中国科学院遗传与发育生物学研究所
农业资源研究中心
Center for Agricultural Resources Research,IGDB, CAS

ChinaFLUX第十九次通量观测理论与技术培训

华北平原主要农业生态系统水碳通量及其对土地利用变化的响应

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2024年8月23日

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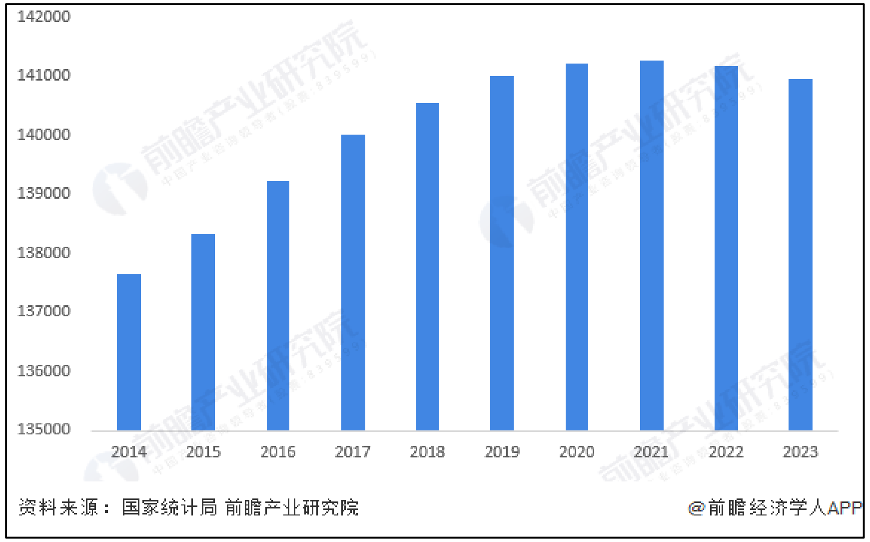
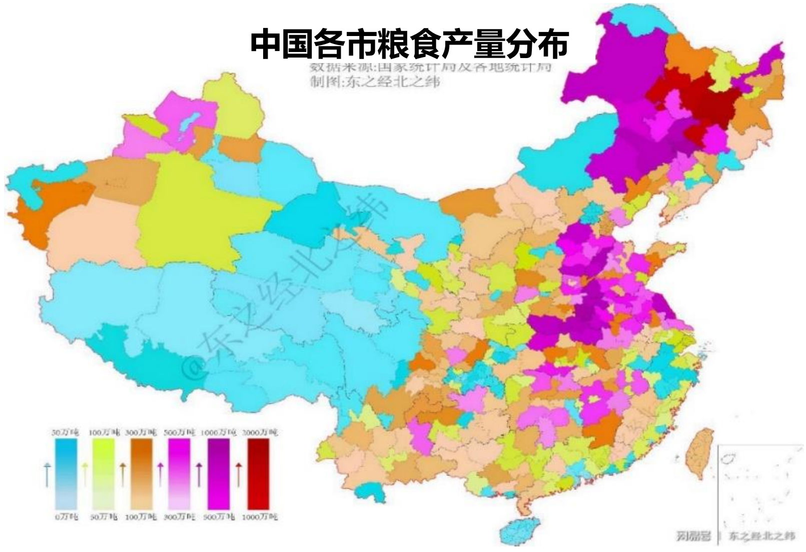
一、国家需求-水资源是国家粮食安全的基本和根本保障

2014-2023中国人口总量（单位：万人）

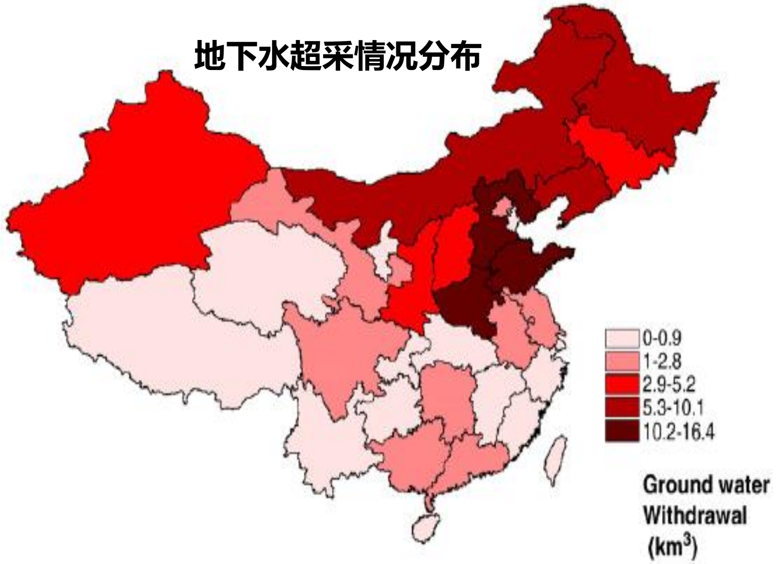


2014-2022年中国进口粮食及对外依存度情况

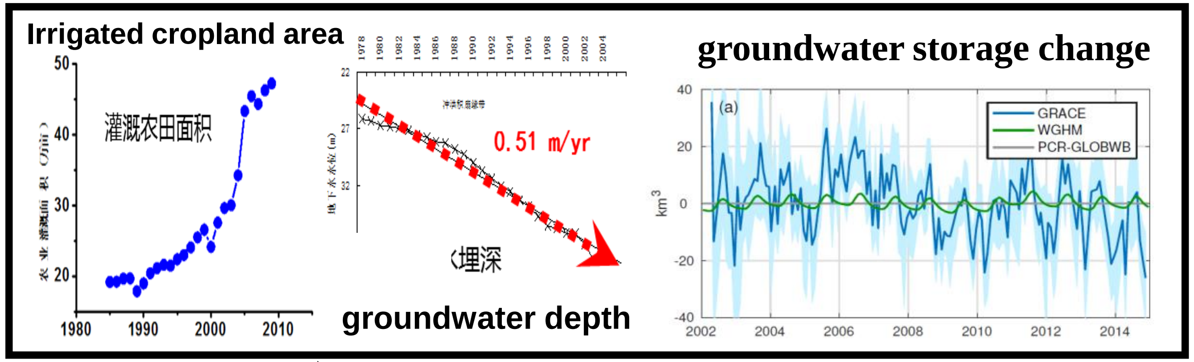
中国各市粮食产量分布

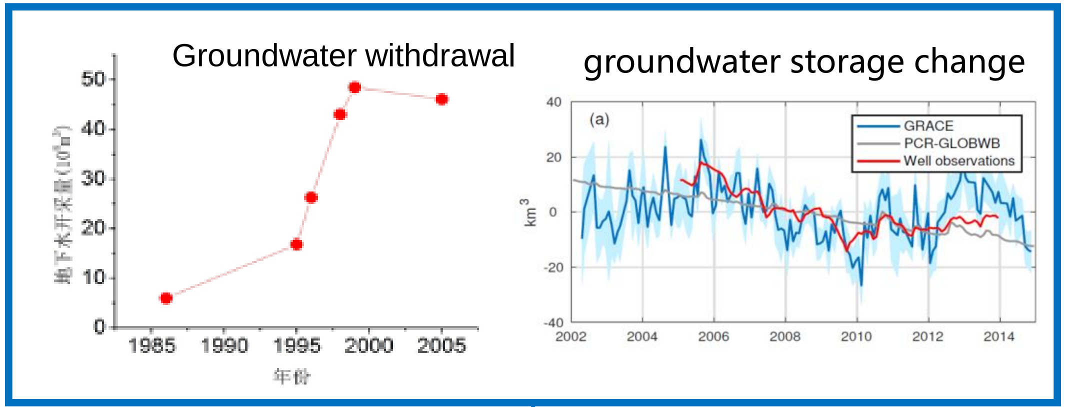


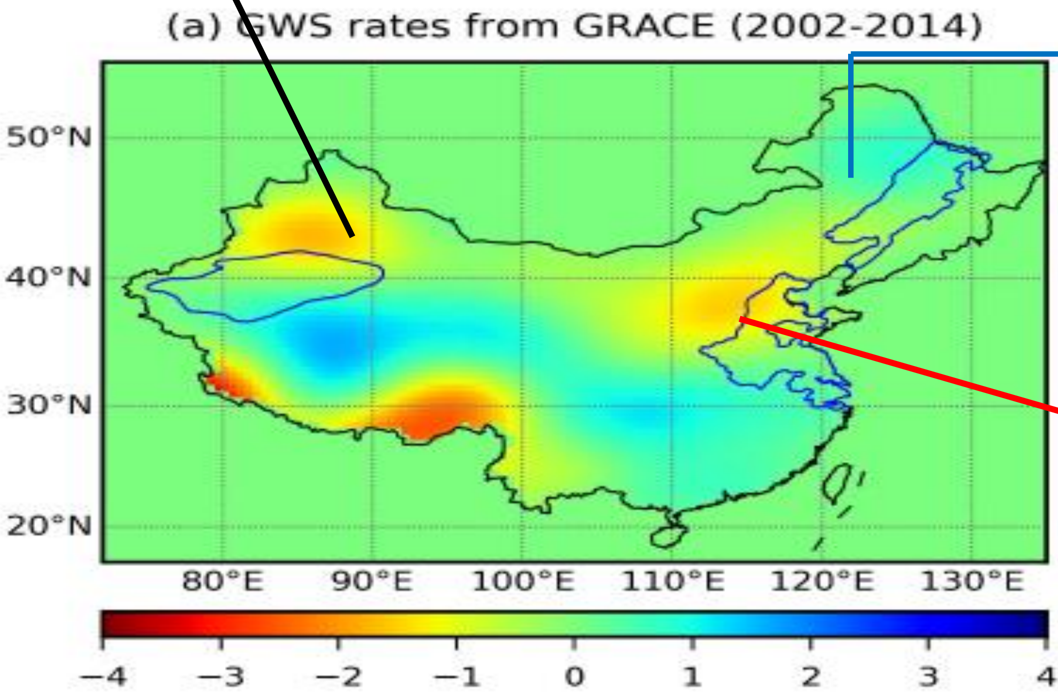
地下水超采情况分布



一、国家需求-华北是我国农业水短缺矛盾最突出区域

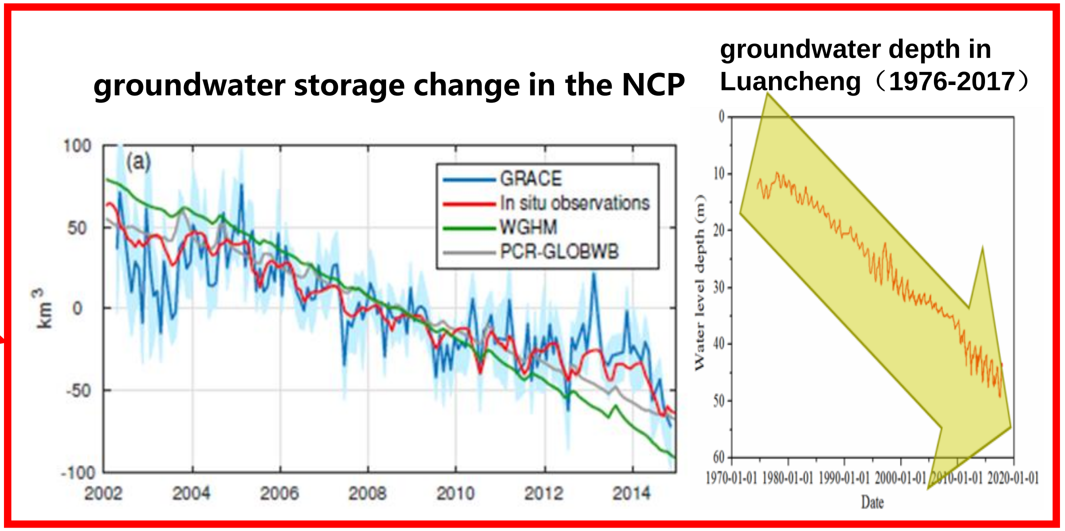






cm/yr

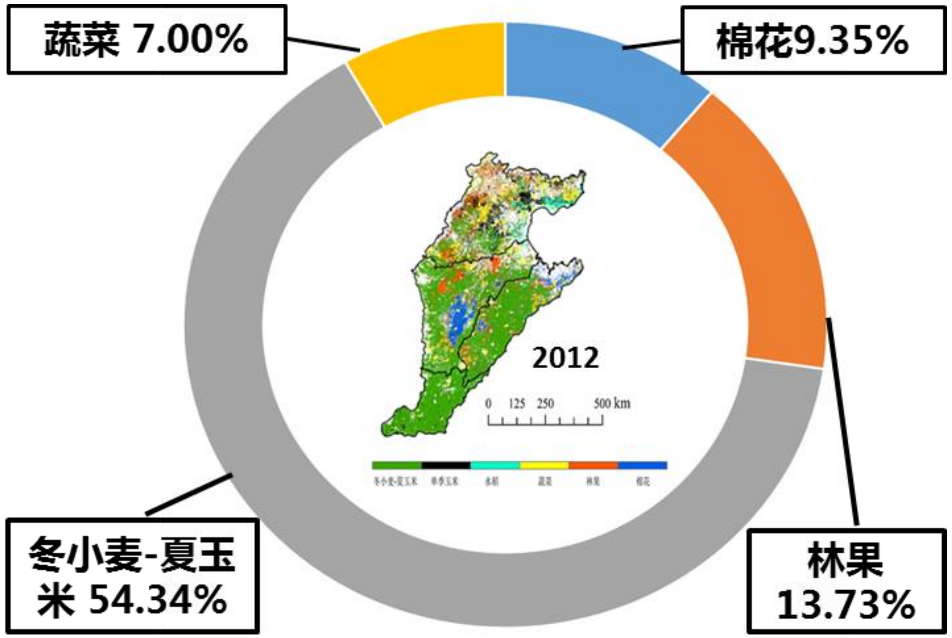
(Feng et al., RS, 2018)

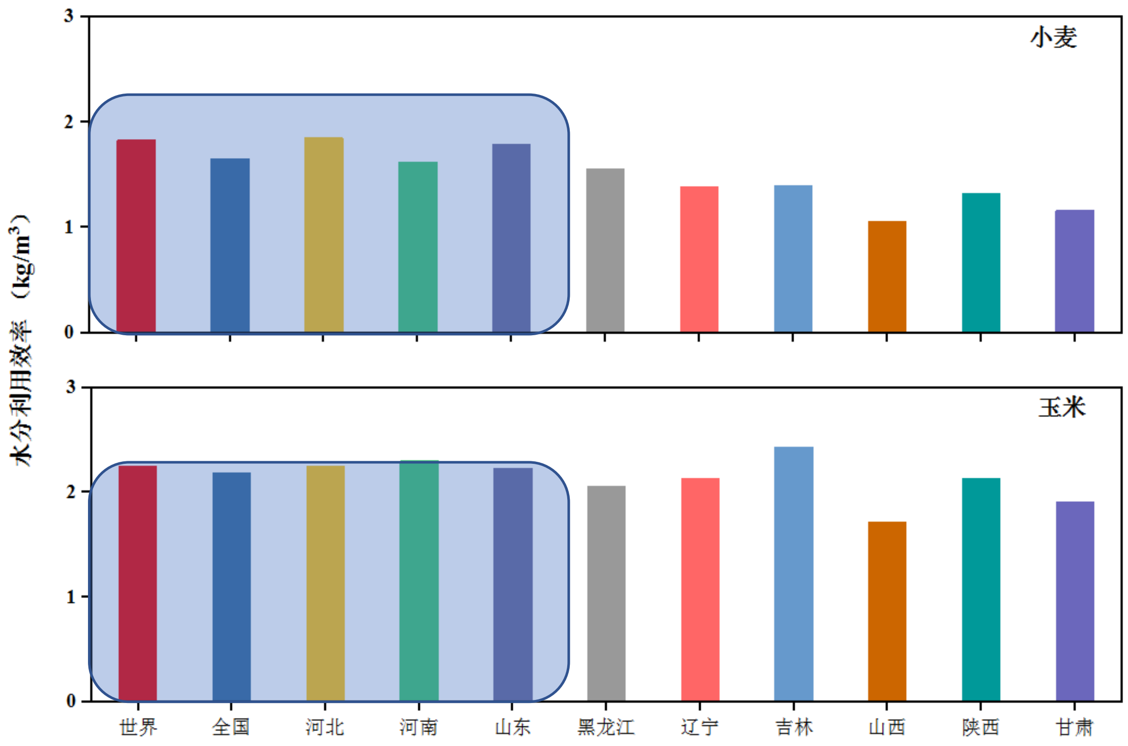


- 节水是统筹解决地下水和粮食问题的关键

一、学科需求-节水高效农业的发展

随着经济和社会发展形成四大类作物为主的种植模式，由旱作农业转变为灌溉农业。





- ☐ 华北平原农业主要的节水潜力所在：种植制度/结构调整

一、科学问题-农业土地利用-区域耗水量-农业产量之间的关系

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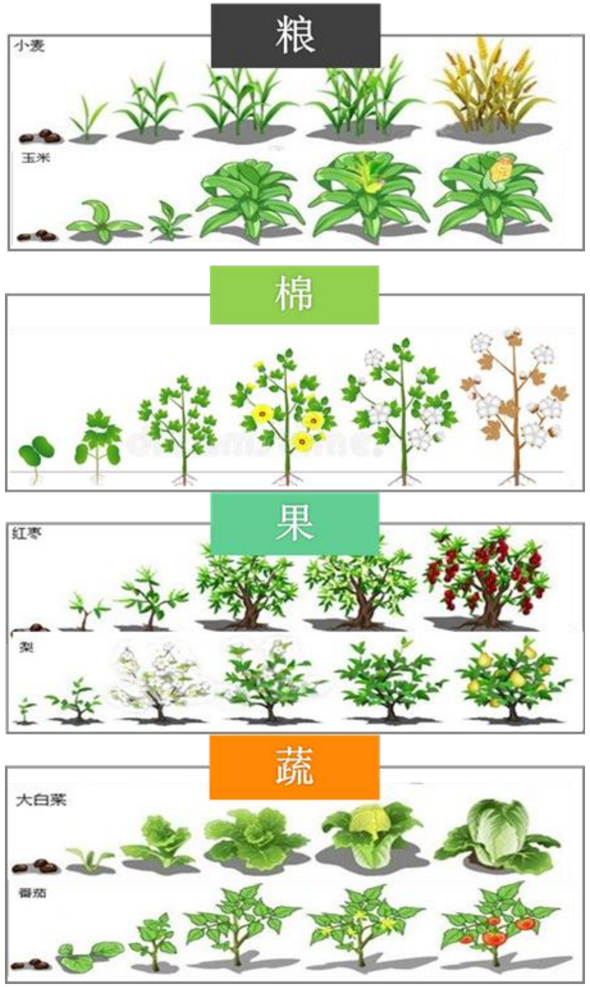
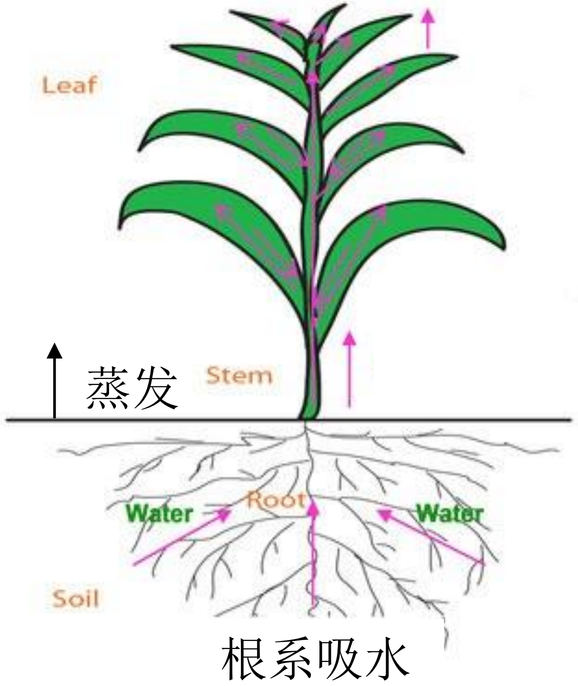
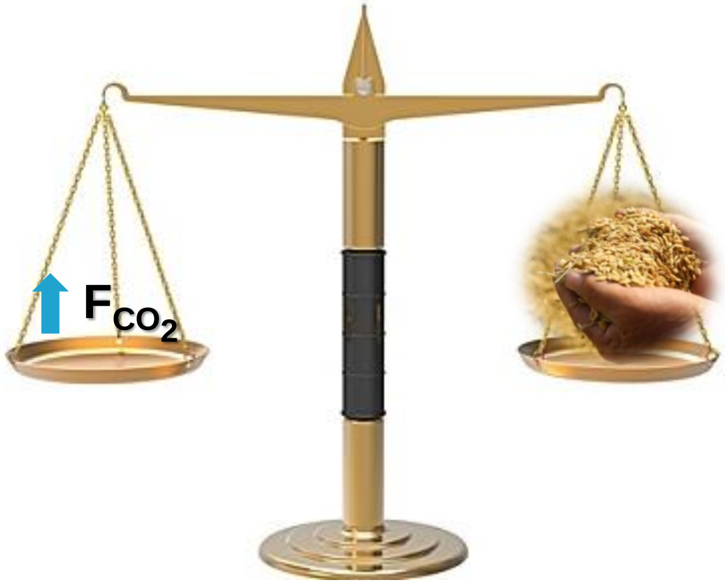






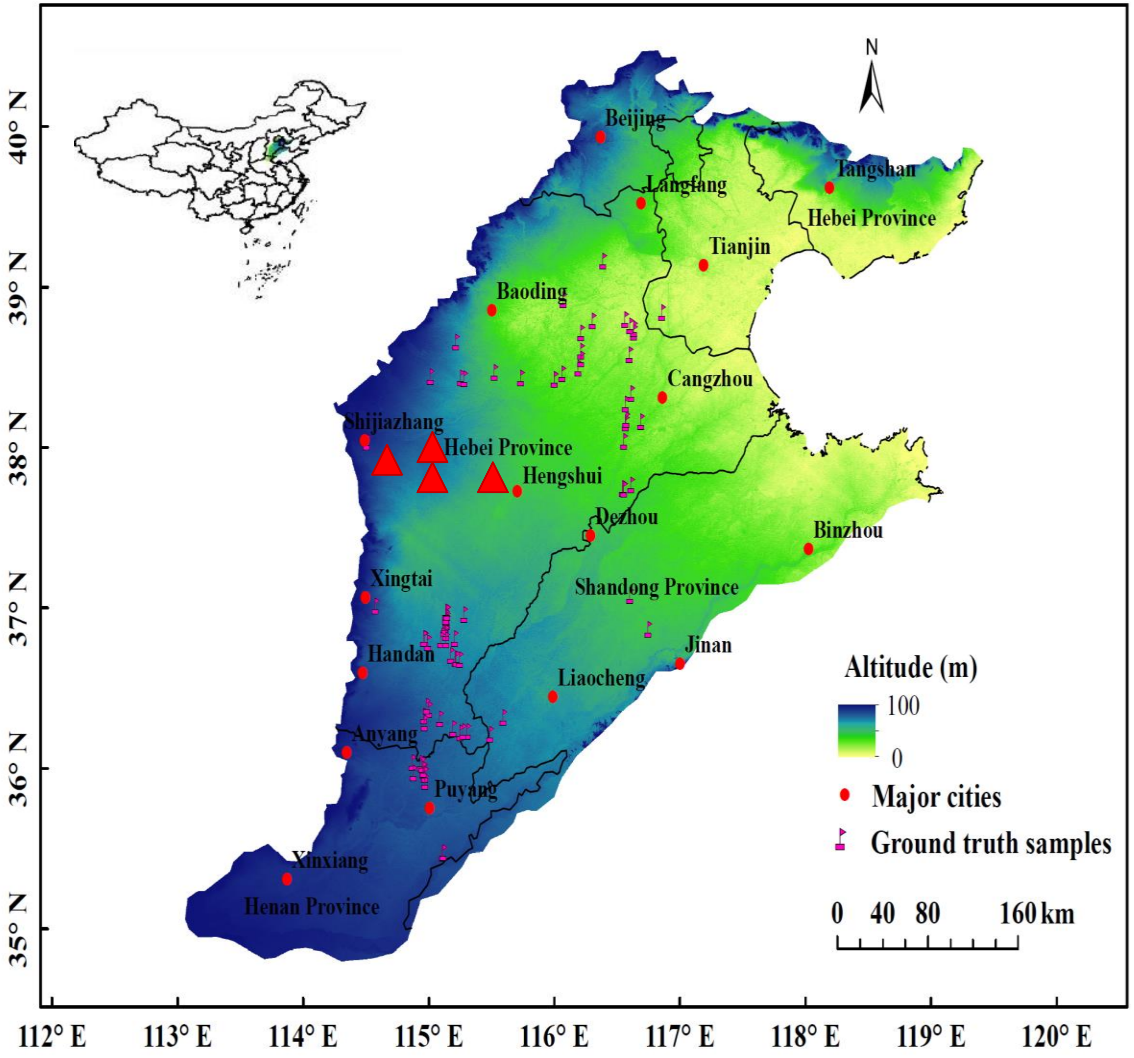
WUE ＝ Y / ET

WUE：水分利用效率

Y：产量 ET：蒸散耗水量

- 华北平原农业土地利用变化对区域耗水量与反映农业产量水平的碳交换量之间的关系

二、研究区概况



- 研究区：34°46′ N ~ 40°25′N，
112°30′E ~ 119°30′E，
面积13.9 × 10^4 km^2
- 温带大陆性季风气候，夏季高温多雨，冬季寒冷少雨，具有明显的季节变化
- 年平均气温10.0~14.2 ℃，年平均降雨量400~500 mm；无霜期180~220 d，年平均日照时间2600~2800 h，年总辐射525.3 kJ/cm^2，年平均水面蒸发量900~1000 mm
- 粮食总产量占全国的10~15%，蔬菜产量占23~34%，梨产量2014年超过70% (Huang et al.， 2019)，棉花产量占6%左右

二、水碳通量观测方法

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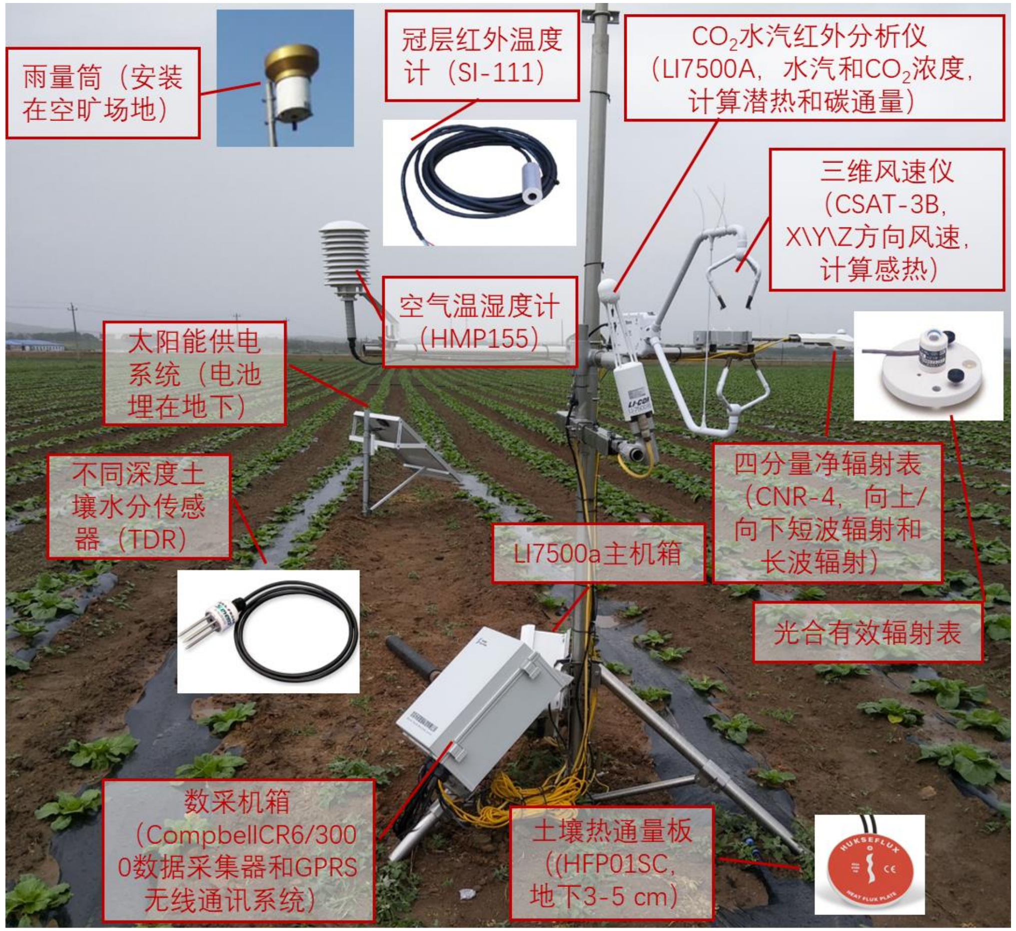
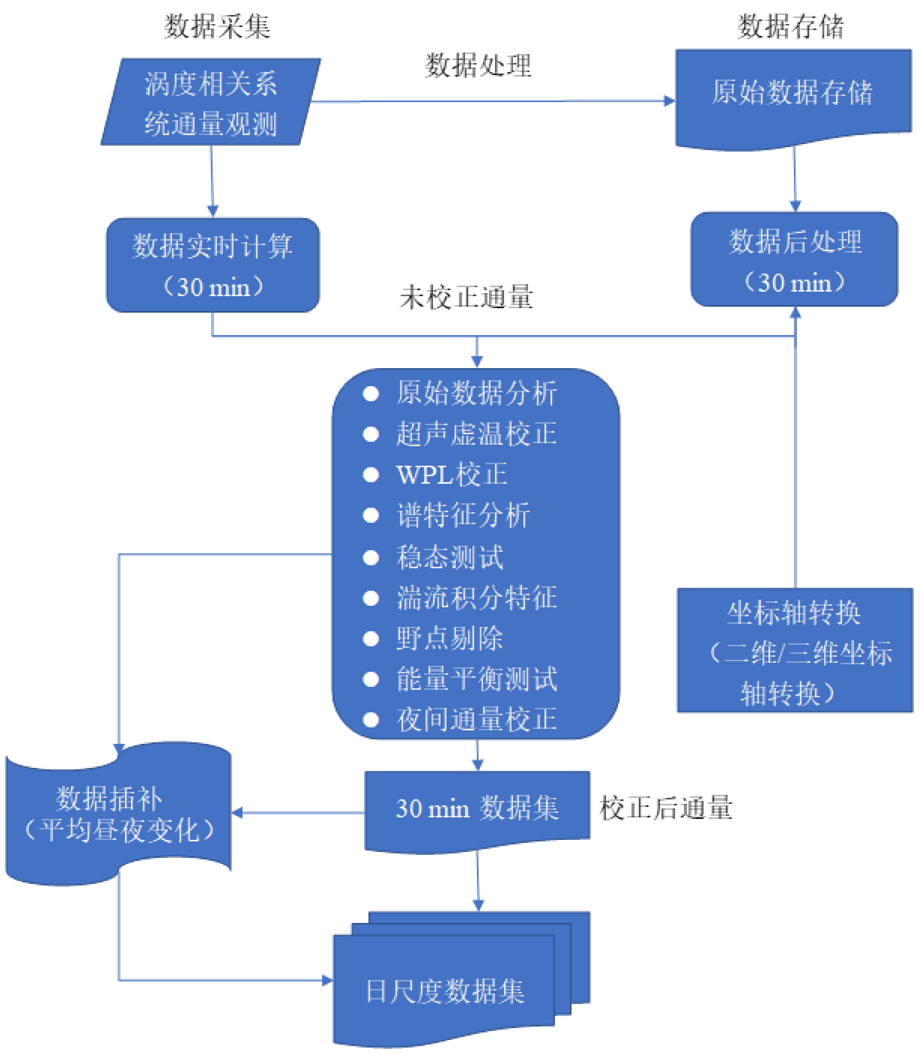
典型农田系统水热碳通量观测网



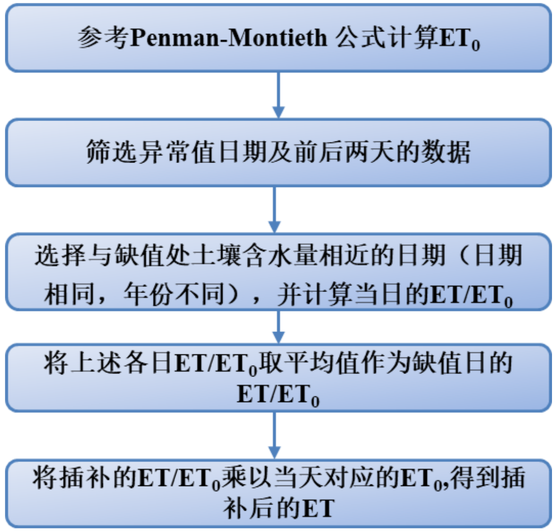
作物类型	地下水埋深 (m)	土壤类型 (容重: g/cm^3)	施肥量 ($kg\ N/ha^{-1}$)	土壤墒情 θ (%)	年均灌溉量 (mm)
Winter wheat – summer maize	45	loam, sandy loam (1.53)	450 ~ 600 kg N/ha^{-1}	28	362
Pear trees	50	sandy loam (1.32)	540~800 kg N/ha^{-1}	30	391
Cotton	22	loamy fluvo-aquic soil (1.43)	259 kg N/ha^{-1}	26	179
Vegetables	40	sandy loam (1.20)	700~900 kg N/ha^{-1}	29	565

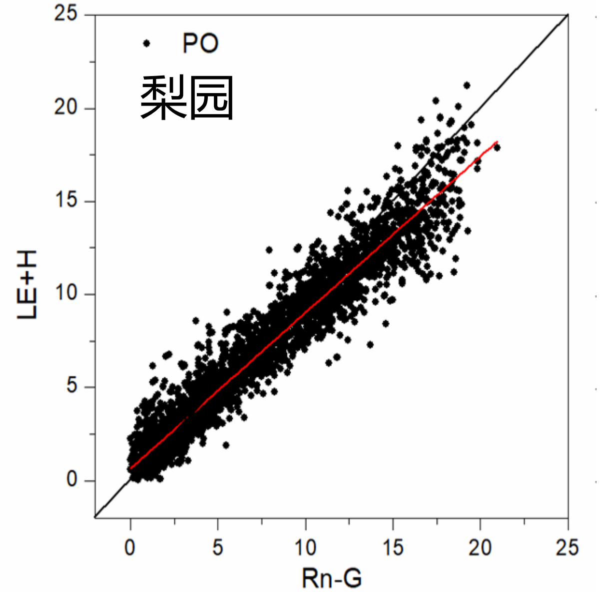
二、通量数据处理方法

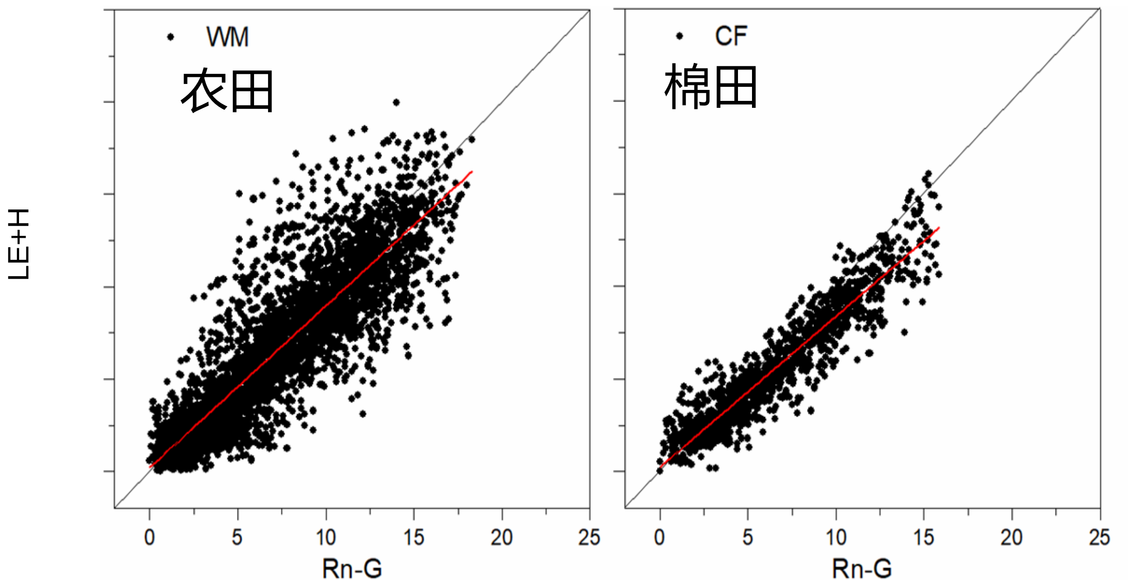


通量数据处理流程（ChinaFlux, 于贵瑞和孙晓敏，2018）

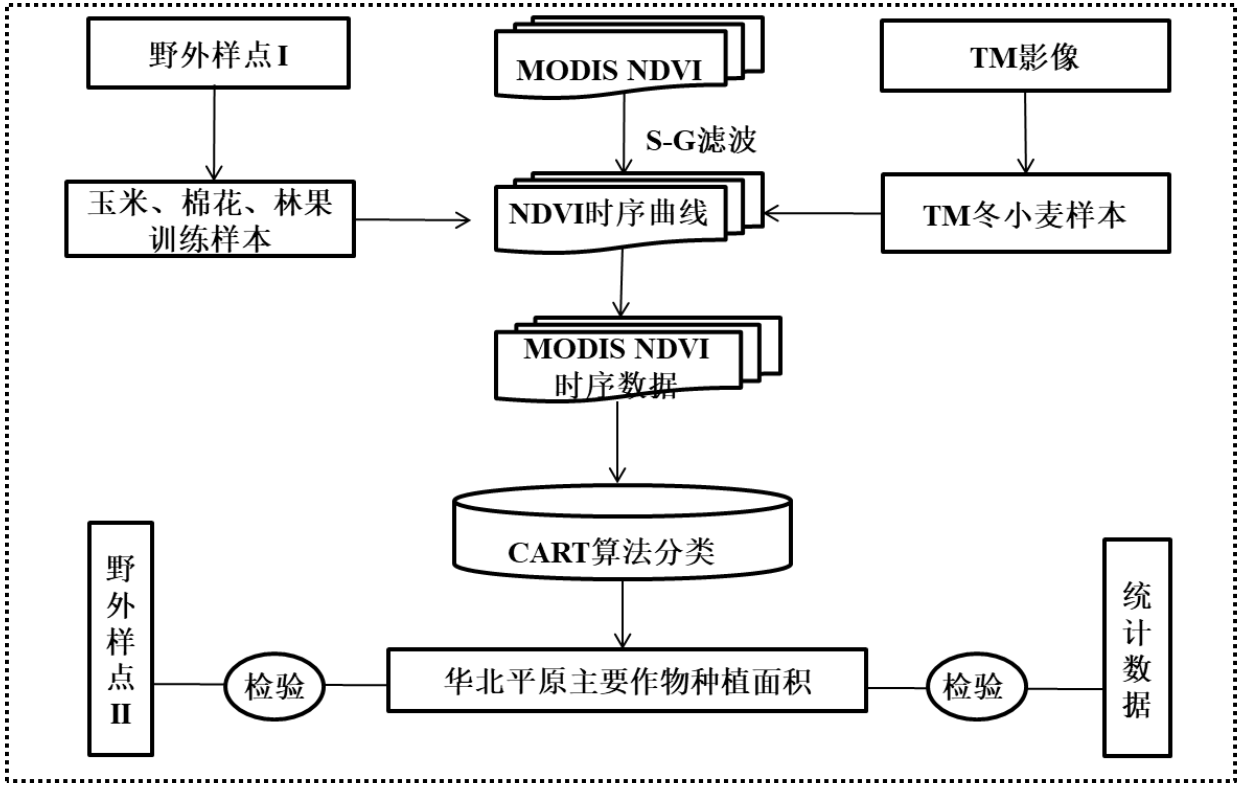
利用土壤含水量与ET/ET_0的定量关系进行ET插补：





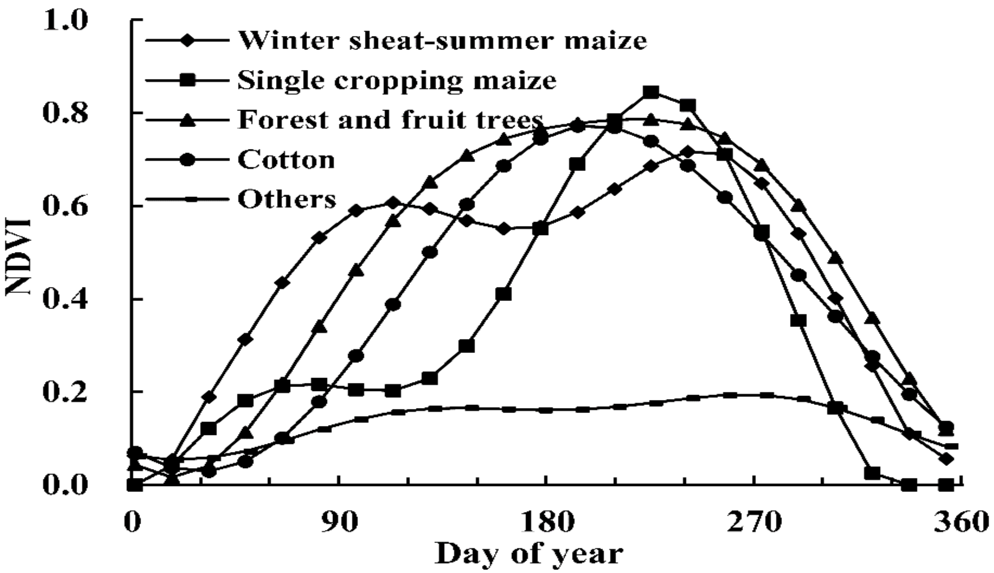


二、农业土地利用分类方法



农业土地利用分类技术路线

Crop types	Growth periods											
	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Wheat-maize	Wintering		Reviving	Jointing / Heading	Filling	Maturity / Seeding	Heading / Flowering	Filling	Maturity	Seeding	Wintering	
Pear trees	Domancy		Sprouting	Blooming	Fruit formation				Fruit maturation	Recovery		Domancy
Cotton					Seeding	Budding	Boll setting	Boll opening		Maturity		
Vegetables			Seeding	Blossom and fruit formation	Fruit maturation		Maturity / Seeding		Rosette / Heading	Maturity		



NDVI time series curves of different crops in the NCP

三、各站点气象因子变化

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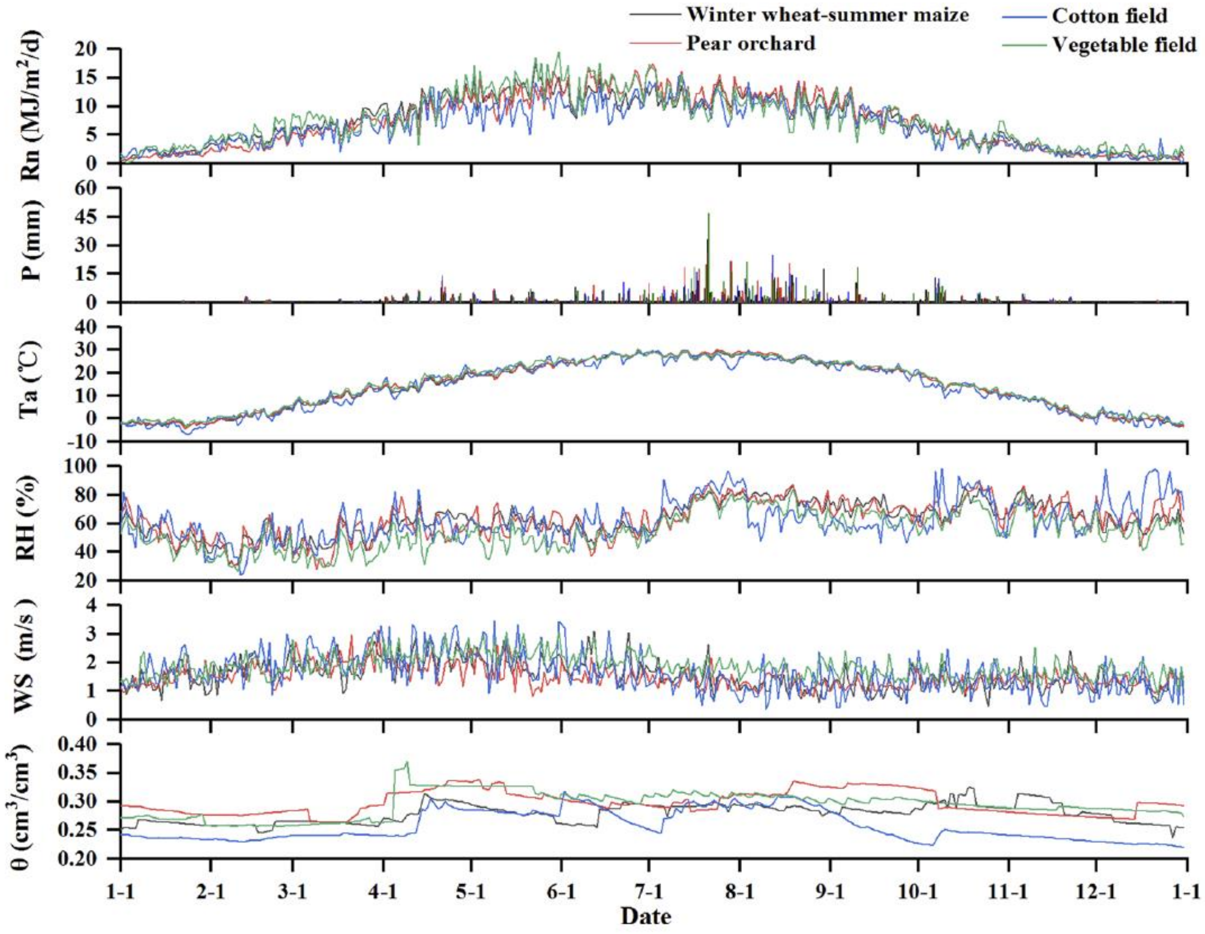
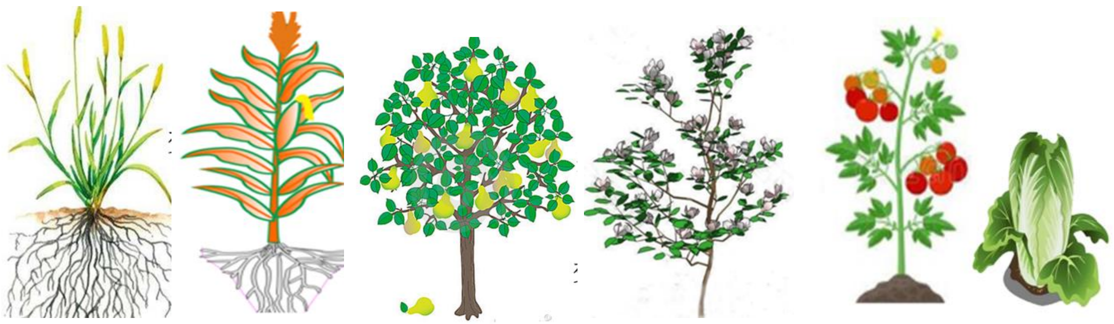


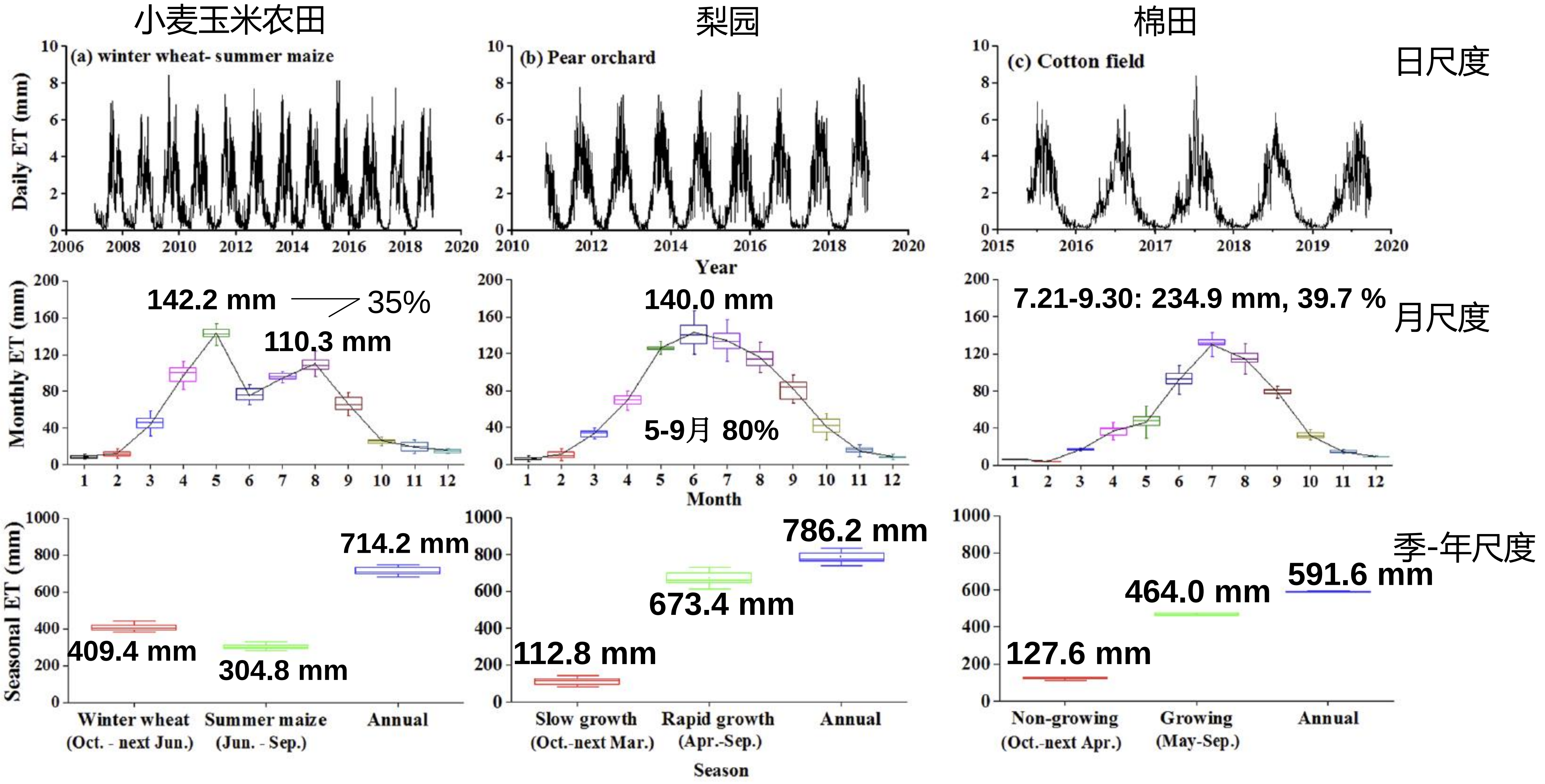
四个试验站点气象因子概况

Meterological factors	Winter wheat – summer maize	Pear orchard	Cotton field	Vegetables (ourdoor/greenhouse)
Annual total radiation (MJ m^{-2})	4194	4617	5000	4300
Annual mean relative humidity (%)	71	73	67	75/88
Annual mean temperature (°C)	12	13	13	13/17
Annual mean precipitation (mm)	466	475	465	476/0
Soil moisture θ (%)	20~35	15~35	15~30	15~35/25~35
Mean annual irrigation (mm)	362	391	179	520/894

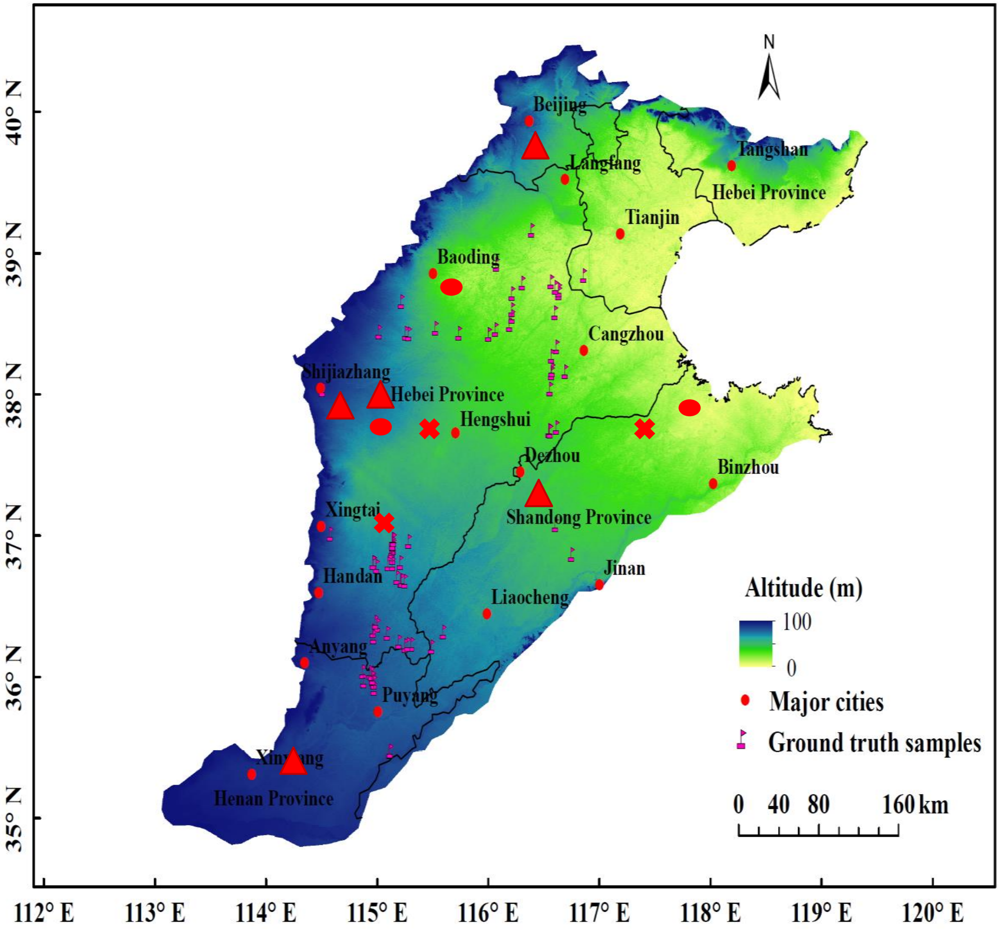


- The four sites are almost at the same latitude. Therefore, the difference in meteorological factors between the stations is not significant.

三、不同时间尺度粮-棉-果-蔬农田耗水变化



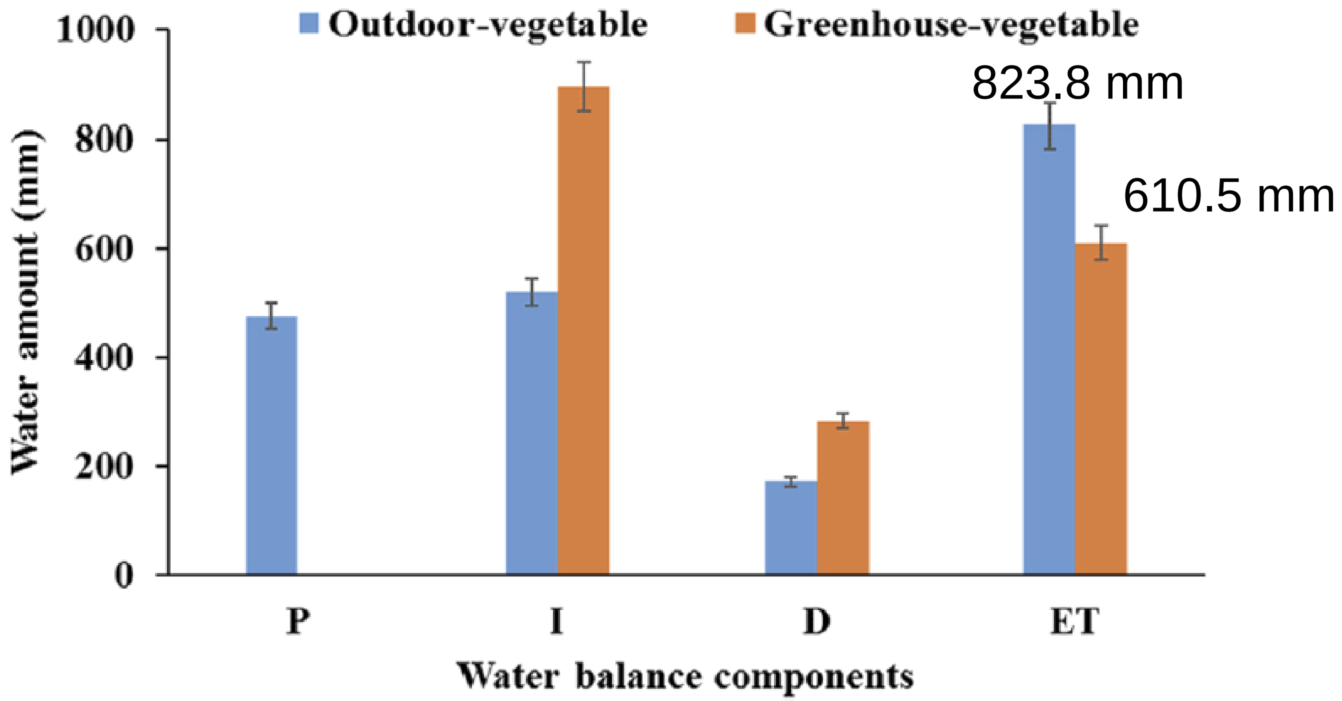
三、不同时间尺度粮-棉-果-蔬农田耗水变化



- The annual ET of WW-SM was similar to that of **Weishan, Daxing, and Xinxiang** located in the **north, east, and south** (Gao et al., 2009; Shen et al., 2013; Zhang et al., 2013).
- Total yield and planting area of **pear, apple, peach and grape** accounted **for 88 % (yield) and 69.2 % (area)**.
- Average annual ET 782 mm: 780.0 mm, 790.6 mm, and 771.2 mm (apple orchards, peach orchards, and vineyards with similar latitudes and climates) (Guo et al., 2012; Parry et al., 2019; Zhao, 2019).
- Almost no research focused on the annual water consumption of cotton fields. ET during the above period generally varied from 470 to 530 mm in NCP (Yang et al., 2015; A. Zhang et al., 2020; H. Zhang et al., 2019), which accounts for approximately 80~89 % of the annual water consumption and seems reasonably.

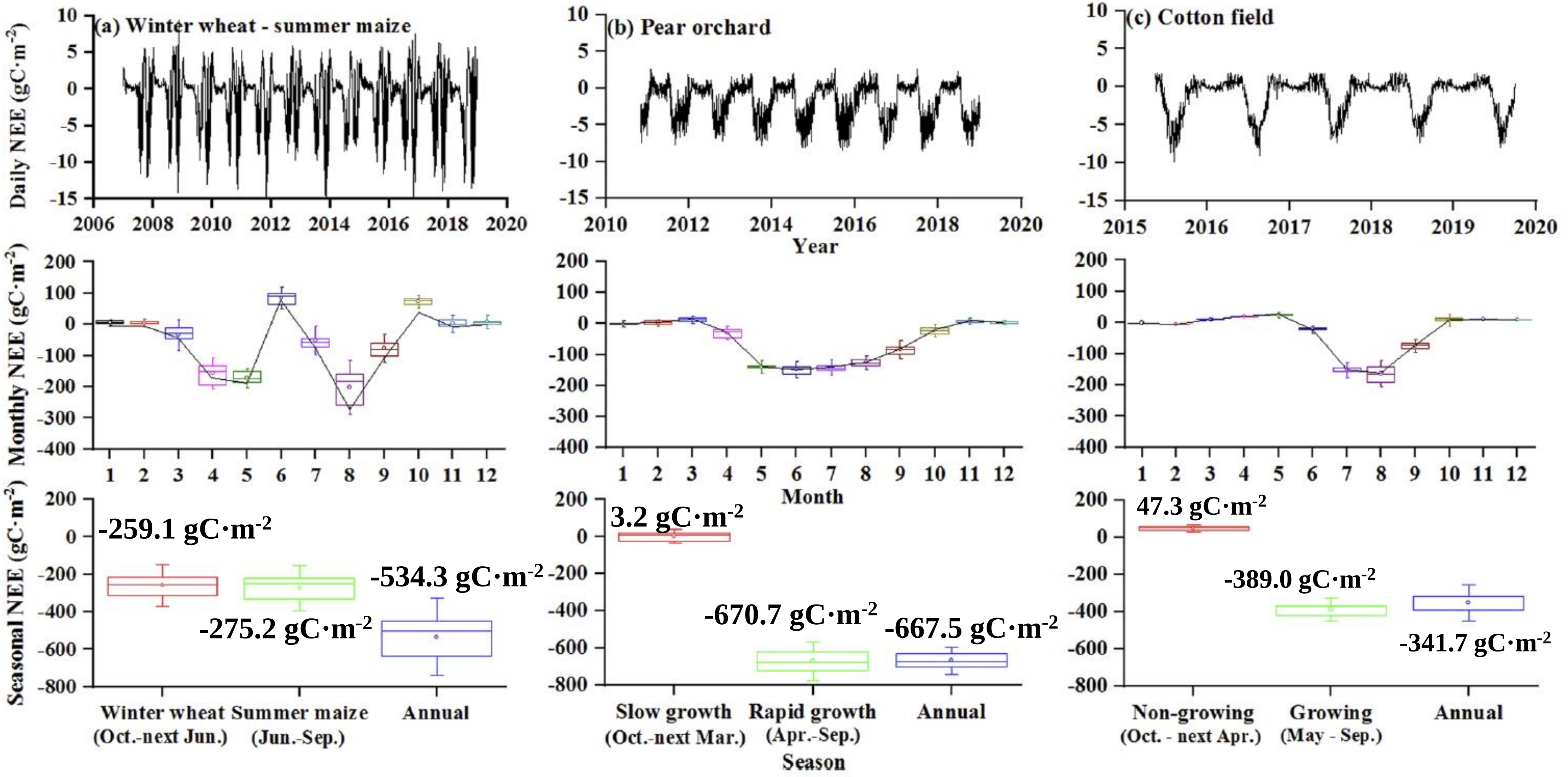
三、不同时间尺度粮-棉-果-蔬农田耗水变化

蔬菜田水平衡对比

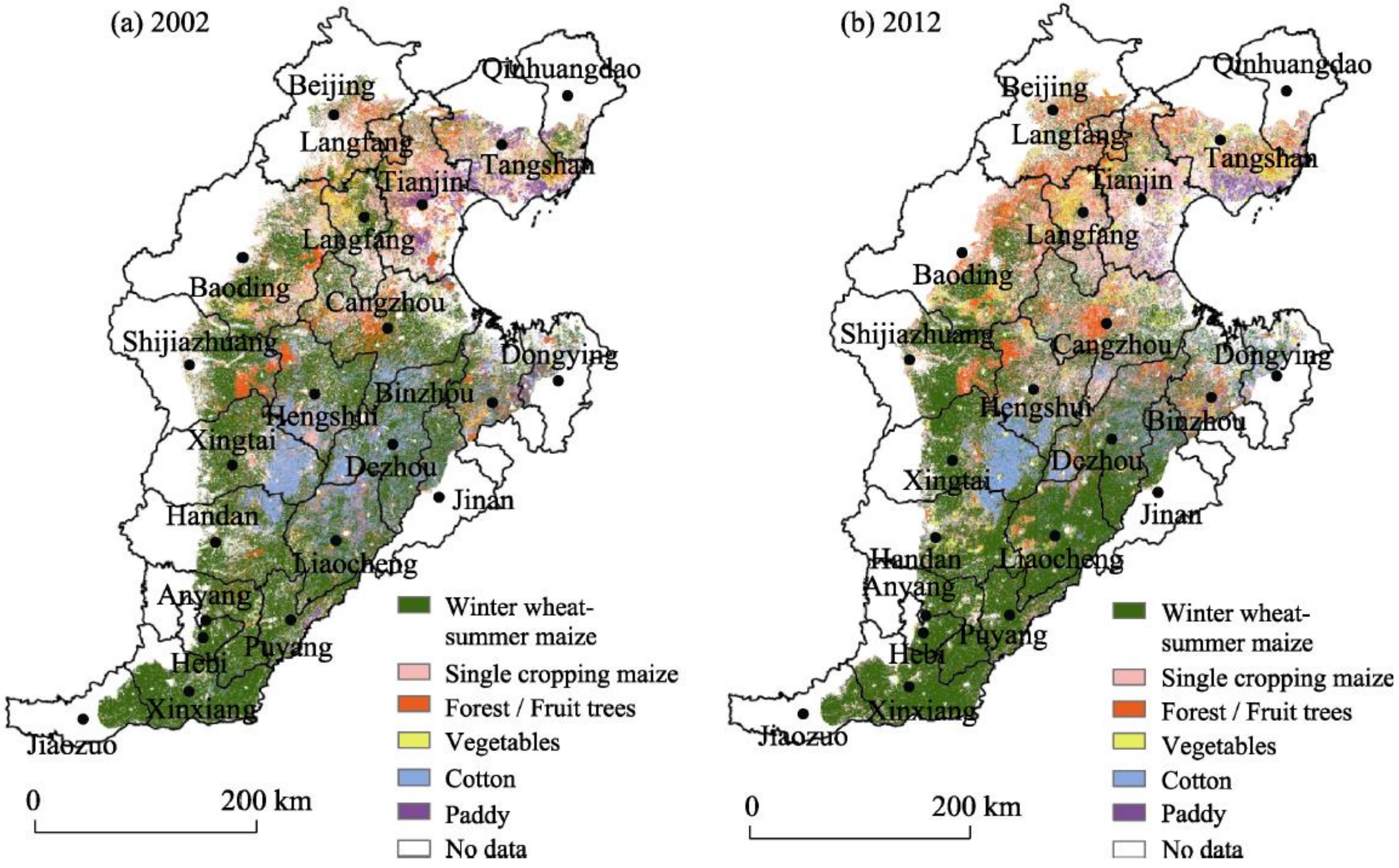


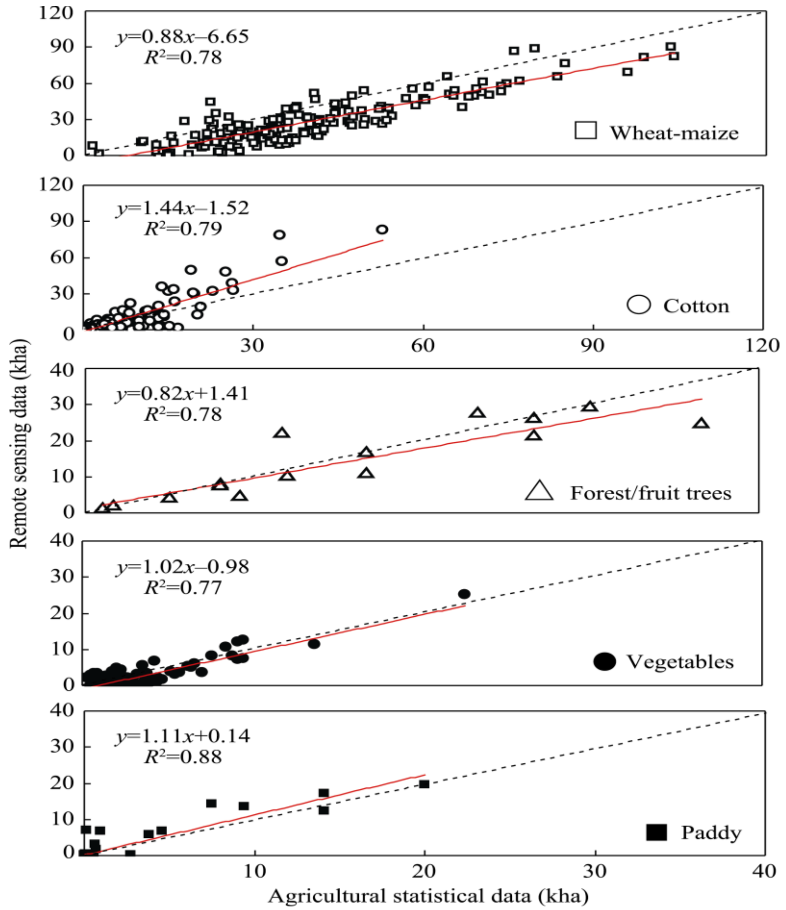
- According to the statistical data, greenhouse-vegetable and outdoor-vegetable accounted for 21.2 % and 78.8 % of the total vegetable growing area in NCP
- Average annual irrigation was 894.5 mm and 520.0 mm, and the soil water drainage was 283.5 mm and 172.2 mm in the greenhouse and outdoor vegetable field, respectively.
- There was no P in the greenhouse vegetable field, while P was 476.0 mm in the outdoor vegetable field during the experimental periods.

三、不同时间尺度粮-棉-果-蔬农田碳通量变化



三、主要类型农业土地利用变化与验证





三、农业土地利用变化对区域耗水与碳通量变化的影响

year	items	Winter wheat – summer maize	cotton	single spring maize	forest / fruit trees	vegetables	paddy	Summation/ **Average**
2002	Area (10^3 ha)	5065.4	1087.4	1045.9	997.6	447.6	283.9	8927.8
	Proportion (%)	56.7	12.2	11.7	11.2	5.0	3.2	100.0
2012	Area (10^3 ha)	5031.2	865.9	1226.1	1271.2	648.0	216.5	9258.9
	Proportion (%)	54.3	9.4	13.2	13.7	7.0	2.3	100.0
Total change of area (10^3 ha)		-34.2	-221.5	180.2	273.6	200.4	-67.4	331.2
ET (mm)		714.2	592.0	600.0	786.2	778.6	999.0	**744.1**
Total change of ET (10^8 m^3)		-2.4	-13.1	10.8	21.5	15.6	-6.7	**25.6**
NEE ($gC \cdot m^{-2}$)		-534.3	-351.3	-509.3	-667.5	-814.8	-1242.0	**-686.5**
Total change of NEE (10^4tonC)		18.3	77.8	-91.8	-182.6	-163.3	83.7	**-257.9**

Notes: [a] ET data of spring maize field was from the research of Sun et al. (Sun et al., 2011) and NEE was from Gao et al. (Gao et al., 2017); [b] NEE of vegetables was from Jia et al. and Zhang et al. (Jia et al., 2012; Zhang et al., 2016), since vegetables are grown three times a year in Southeast China and twice a year in the North China Plain, the NEE results for outdoor vegetables are obtained by multiplying the literature value by two-thirds; [c] ET data of paddy was from Maruyama et al. (Maruyama et al., 2014) and NEE was from Saito et al.(Saito et al., 2005).

三、结论

- 华北平原春玉米、果树(林地)和蔬菜的土地面积明显增加，农业用地总面积增加了331.2×10^3 ha
- 区域ET和NEE分别增加了25.6×10^8 m^3和257.9×10^4 t C，区域碳汇增加的代价是耗水量的大幅增加
- 明确了华北平原主要农业土地利用类型的变化对耗水和碳交换的影响，建议在满足该区域农产品需求的前提下，减少高耗水量作物的种植
- 对华北平原合理调整种植结构，促进农业可持续发展具有重要意义

参考论文

Agriculture, Ecosystems and Environment 338 (2022) 108103

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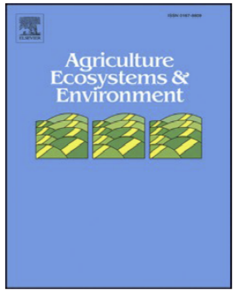

Evapotranspiration and carbon exchange of the main agroecosystems and their responses to agricultural land use change in North China Plain

Check for updates

1. **<u>Zhang, Y.,</u>** Guo, X., Pei, H., Min, L., Liu, F., Shen, Y.*, 2022. Evapotranspiration and carbon exchange of the main agroecosystems and their responses to agricultural land use change in North China Plain. Agriculture, Ecosystems & Environment, 338: 108103.
2. **<u>Zhang, Y.,</u>** Qi, Y.*, Shen, Y., Wang, H., Pan, X., 2019. Mapping the agricultural land use of the North China Plain in 2002 and 2012. Journal of Geographical Sciences, 29(6): 909-921.

致谢

中国科学院遗传与发育生物学研究所农业资源研究中心

Center for Agricultural Resources Research, IGDB，CAS

- 国家自然科学基金面上项目，42171023，基于稳定同位素的作物水-碳耦合关系对水分胁迫的响应机制研究，2022/01-2025/12
- 中国科学院青年创新促进会人才计划项目，2017138，华北平原典型农业生态系统耗水机制及其调控研究，2017/01-2020/12
- 国家自然科学基金面上项目，31870422，华北平原典型农田生态系统用水有效性与调控机制的多尺度研究，2019/01-2022/12
- 国家重点研发计划重点专项专题，2016YFC0401403-2，农田系统耗水监测与田间水管理机制研究，2016/07-2020/12
- **ChinaFlux 通量观测专项，栾城小麦玉米轮作农业生态系统通量观测研究站，2013-**

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