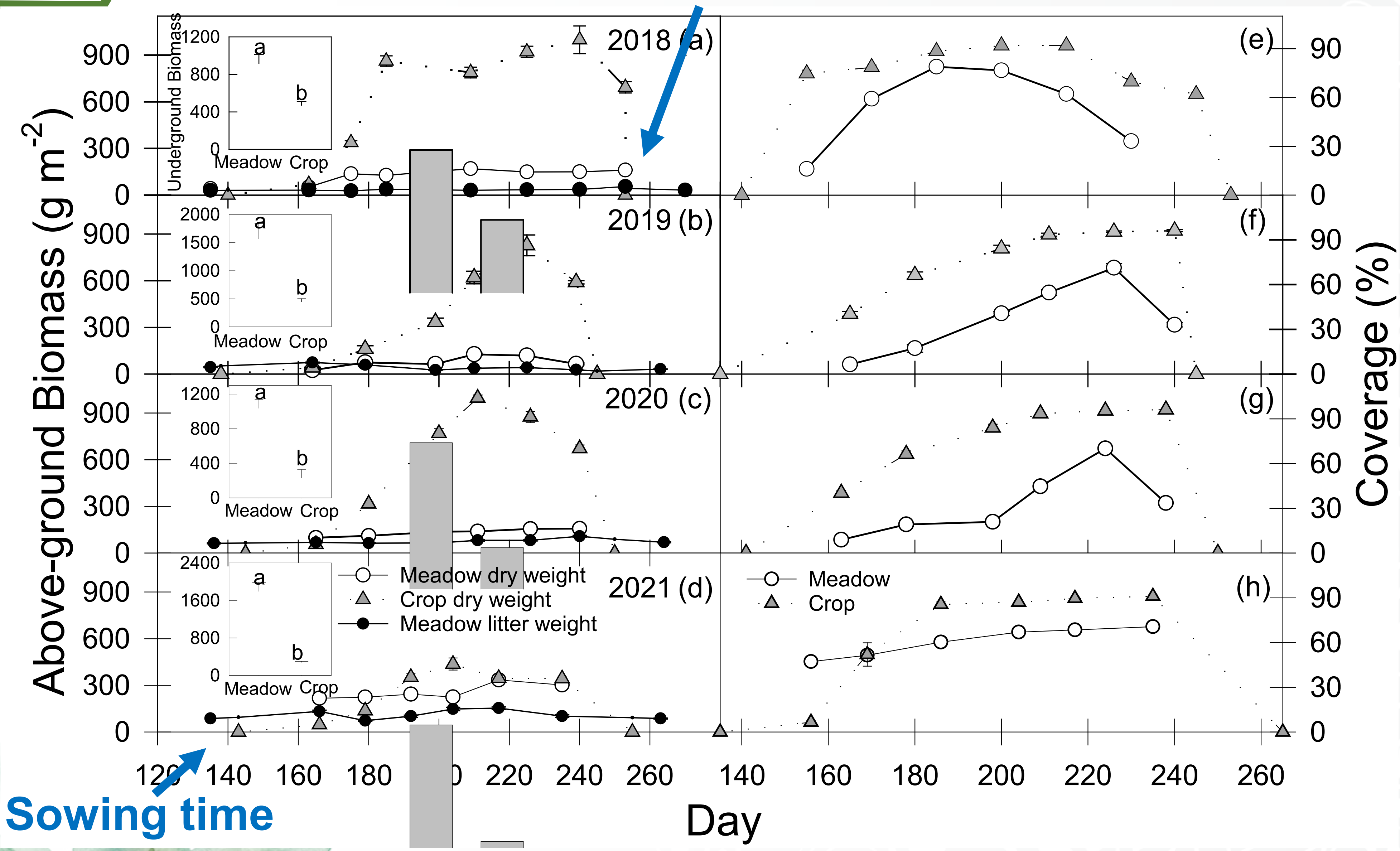
12-fold increase

150,800 ha (1949 year)

（Hulunbeier Yearbook 2018）



Biomass & Cover



Biomass:

Dry:

Crop>>Meadow

Under-ground Bio：

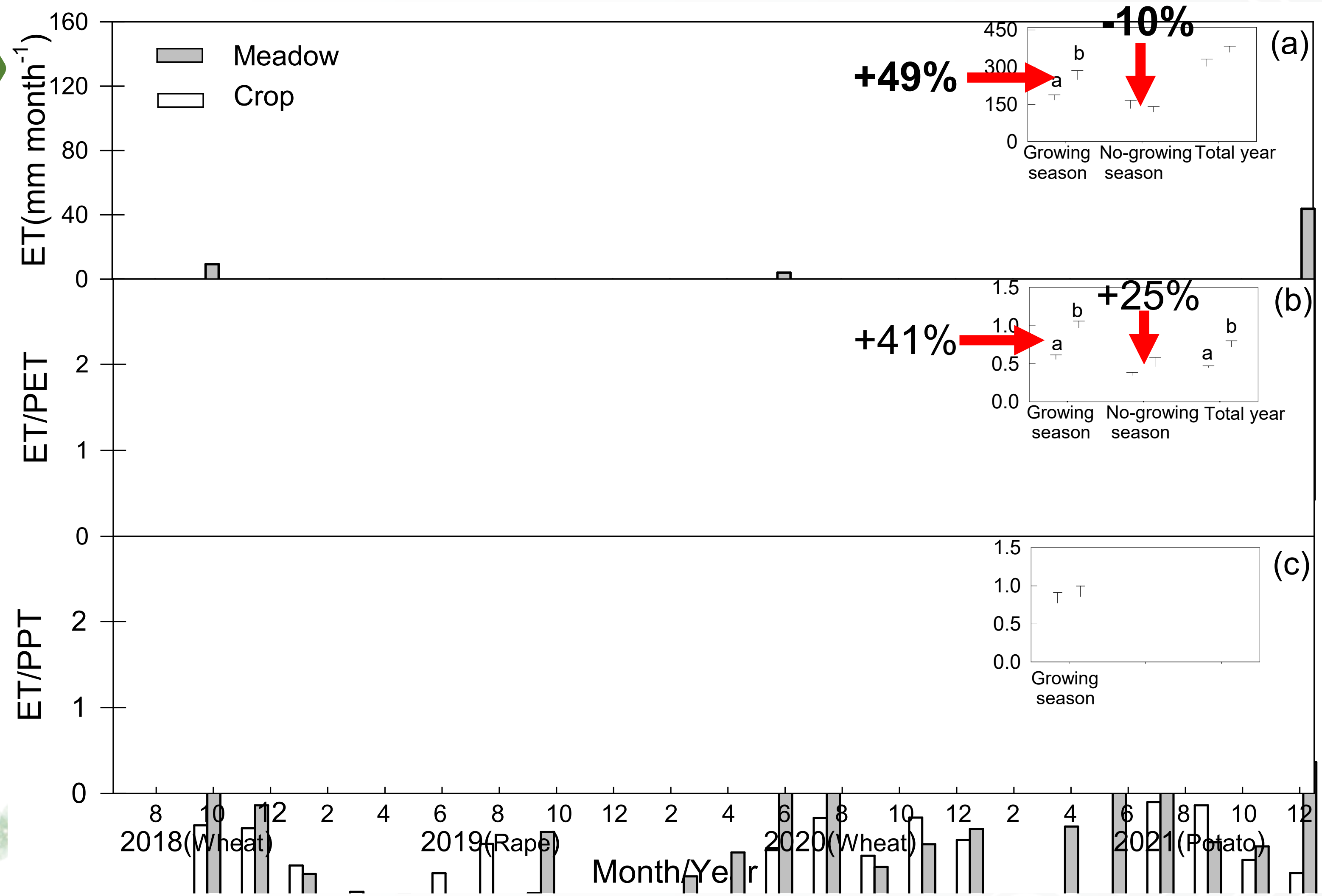
Meadow>>Crop

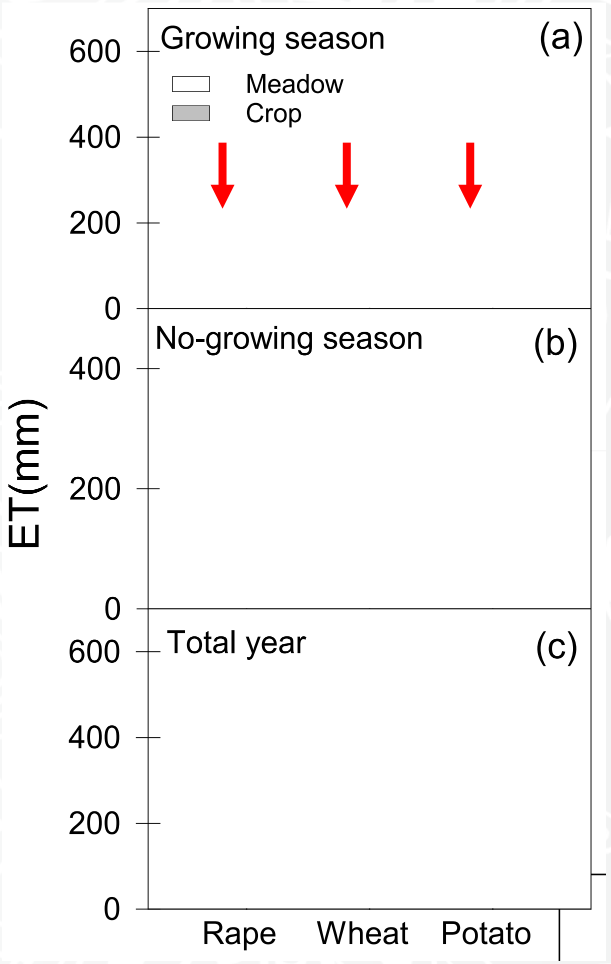
Meadow:

Non-growing season:

Covered

Seasonal changes in biomass and cover of grasses associated with farmland in Hulunbeier, Inner Mongolia, 2018-2020

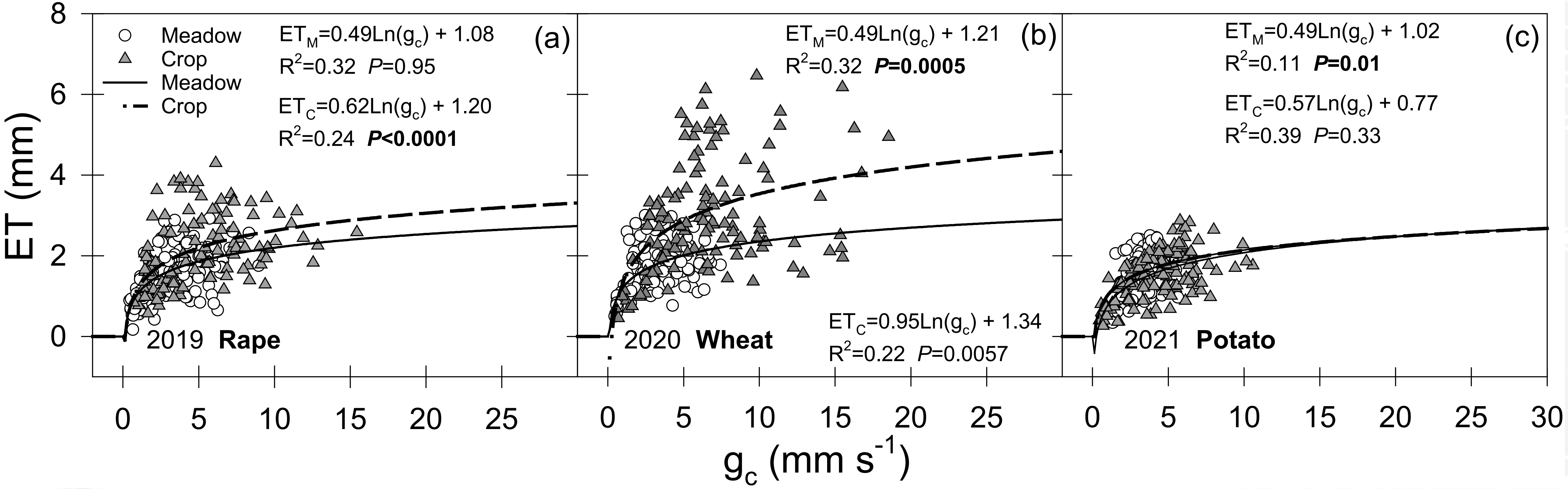




Peak ET: Crop, July **Meadow**, Changes based on climate impacts

ET/PET： water supply restrictions **Meadow** > **Crop** **ET/PPT：** **Crop**(72%) > **Meadow**(58%)

Crop(ET)： Wheat (343mm) > Rape(239mm) > Potato(169mm)



Canopy Surface Conductance (g_c) was significantly and exponentially correlated with ET

Crop(g_c) > Meadow(g_c)

Summaries

1. Annual ET for **Meadow** and **Crop** 303mm, 376mm, respectively.

   Growing season:168mm(**Meadow**), 250mm(**Crop**)

2. **Cropland** increased ET by 23% compared to **Meadow**

   Growing season: **+49%**

   No-growing season: **-10%**

3. **Different crops(ET):**

   Wheat(343mm) > Rape(239mm) > Potato(169mm) ≈ Grassland(168mm)

   推荐种土豆！！！

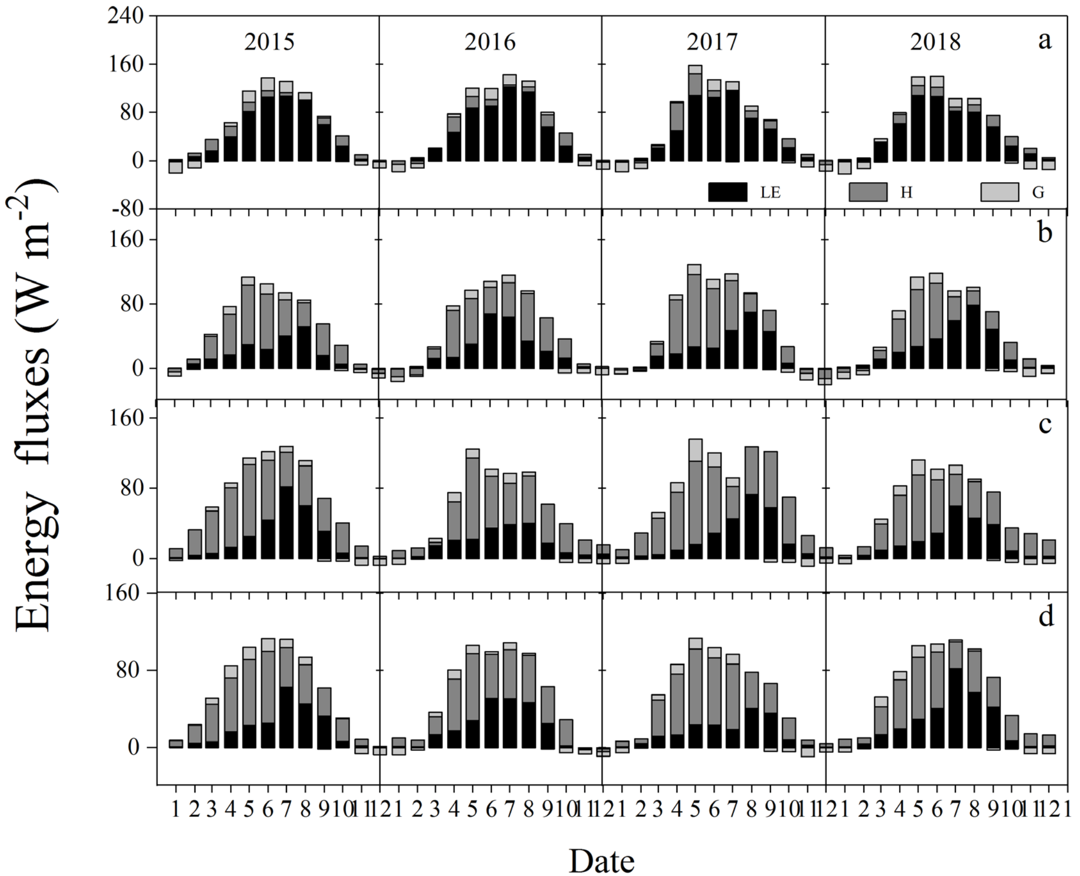
4. The main influencing factor between Cropland and Meadow is Rn and PPT.

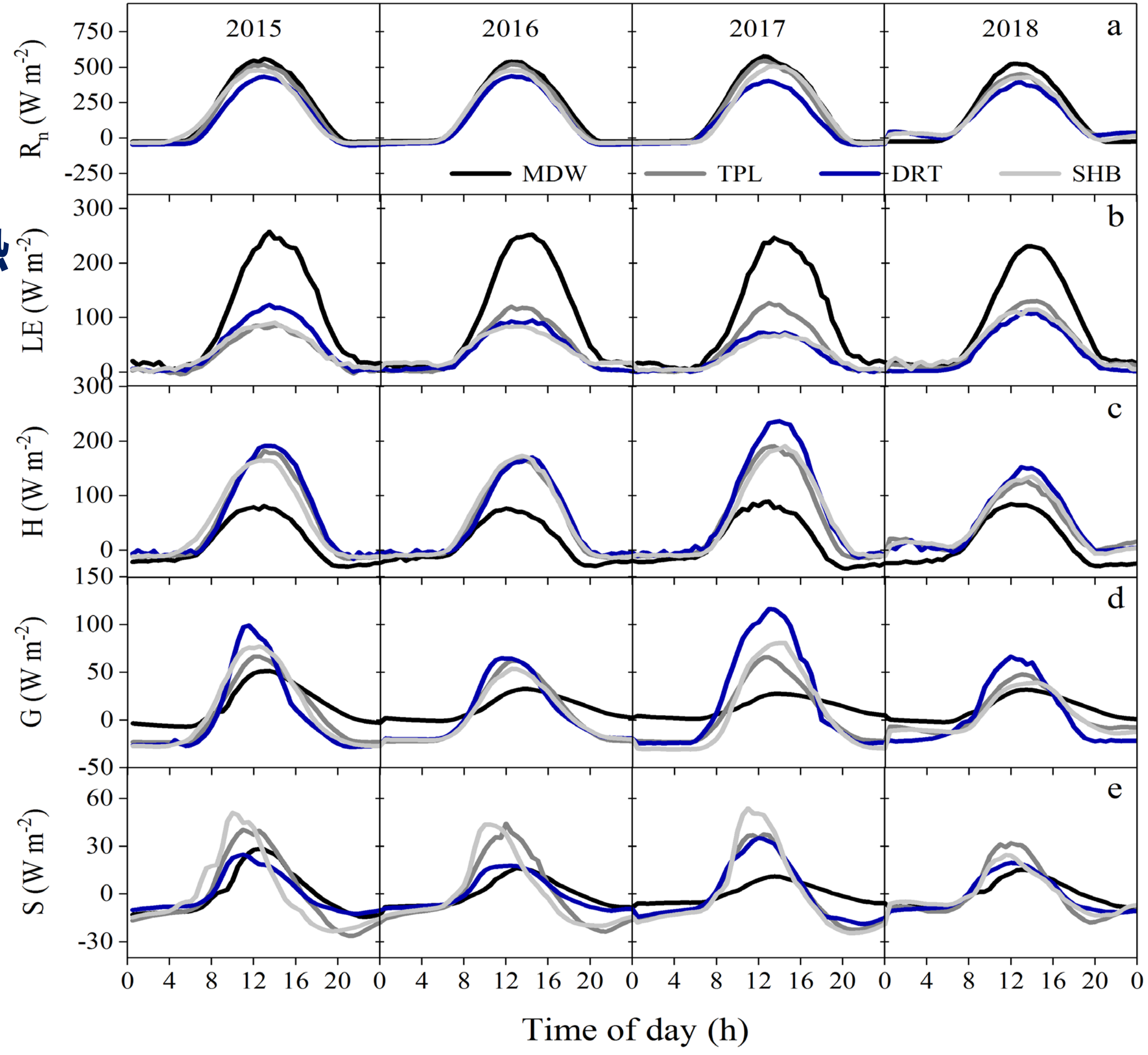
Dong&Shao et al，JEM二审

3. 能量收支

能量平衡与能量分配

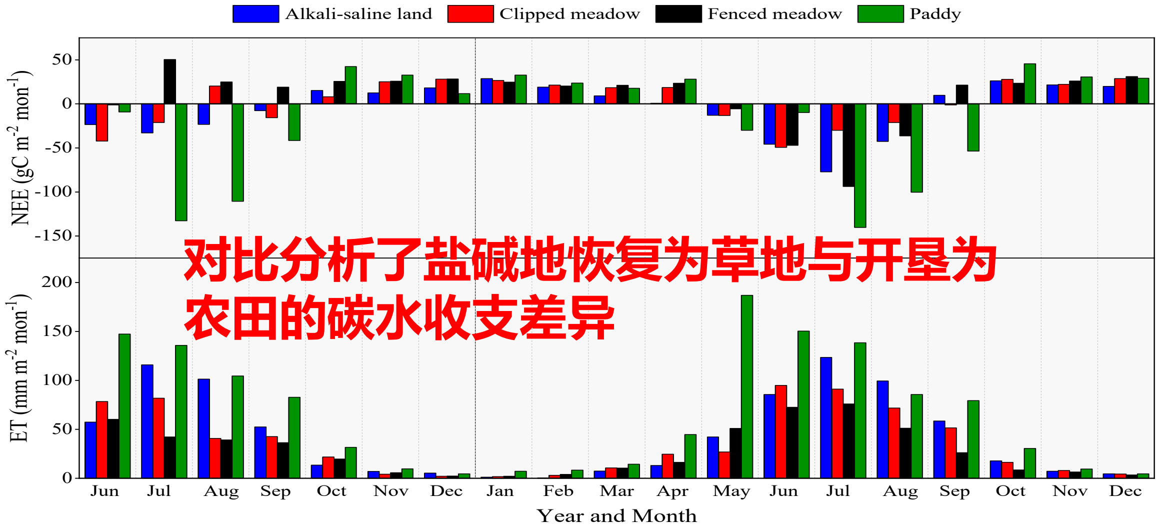
- 草原灌木化降低了总可用能量20%，放牧降低10%
- 草甸生长季初期水涝增加潜热，而高峰期则降低潜热



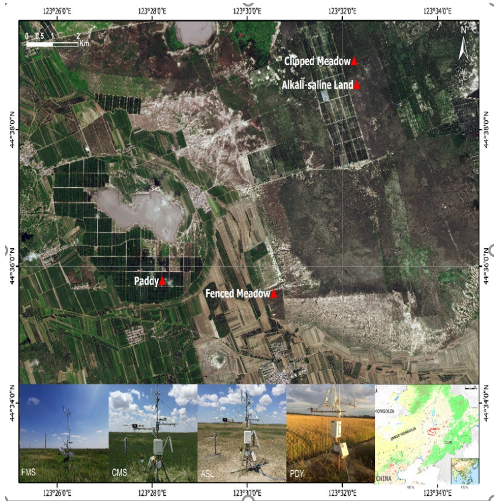


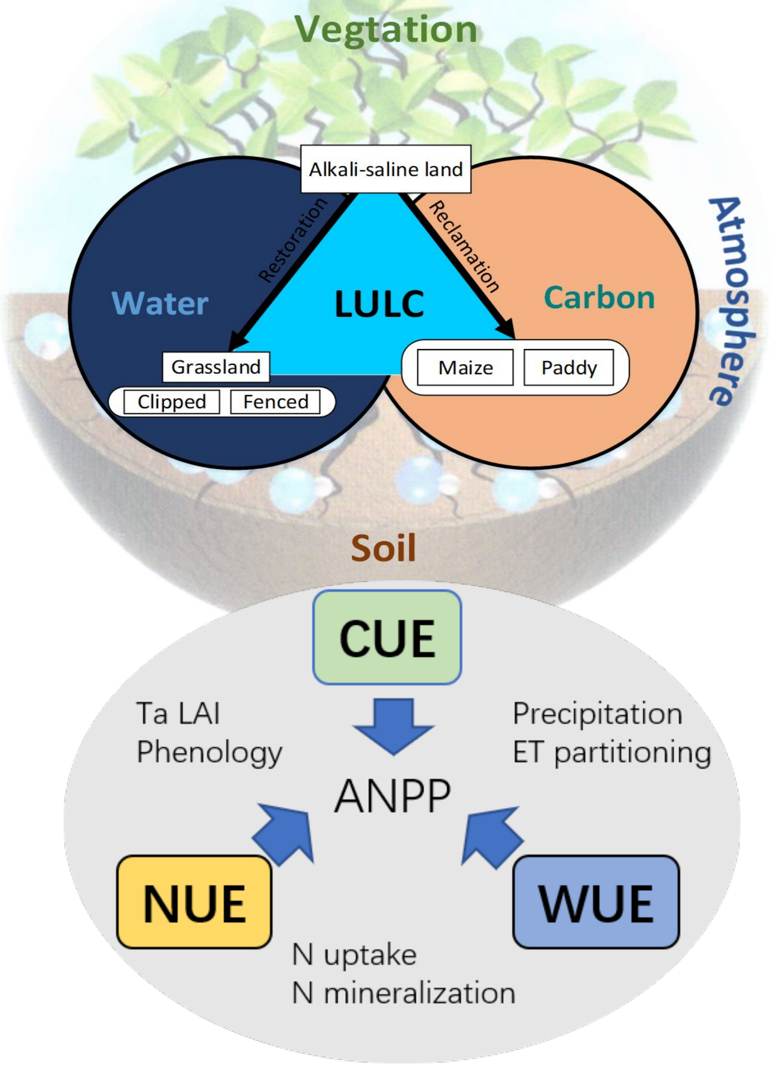
Chen&Shao et al, Ecological Processes, 2019

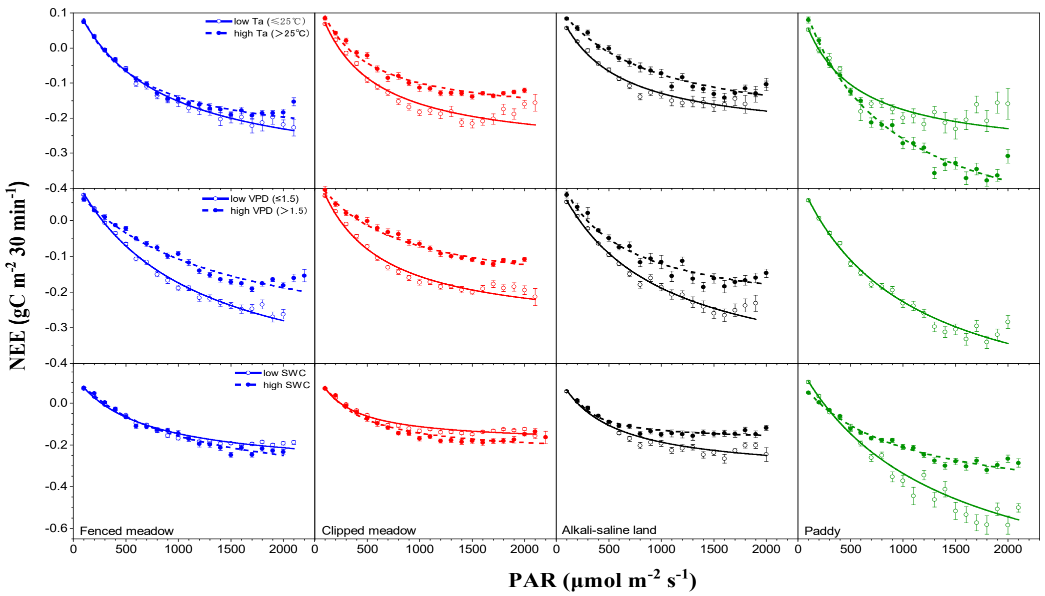
4. WUE-不同土地利用



对比分析了盐碱地恢复为草地与开垦为农田的碳水收支差异





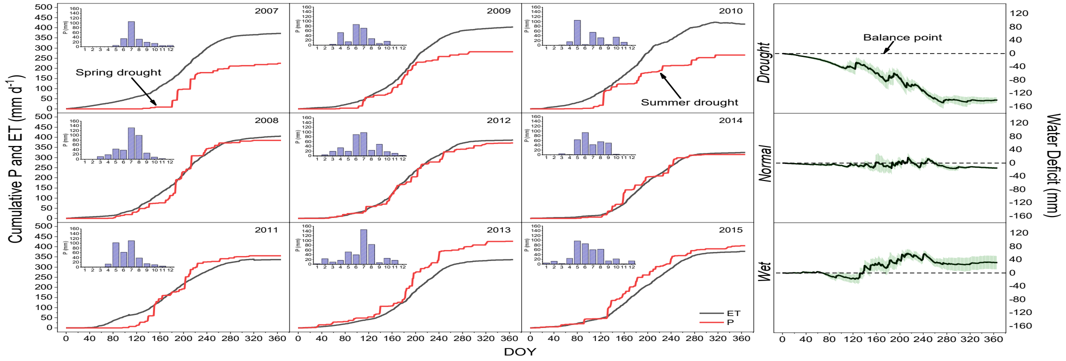


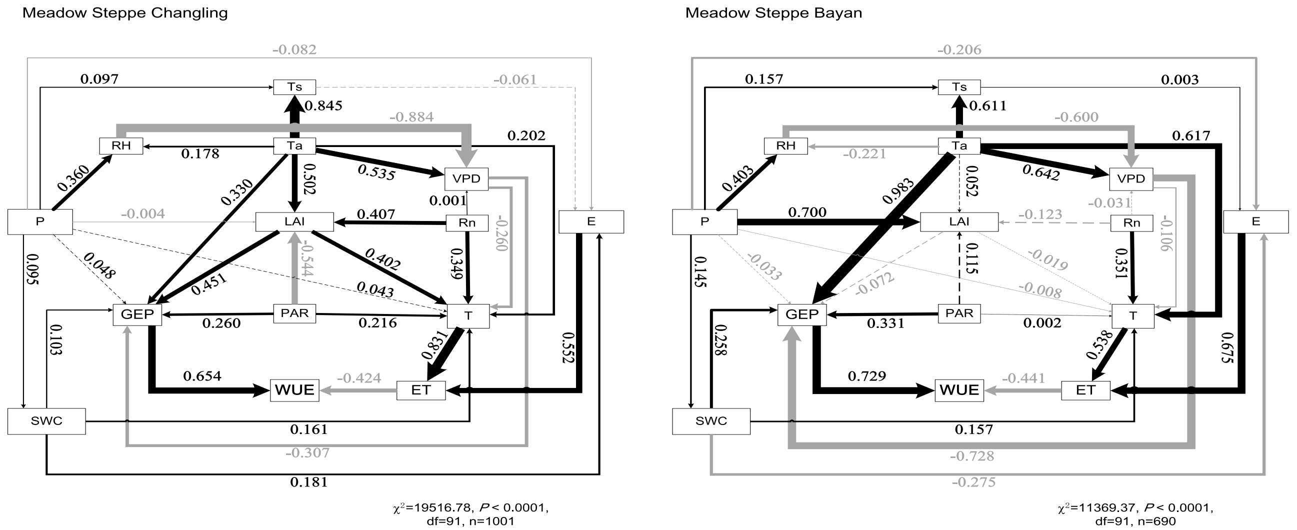
Site	Class	Pm	a	Rd
		Ta Level		
Fenced meadow	Low Ta	-0.5050	0.000672	0.1364
	High Ta	-0.4407	0.000909	0.1577
Clipped meadow	Low Ta	-0.4541	0.001020	0.1553
	High Ta	-0.3678	0.000984	0.1679
Alkali-saline land	Low Ta	-0.3787	0.000751	0.1227
	High Ta	-0.3737	0.000434	0.1256
Paddy	Low Ta	-0.4484	0.001090	0.1421
	High Ta	-0.7691	0.000982	0.1726
		VPD Level		
Fenced meadow	Low VPD	-0.6279	0.000587	0.1289
	High VPD	-0.4694	0.000351	0.0932
Clipped meadow	Low VPD	-0.4573	0.000907	0.1481
	High VPD	-0.3386	0.000454	0.1227
Alkali-saline land	Low VPD	-0.5734	0.000641	0.1138
	High VPD	-0.4079	0.000717	0.1391
Paddy	Low VPD	-0.7010	0.000699	0.1229
	High VPD	-	-	-
		SWC Level		
Fenced meadow	Low SWC	-0.4618	0.000743	0.1392
	High VWC	-0.5631	0.000616	0.1371
Clipped meadow	Low SWC	-0.3560	0.001270	0.1662
	High VWC	-0.4289	0.001300	0.1792
Alkali-saline land	Low SWC	-0.4916	0.001060	0.1497
	High VWC	-0.7363	0.010070	0.5564
Paddy	Low SWC	-1.2157	0.000931	0.1910
	High VWC	-0.6229	0.000694	0.1167

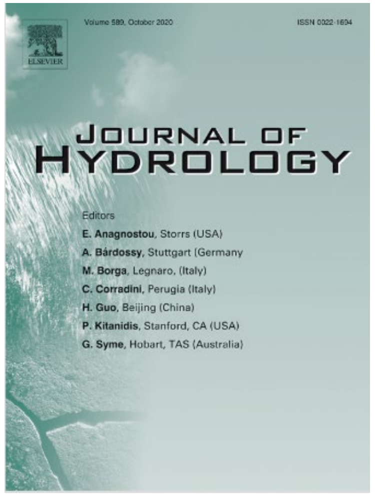
Dong&Shao et al, ERL, 2020

4. WUE-内外蒙古的比较

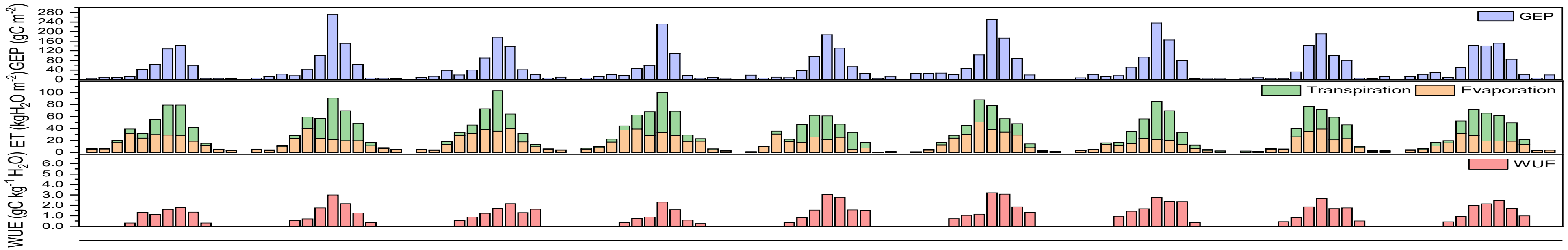
草甸草原水分平衡研究

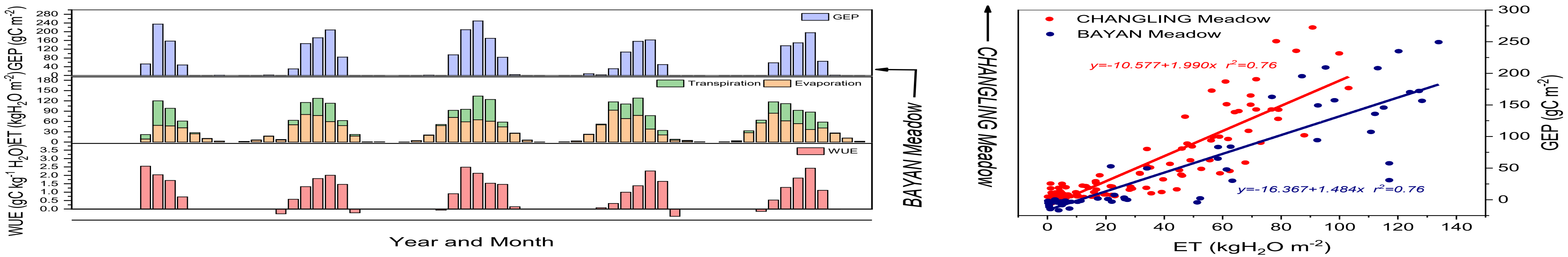






(Dong&Shao et al, 2021)





提　纲

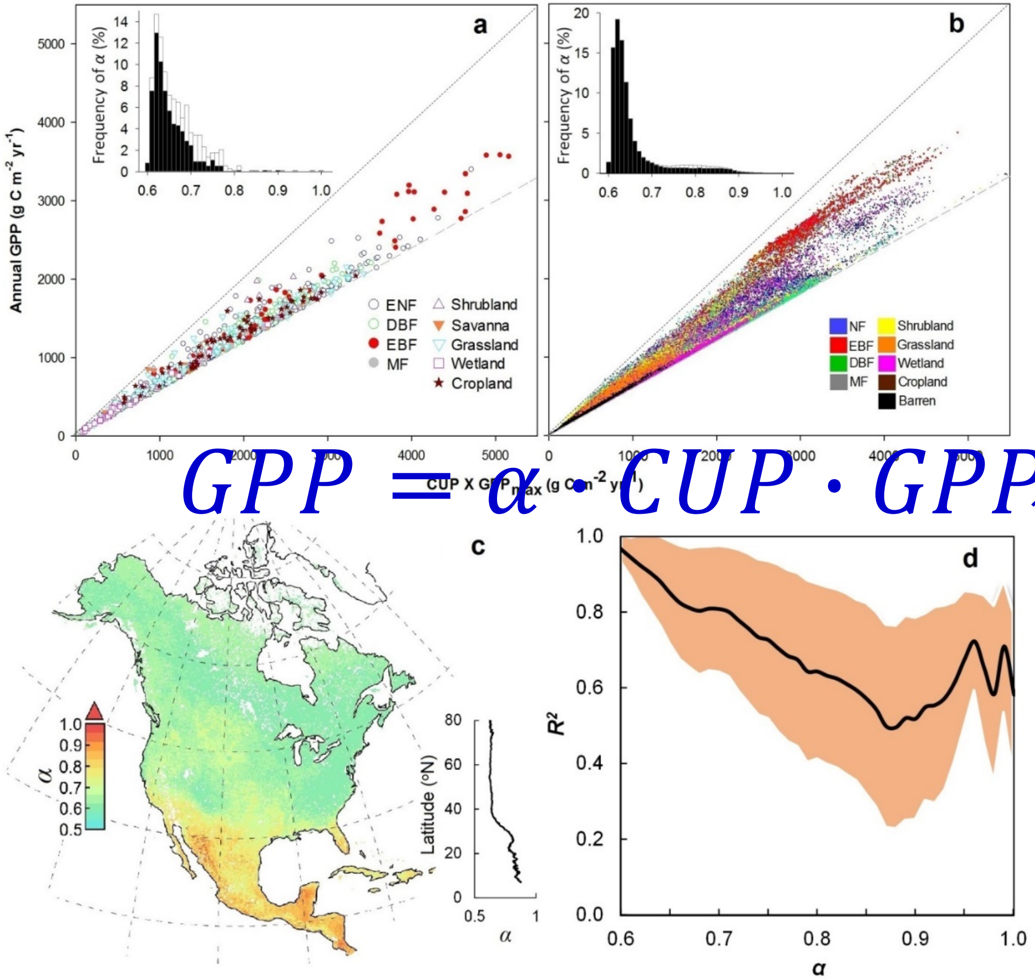
1 蒙古高原通量观测网

2 主要进展-通量

3 主要进展-通量塔群

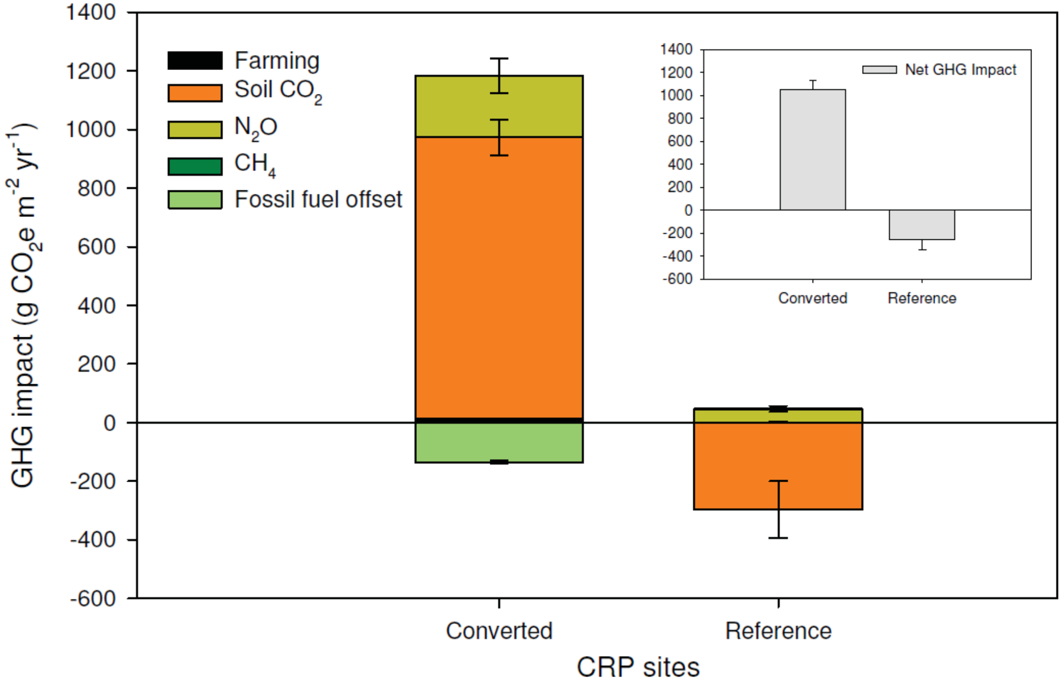
4 主要进展-极端气候

1. 单一站点较难发表高质量成果



$$GPP = \alpha \cdot CUP \cdot GPP_{max}$$

Xia et al. PNAS, 2015



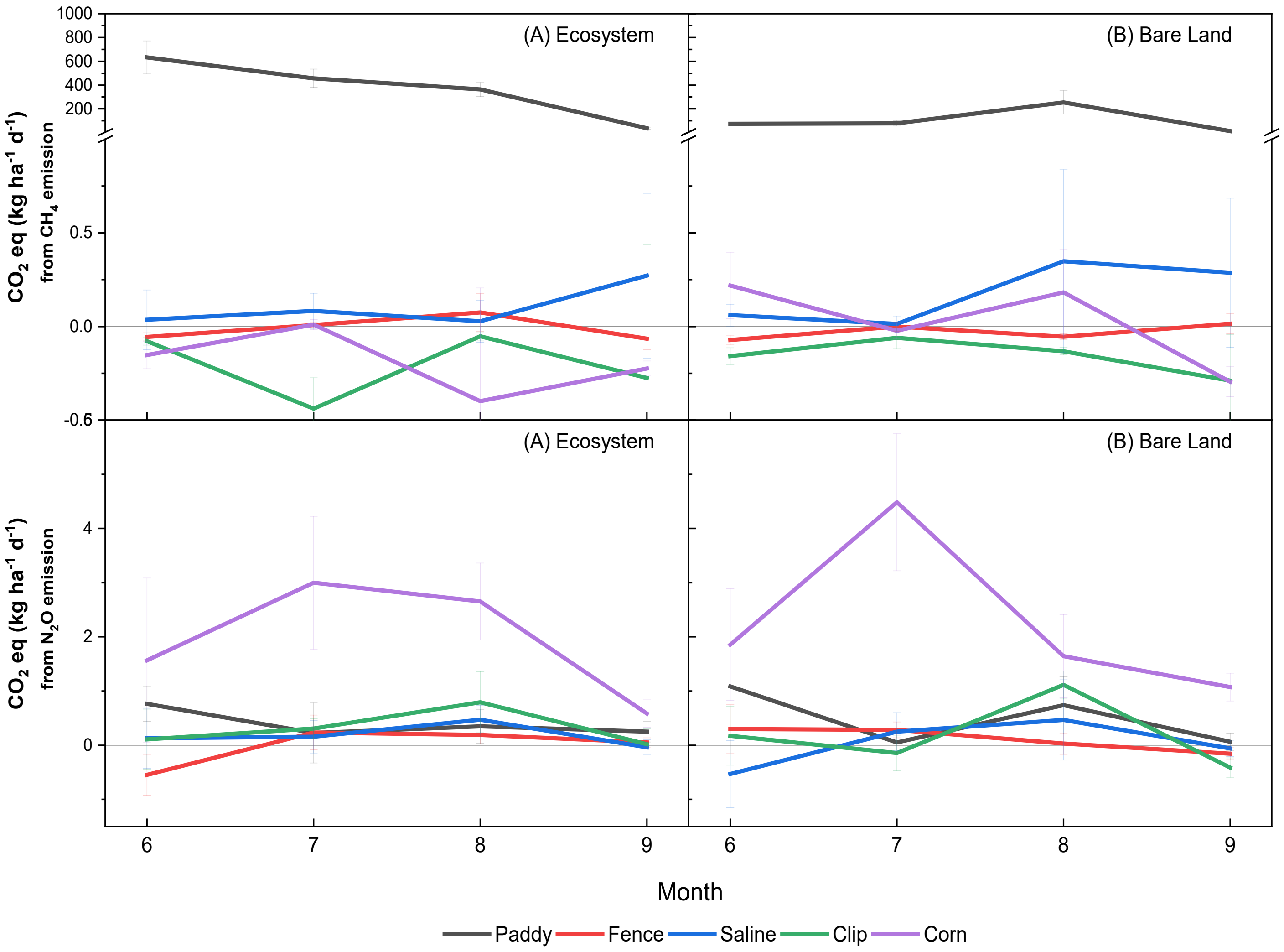
农田和草原间的碳债（Carbon debt）：

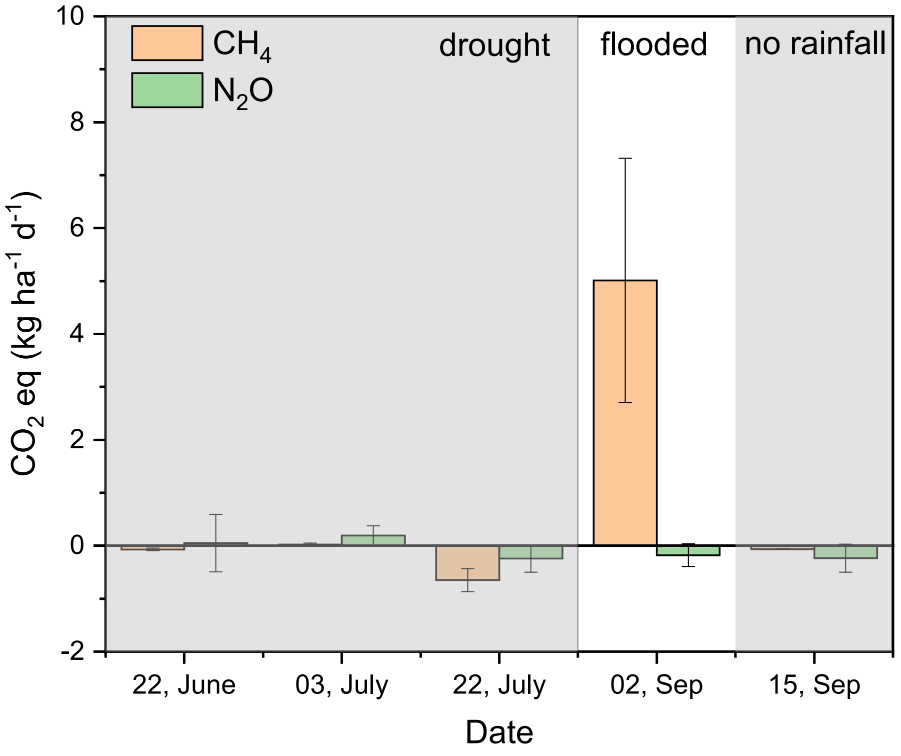
- 玉米免耕，需要76年来偿还
- 玉米耕种，需要172年
- 玉米-大豆轮作，需88年（免耕）或196（耕）年

(Ilya et al, 2011, *PNAS*)

GWP under LUCC——Example in Changling, Jilin, China.

Monthly Dynamics and increased GWP in flooded meadow

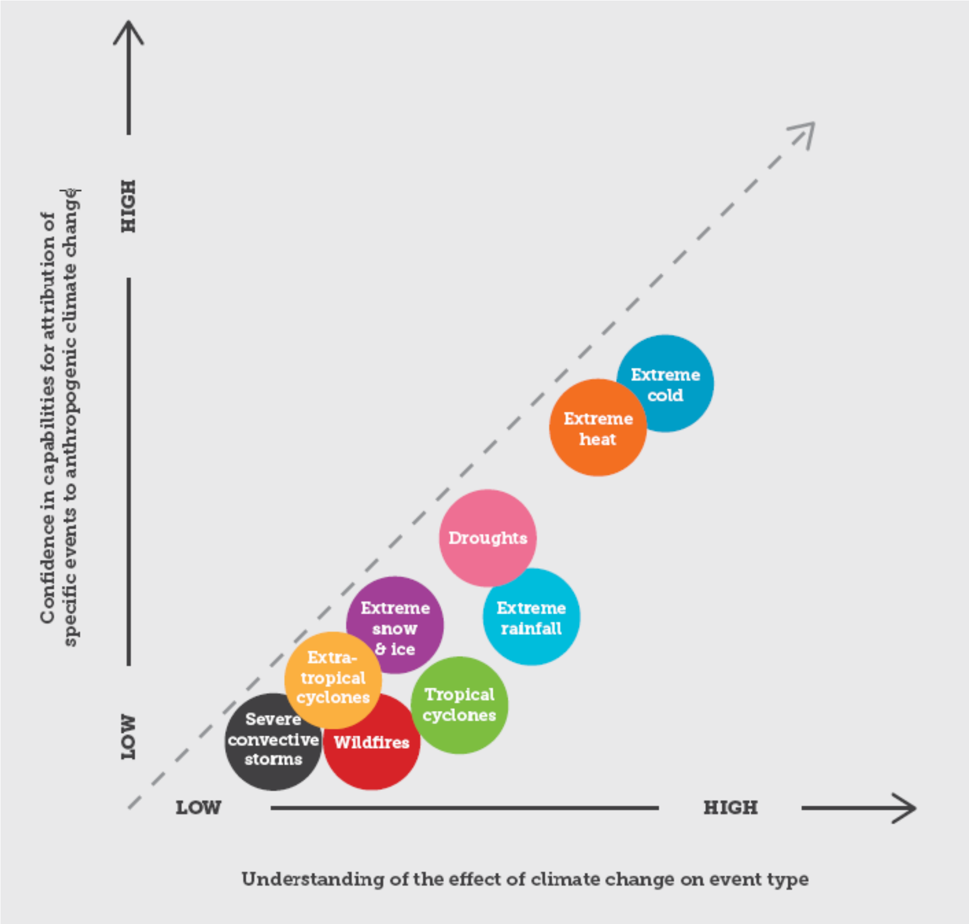


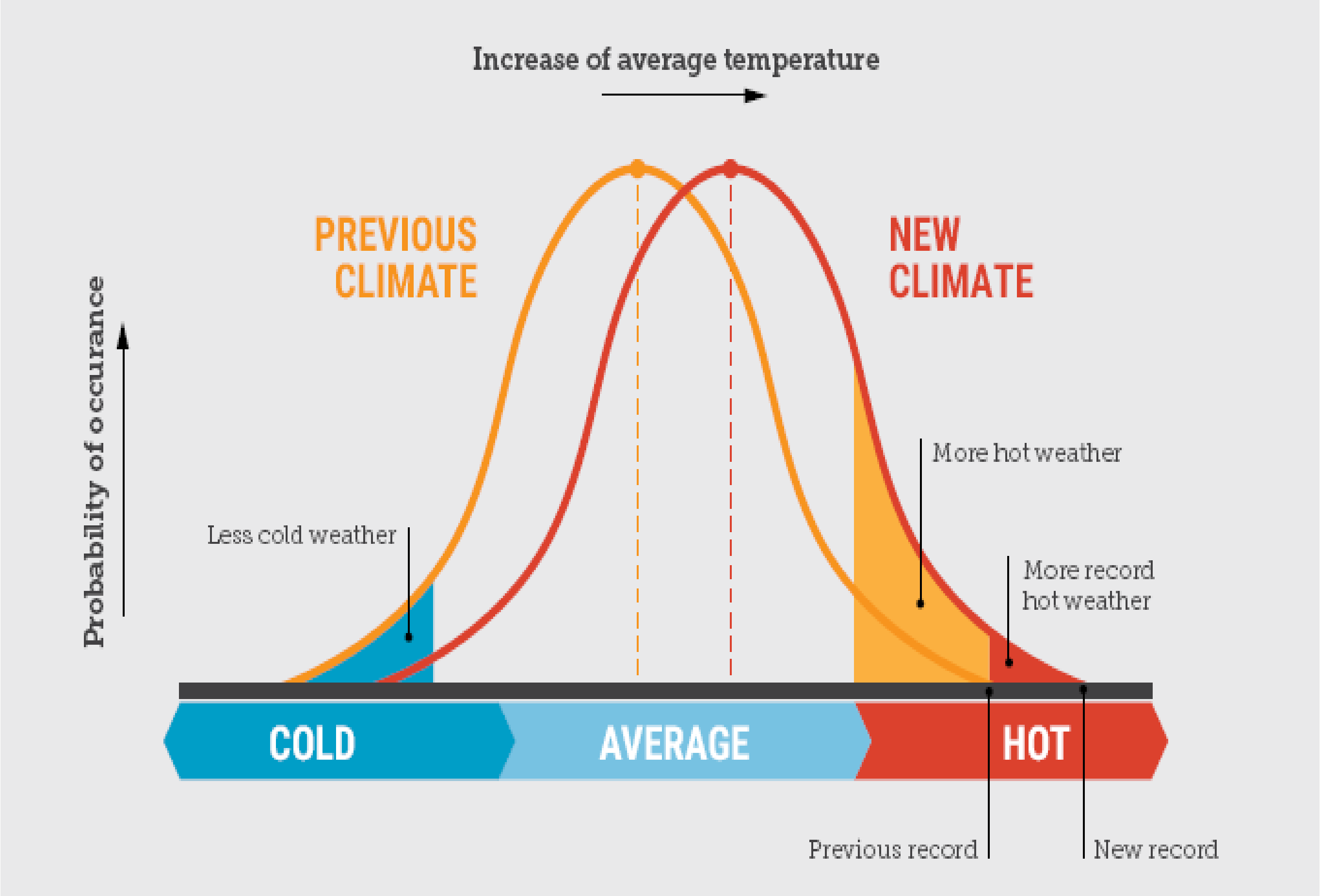


In August, 2022, clipped meadow stayed flooded because of continuous heavy rainfall events. Therefore, there was a sharp increase in GWP between pre-flooding and post-flooding periods due to the surge of CH_4 emission.

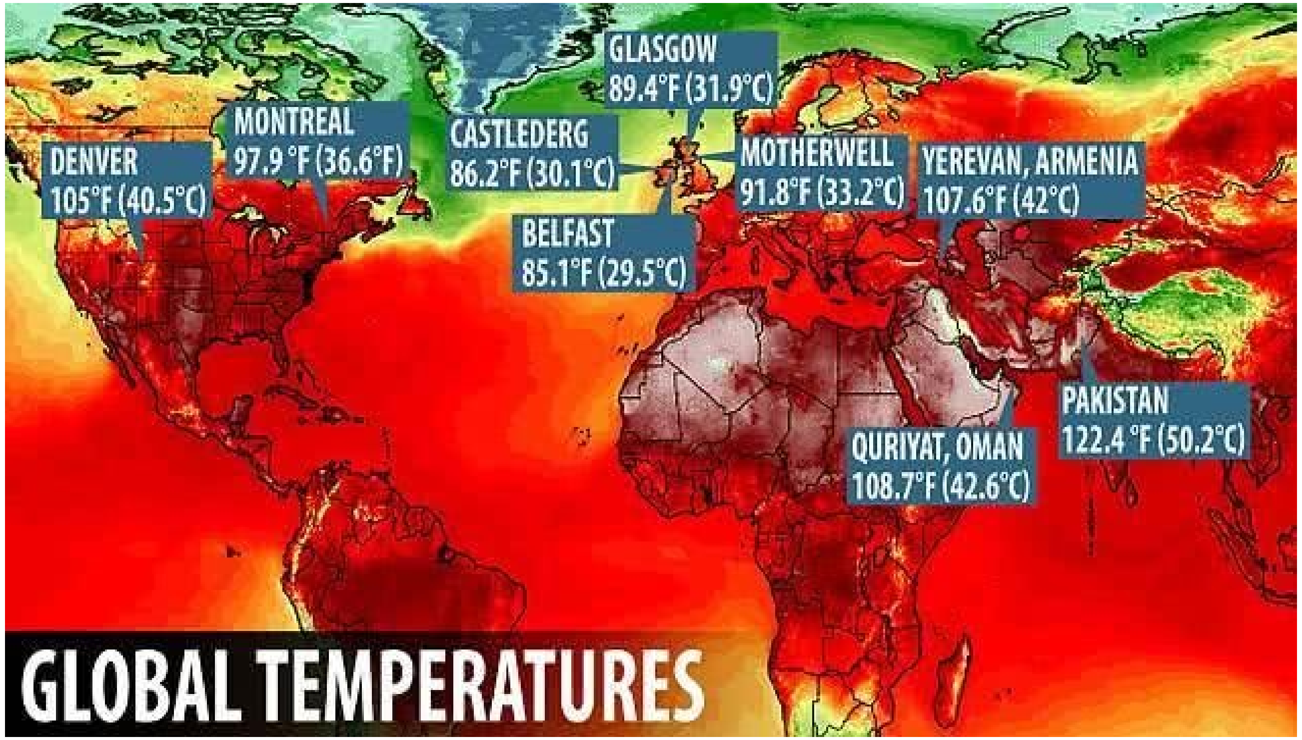
提　纲

More extreme weather events in the future





AU, C. O. (2017). Cranking up the intensity: climate change and extreme weather events

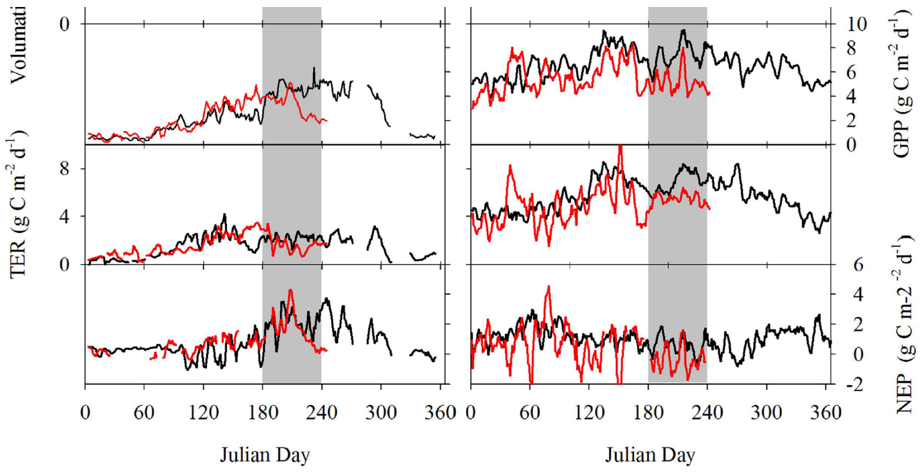


- Heat wave (HW) is a typical extreme weather event under the global warming
- The frequency and intensity of HWs increased significantly, affecting 73% of the global terrestrial area since the mid-20th century (IPCC, 2020)

HW effects on ecosystems

Severe summer heatwave and drought strongly reduced carbon uptake in Southern China

Wenping Yuan[1,2], Wenwen Cai[1], Yang Chen[1], Shuguang Liu[3], Wenjie Dong[1], Haicheng Zhang[1], Guirui Yu[4], Zhuoqi Chen[5], Honglin He[4], Weidong Guo[6], Dan Liu[1], Shaoming Liu[7], Wenhua Xiang[3], Zhenghui Xie[8], Zhonghui Zhao[3] & Guomo Zhou[9]



Qu & Shao et al.
Heat waves reduce ecosystem carbon sink strength in a Eurasian meadow steppe
Environmental research, 2016, 144: 39-48.

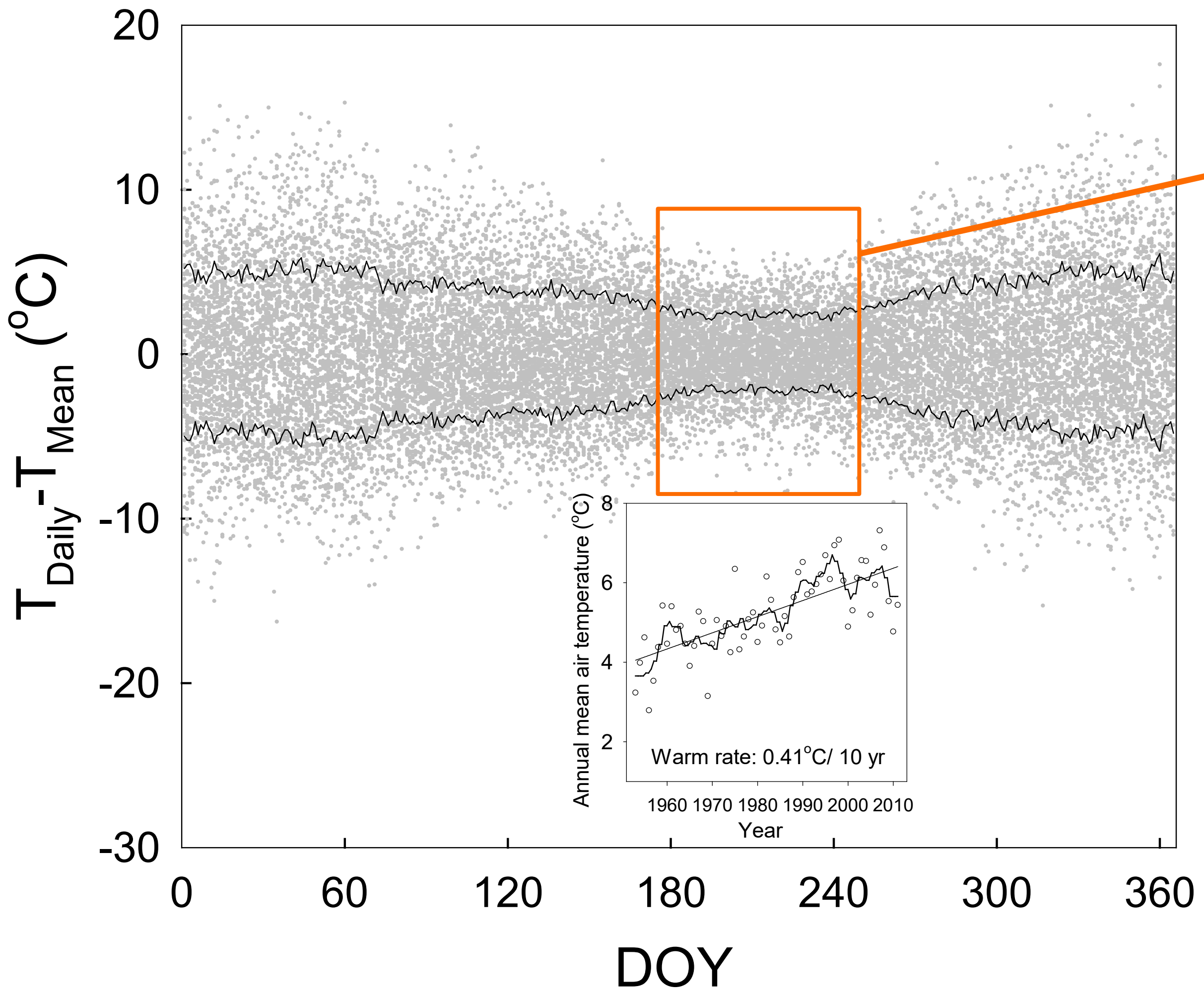
d 4 years

GPP reduced 30-53%

GPP reduced 50%

Analysis of natural HWs at a meadow based on the eddy covariance (EC) data

Pick up the HW events using 60-year temperature data



May-September
10% maximum temperature

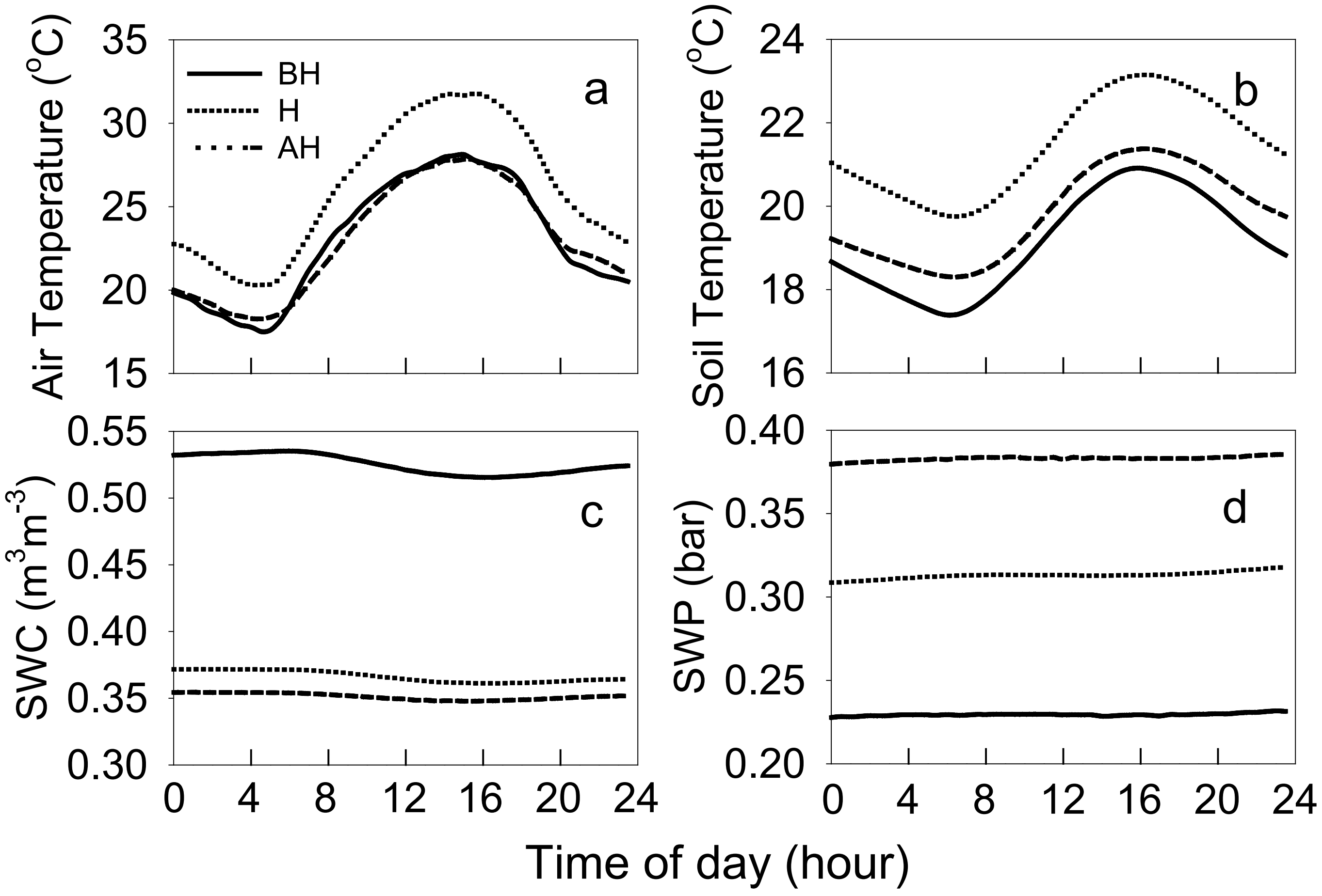
Recent 60-year HWs trends in the meadow

	Hot day (day/10yr)	Heat wave (times/10yr)	Mean HW length (day)	Max HW length (day)	Times per month		
					June	July	August
1954-1963	141	1	11.0	11	-	1	-
1964-1973	142	2	6.0	6	-	2	-
1974-1983	184	7	9.6	15	1	5	1
1984-1993	95	3	6.3	11	-	1	2
1994-2003	195	7	9.0	15	2	5	-
2004-2013	166	7	7.1	9	5	-	2
total	923	27	8.2	15	8	14	5

EC observed HWs during the 6 years（1954-2013)

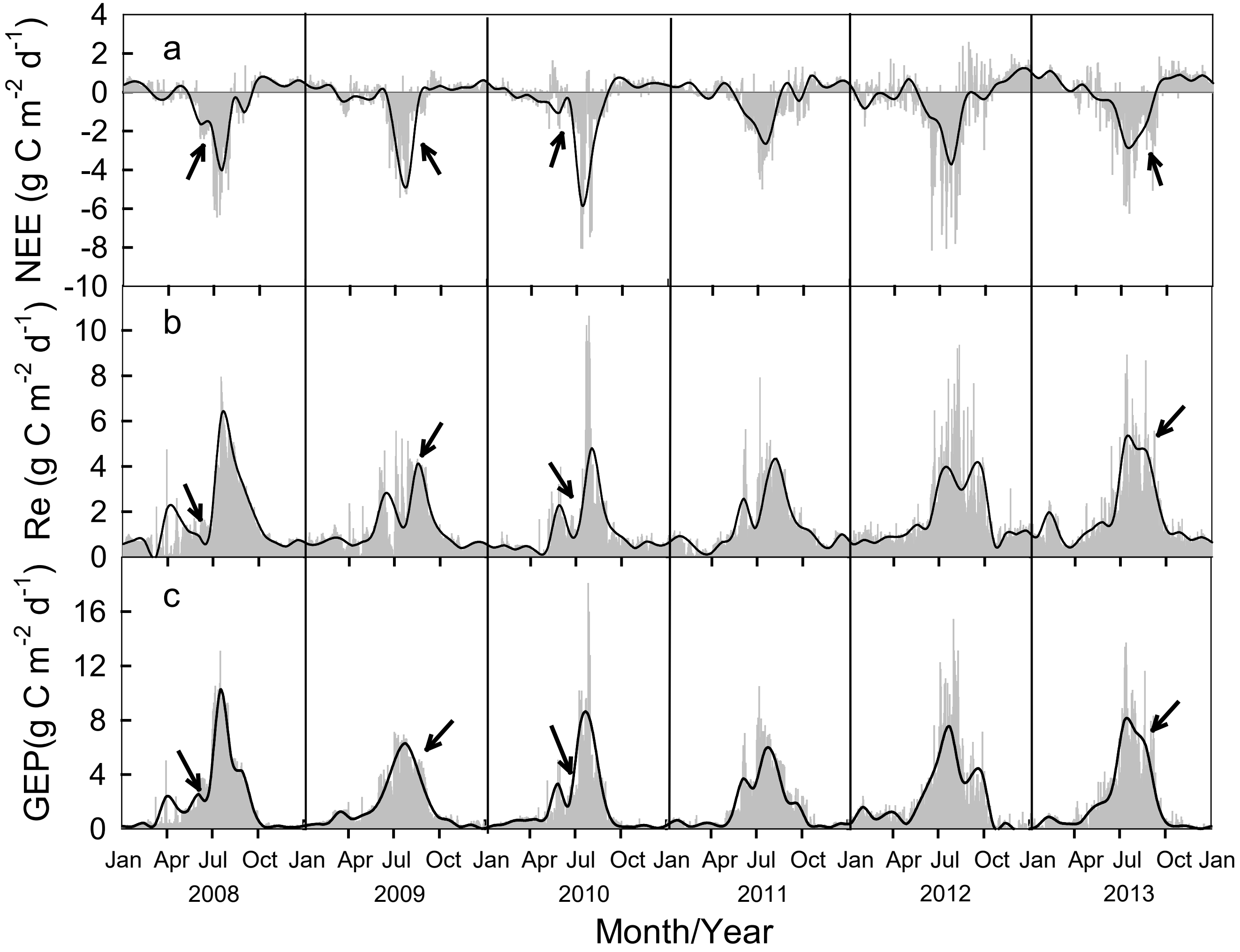
Name	Year	Time	Length (days)
HW1	2008	6.13 ~ 6.18	6
HW2	2009	8.5 ~ 8.10	6
HW3	2010	6.3 ~ 6.11	9
HW4	2010	6.23 ~ 6.27	5
HW5	2013	8.6 ~ 8.11	6

Met changes



Before(BH), during （H） and after (AH) HW

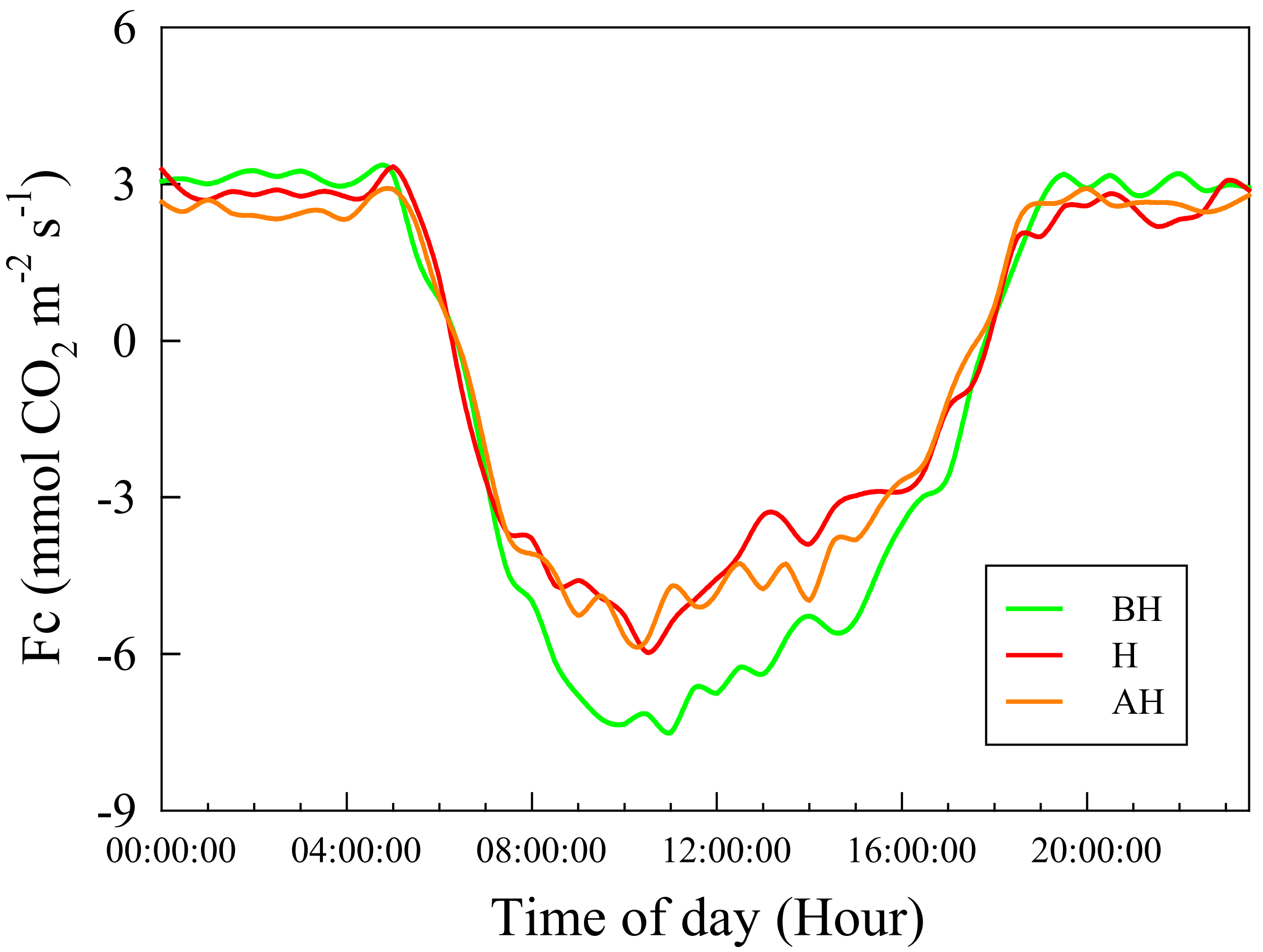
C fluxes changes



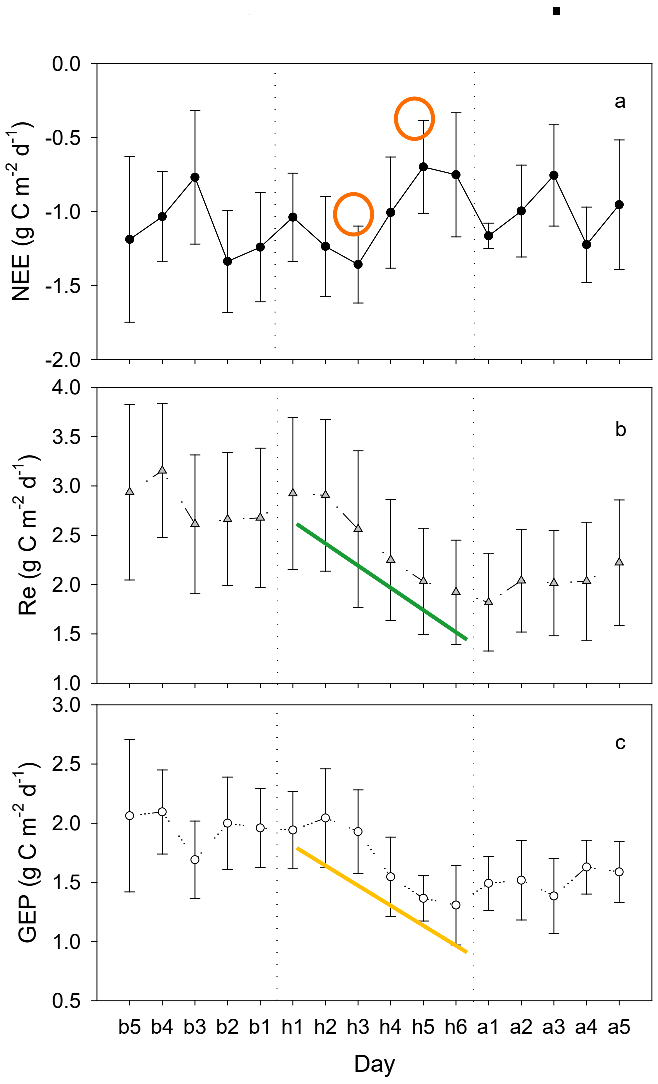
C fluxes

	Year	May	June	July	August	September	Non growing season	Growing season	Entire year
NEE (g C m-2 d-1)	2008	-0.21±0.05 ab	-2.03±0.14 a	-4.04±0.26 a	-0.71±0.17 ab	0.00±0.10 abc	0.33±0.02 c	-1.40±0.14 a	-0.39±0.08 ab
	2009	-0.04±0.05 b	-1.28±0.21 b	-2.84±0.30 b	-0.68±0.08 ab	0.47±0.06 c	0.11±0.03 a	-0.88±0.12 b	-0.30±0.06 ab
	2010	-0.03±0.16 b	-0.69±0.12 c	-3.24±0.54 ab	-0.79±0.11 ab	0.22±0.05 bc	0.14±0.02 a	-0.92±0.15 b	-0.30±0.07 ab
	2011	-0.11±0.06 b	-1.36±0.12 b	-2.51±0.23 b	-0.48±0.11 b	-0.15±0.16 ab	0.24±0.02 b	-0.92±0.10 b	-0.25±0.05 ab
	2012	-0.46±0.12 a	-2.16±0.33 a	-3.61±0.39 ab	-1.17±0.45 ab	0.08±0.20 abc	0.34±0.04 c	-1.47±0.18 a	-0.41±0.09 a
	2013	-0.23±0.13 ab	-1.43±0.18 b	-2.91±0.30 b	-1.19±0.14 a	-0.34±0.28 a	0.59±0.03 d	-1.23±0.12 ab	-0.17±0.07 b
Re (g C m-2 d-1)	2008	1.13±0.05 ab	1.28±0.04 a	4.74±0.26 c	4.14±0.16 b	2.08±0.11 bc	0.67±0.03 b	2.69±0.14 bc	1.51±0.08 b
	2009	1.24±0.08 abc	1.72±0.26 ab	2.85±0.24 a	3.84±0.06 b	1.85±0.15 b	0.67±0.02 b	2.31±0.11 ab	1.36±0.06 ab
	2010	1.44±0.16 c	1.27±0.07 a	4.23±0.60 bc	2.72±0.12 a	0.80±0.07 a	0.47±0.02 a	2.10±0.16 a	1.16±0.08 a
	2011	1.12±0.07 a	1.84±0.22 b	3.51±0.24 ab	3.75±0.10 b	1.63±0.05 b	0.64±0.02 b	2.38±0.11 ab	1.37±0.07 ab
	2012	1.05±0.09 a	2.44±0.24 c	4.48±0.23 bc	4.40±0.40 b	3.04±0.26 d	0.89±0.02 c	3.09±0.16 c	1.81±0.09 c
	2013	1.41±0.09 bc	2.07±1.01 bc	4.68±0.35 c	4.12±0.26 b	2.33±0.22 c	0.87±0.03 c	2.93±0.15 c	1.73±0.08 c
GEP (g C m-2 d-1)	2008	1.35±0.04 ab	3.32±0.81 b	8.79±0.23 b	4.85±0.24 bcd	2.08±0.18 bc	0.34±0.03 ab	4.09±0.23 b	1.91±0.14 bc
	2009	1.28±0.06 abc	3.00±0.15 b	5.69±0.21 a	4.47±0.08 abc	1.37±0.17 b	0.56±0.03 c	3.18±0.15 a	1.65±0.10 ab
	2010	1.47±0.23 a	1.96±0.14 a	7.46±0.77 b	3.51±0.17 a	0.58±0.06 a	0.33±0.02 ab	3.02±0.26 a	1.46±0.12 a
	2011	1.23±0.08 ab	3.20±0.24 b	6.03±0.18 a	4.23±0.18 ab	1.77±0.14 b	0.39±0.03 b	3.30±0.17 a	1.61±0.10 ab
	2012	1.51±0.13 a	3.40±0.22 b	8.09±0.48 b	5.57±0.69 d	2.96±0.29 d	0.56±0.04 c	4.32±0.26 b	2.13±0.15 c
	2013	1.64±0.19 bc	3.13±0.17 b	7.59±0.53 b	5.32±0.32 cd	2.67±0.44 cd	0.28±0.03 a	4.09±0.24 b	1.88±0.14 bc

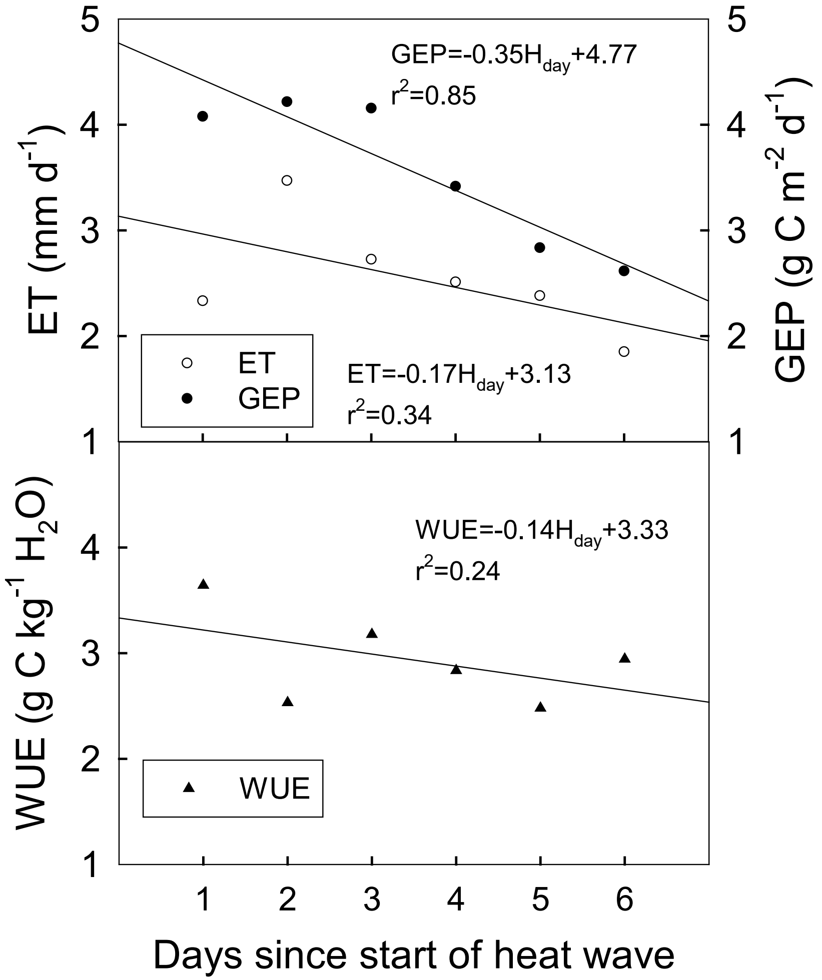
Before (BH), during (H) and after HW



NEE (net ecosystem C exchange), Re (respiration) and GEP (gross ... ivity)



HW effects on ET and WUE



WUE=GEP/ET

Conclusions

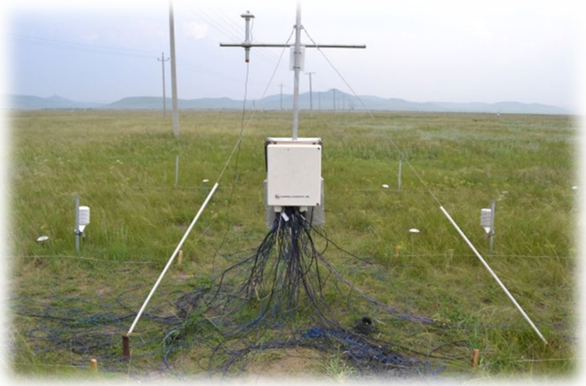
1. HWs enhanced C sink capacity firstly, and then reduced it

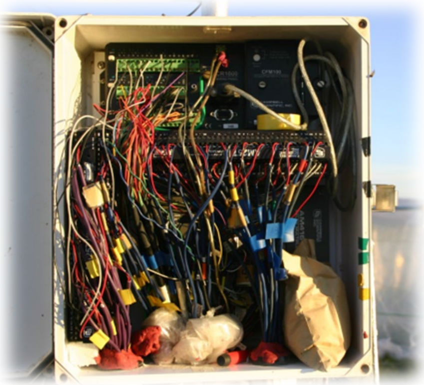
2. HW decreased both Re and GEP by 30% and 50%, respectively

3. Drought maybe a main reason caused the reduce of ecosystem C fluxes

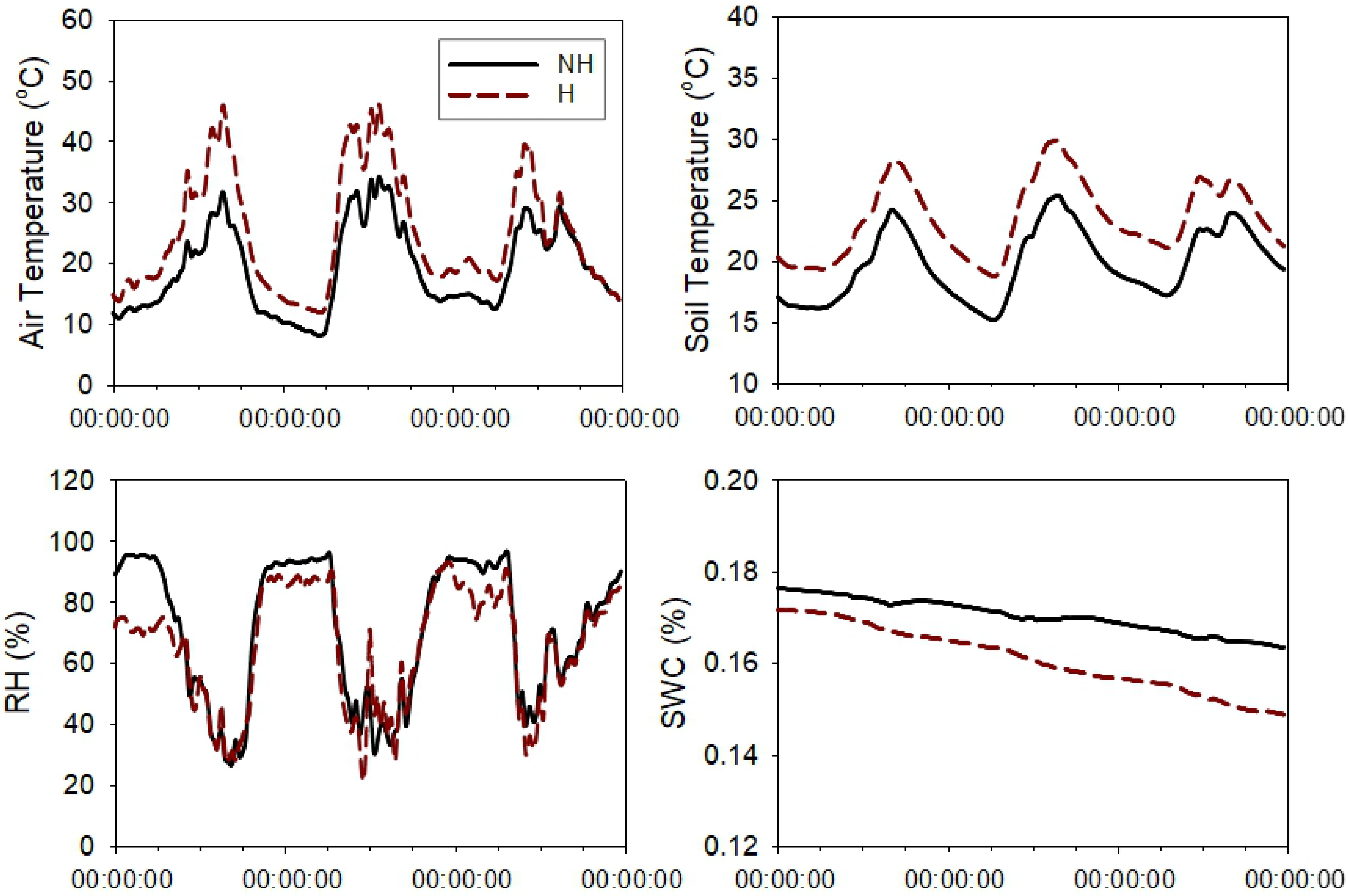
Manipulative HWs

Field design

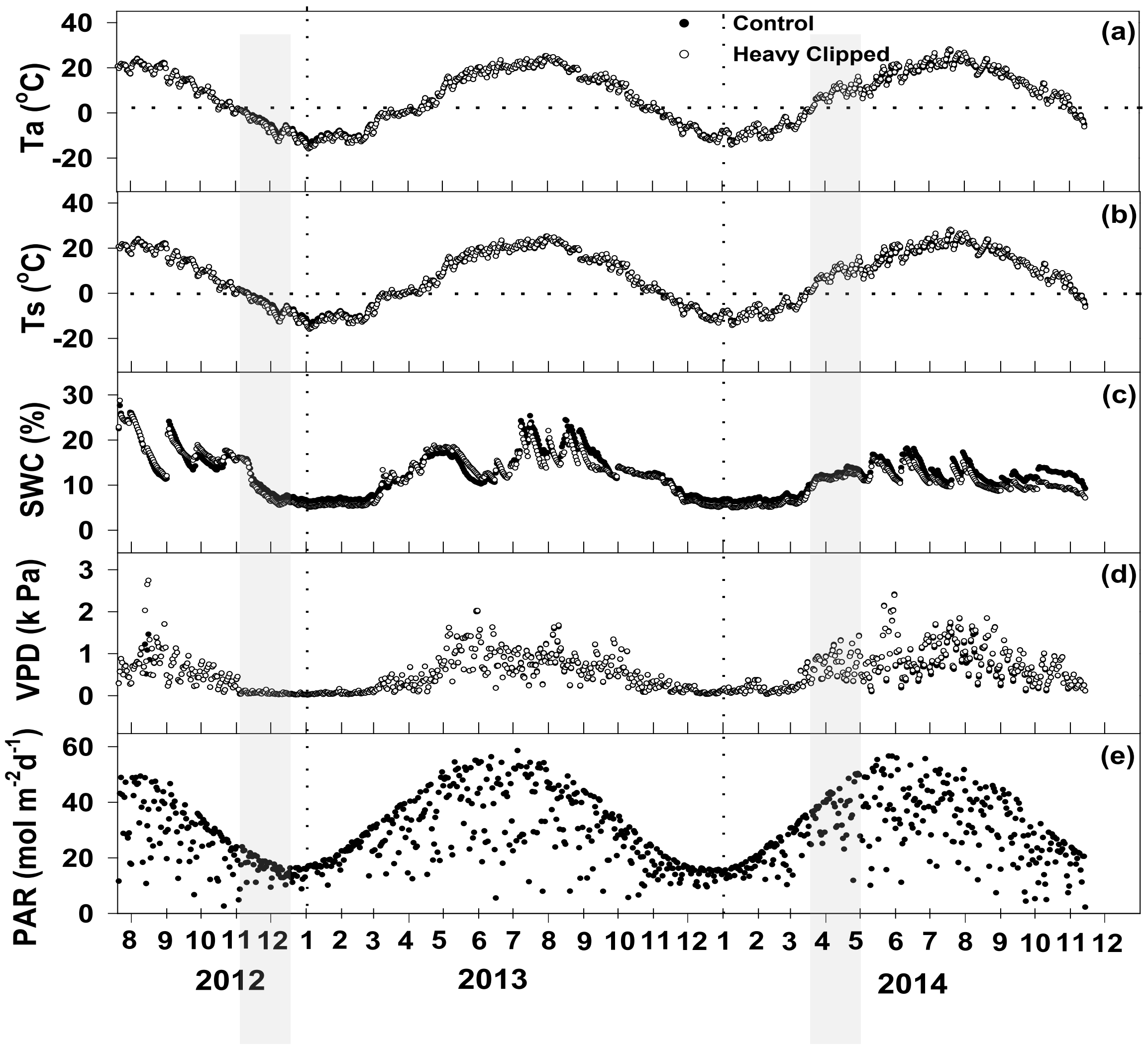




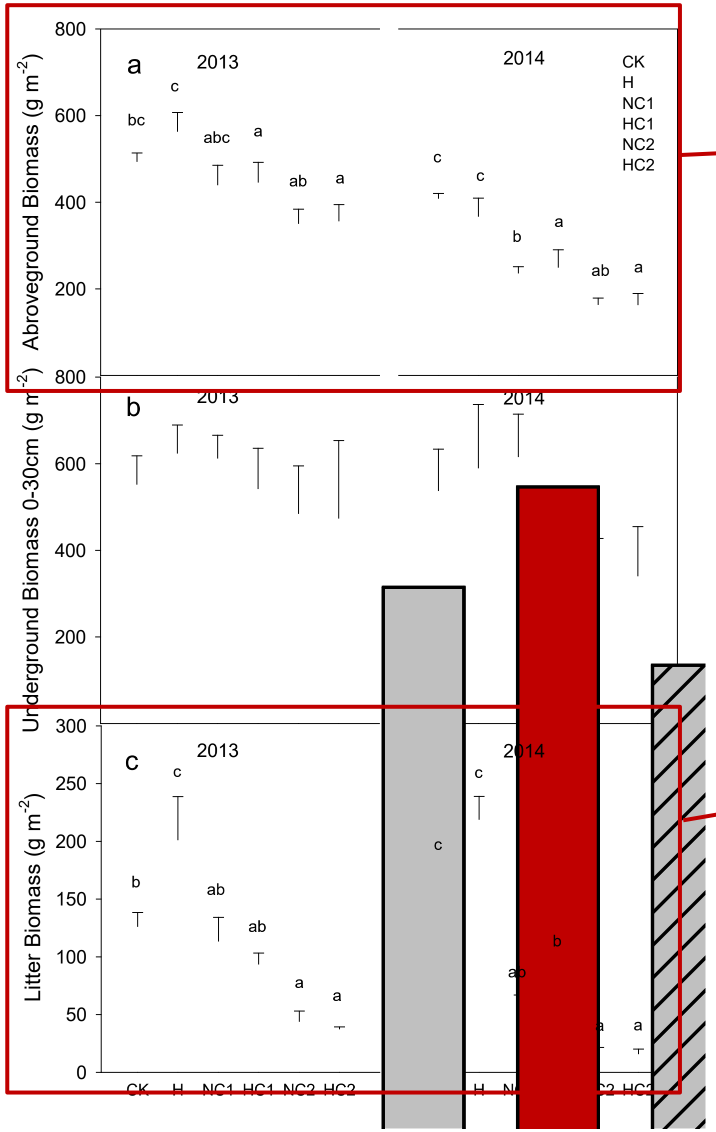
HW simulation: met



Results-3 years continuous met



Results-Biomass



- HWs affected more on aboveground biomass, other than belowground biomass

- HWs increased Litter biomass

Results-C fluxes

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Heavy mowing enhances the effects of heat waves on grassland carbon and water fluxes

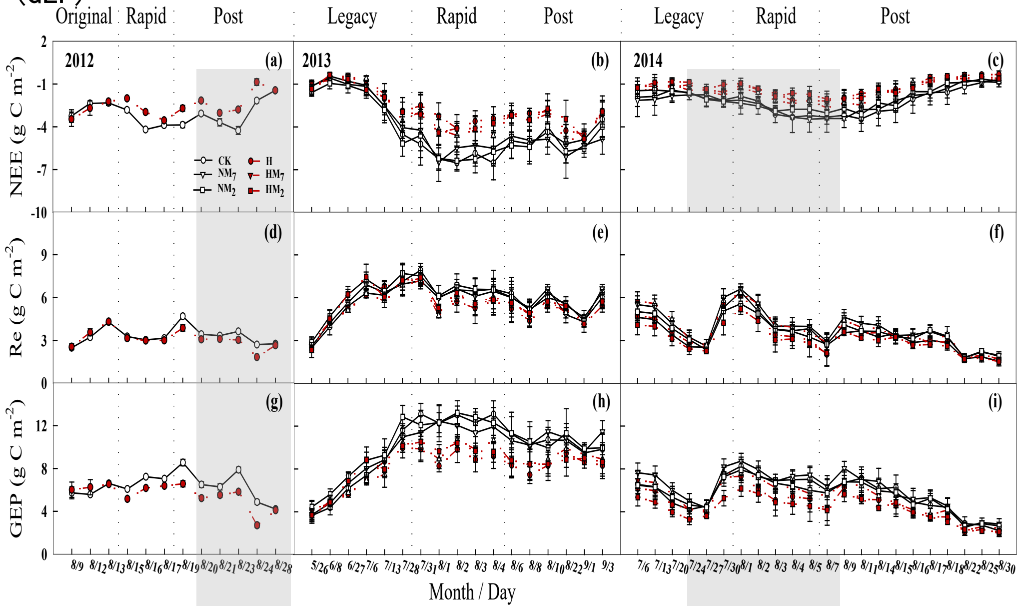
Luping Qu [a], Jiquan Chen [b], Gang Dong [c], Changliang Shao [d,*]

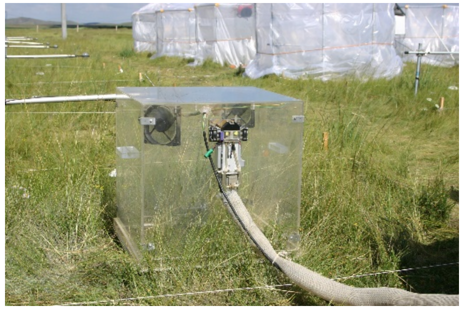
- "Three stages" method on extreme climate events
- "Additive effect" on HWs

Stipa krylovii steppe

Heat wave simulation

Heat Waves significantly decreased ecosystem CO_2 exchange (NEE), ecosystem respiration (Re), and gross ecosystem productivity (GEP)

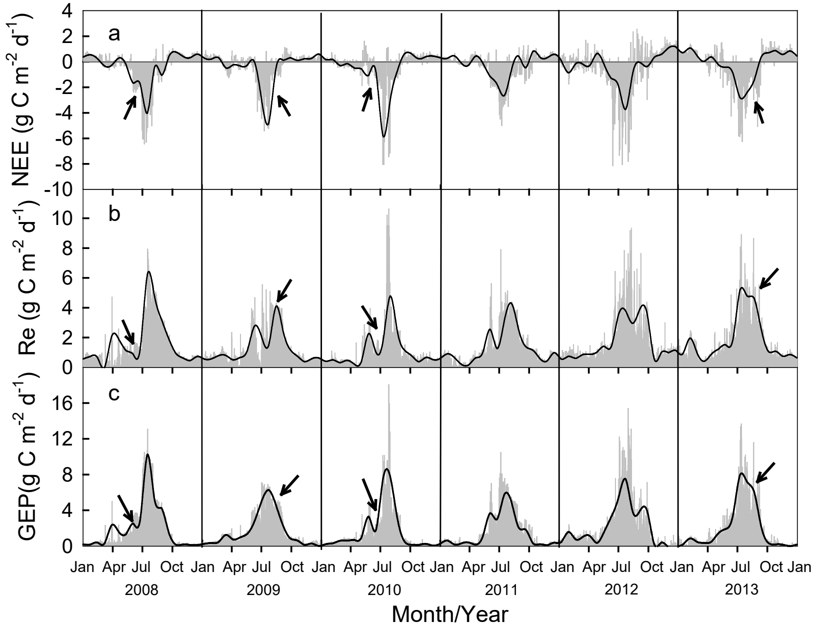


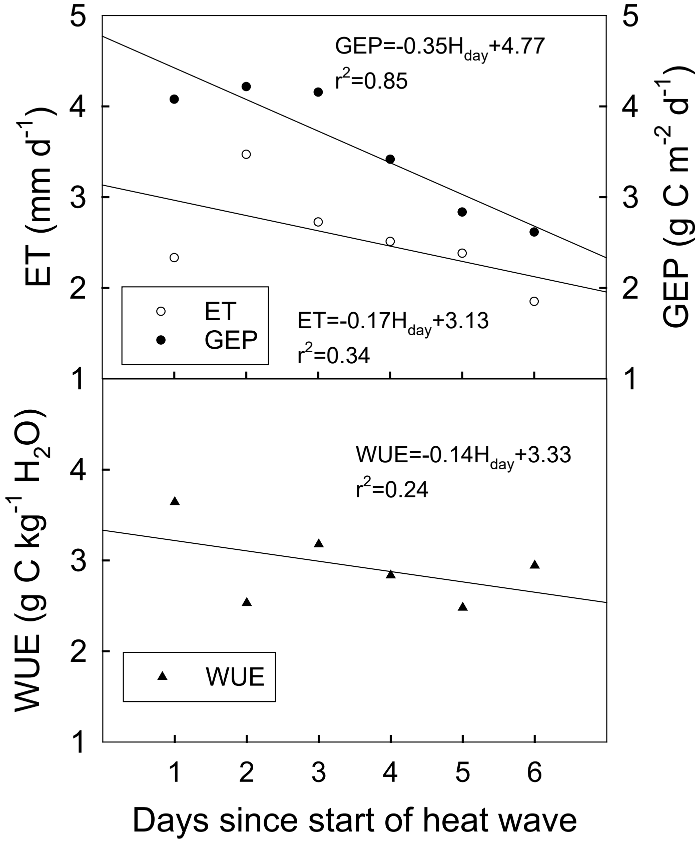


热浪-极端气候事件下的碳水通量

自然热浪-通量观测

- 定义了草原“热浪事件”
- 热浪使草甸水分利用效率持续下降
- 热浪可导致碳吸收下降1/3





热浪降低了草甸草原碳吸收和WUE

Qu&Shao et al, ER 2015，2024

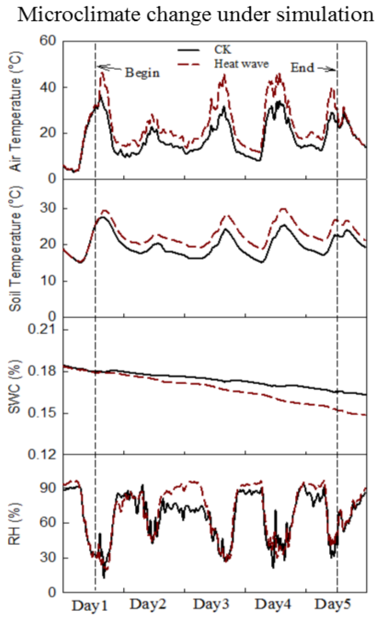
极端气候事件下的碳水通量

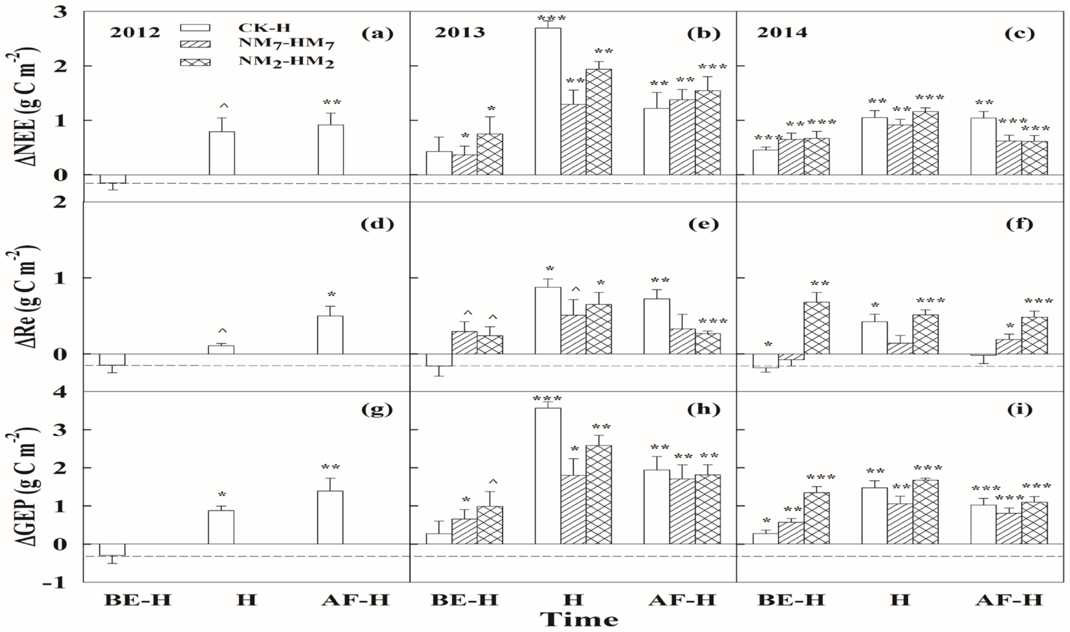
模拟热浪+自然热浪

- 模拟热浪同样发现降低草地碳吸收
- 热浪存在持续效应，且影响会叠加
- 重度刈割加剧热浪对生态系统影响

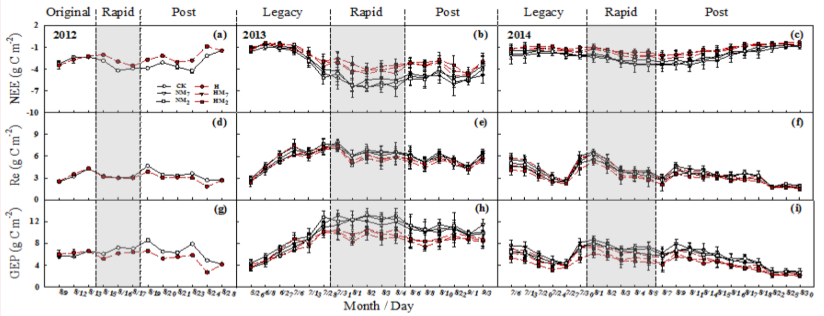
Stipa krylovii steppe

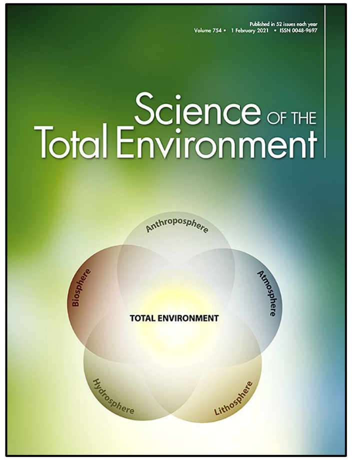
Heat wave Simulation





Heat Waves significantly decreased ecosystem CO_2 exchange (NEE), ecosystem respiration (Re), and gross ecosystem productivity (GEP)



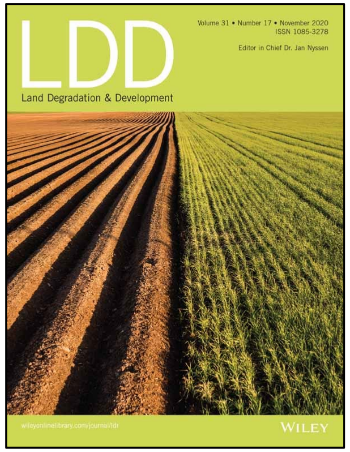


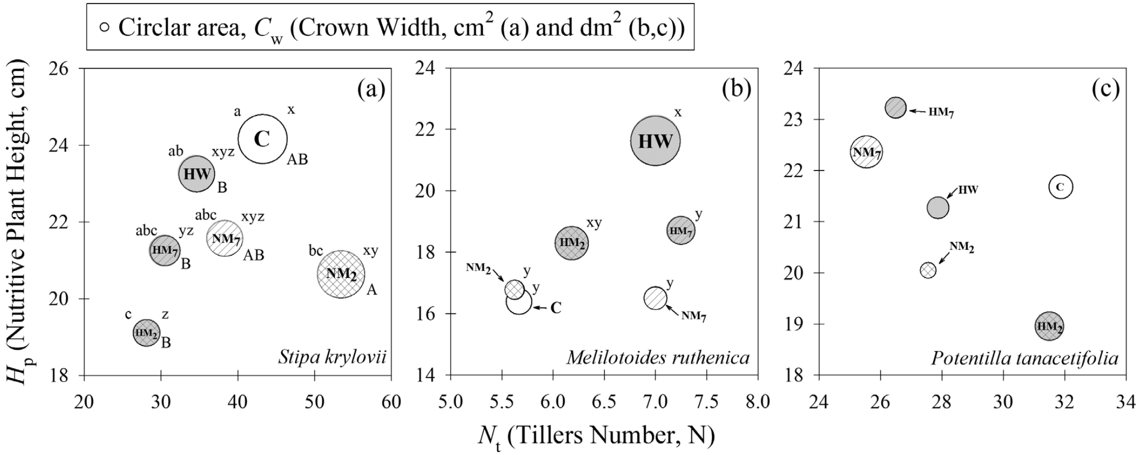
Qu&Shao et al，2018

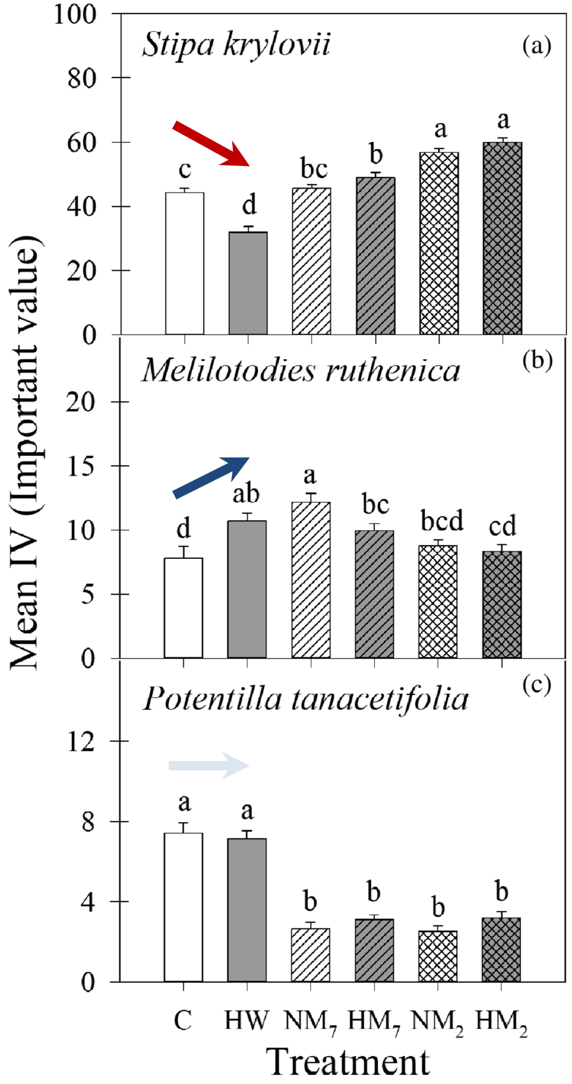
极端气候事件下的碳水通量

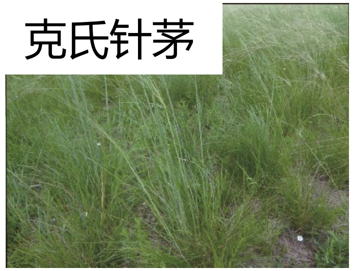
热浪对草地群落结构变化的持续影响

- 热浪和刈割导致植株形态及物候期长短发生变化
- 热浪导致草地群落组成发生变化
- 草地群落发生逆行演替，群落功能退化









Qu&Shao et al，2020

谢谢聆听！欢迎合作！