
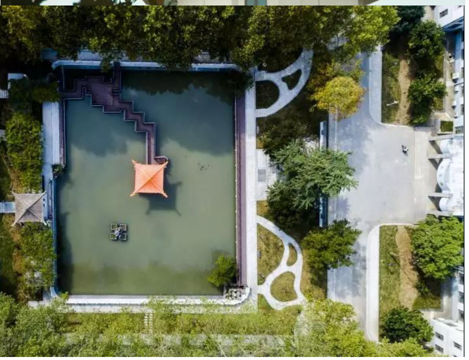

Land management extends the duration of climate extreme impacts on vegetation over a double-cropping region in China

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Climate extremes and the carbon cycle

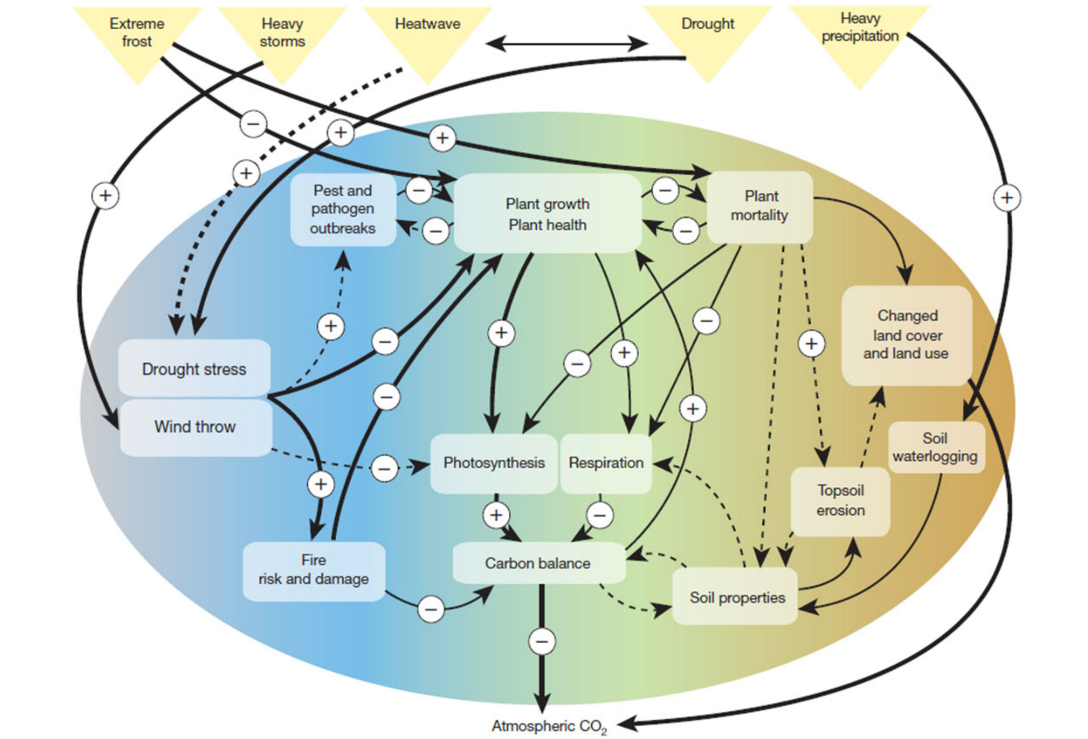


Figure 1 | Processes and feedbacks triggered by extreme climate events. The extreme events considered are droughts and heatwaves, heavy storms, heavy precipitation and extreme frost. Solid arrows show direct impacts; dashed arrows show indirect impacts. The relative importance of the impact relationship is shown by arrow width (broader arrows are more important).

Table 1 | How forest, grasslands and croplands are affected by climate extremes

Land-cover type	Extremes	Key impact mechanisms	Examples of documented highly susceptible regions	Scientific understanding of future occurrence[12]	Scientific understanding of carbon-cycle impact
Forest	Storms	• Wind throw transforms carbon stock from living biomass to dry, dead wood • Wind throw increases risk of fires and pathogen outbreaks	The Amazon[38], North America[36,37], central Europe[35]	Low	Medium
	Drought Heat	• Water availability affects plant physiology, phenology and carbon allocation patterns • Increased tree mortality, fire risk and susceptibility to pathogens • Shifts in vegetation composition (impacts are large and delayed owing to the longevity of trees)	Central Europe[27,28], western North America[31], the Amazon[30,32]	Low to medium Medium to high	Low Low
	Fire	• Tree mortality has a large, fast impact on large carbon stocks in forests	Western North America[76], southeastern Asia[7], the Mediterranean[77], the circum-boreal areas[39], the Amazon[78]	Low	Low
	Ice storm and frost	• Physical damage can include destruction of whole forest • Xylem embolism and desiccation[79]	China[80], North America[81,82]	Medium to high (for cold temperatures)	Low
Grasslands	Drought Heat	• Species composition shifts (especially combined with additional pressure such as overgrazing) • Degradation and desertification (especially combined with overgrazing) • Erosion (combined with heavy precipitation or storms)	North America[83,84], Europe[85], central Asia[86]	Low to medium Medium to high	Medium Low
Croplands	Storms	• Wind erosion and soil displacement with unclear consequences for the carbon cycle • Direct crop damage	China[87], North America[88]	Low	Low
	Heavy precipitation (including hail)	• Erosion causing loss and displacement of soil and hence carbon • Erosion affecting the soil's long-term productive capacity • Crop damage or failure caused by hail and waterlogging of soils and subsequent anaerobic conditions • Crop lodging, that is, the permanent displacement of cereal stems from the vertical • Increase of pests and pathogens	The tropics[89], North America[90], Australia[91], the Mediterranean[92], western Europe[52], east Asia[93]	Medium to high (low for hail)	Low
	Drought and heat	• Reduced growth or complete crop failure	Europe[5,34,93], North America[94], China[95]	Low to medium	Medium
	Extreme cold	• Reduced growth • Complete winter-crop failure, especially during spring frosts (combined with drought stress)	North America[96], south Australia[97], Europe[98]	Medium to high	Low

It says" evidence is mounting that climate extremes such as droughts or storms can lead to a decrease in regional ecosystem carbon stocks and therefore have the potential to negate an expected increase in terrestrial carbon uptake."

Reichstein, M., et al. 2013. Climate extremes and the carbon cycle. *Nature*, *500*(7462), pp.287-295.

Climate extremes and the carbon cycle

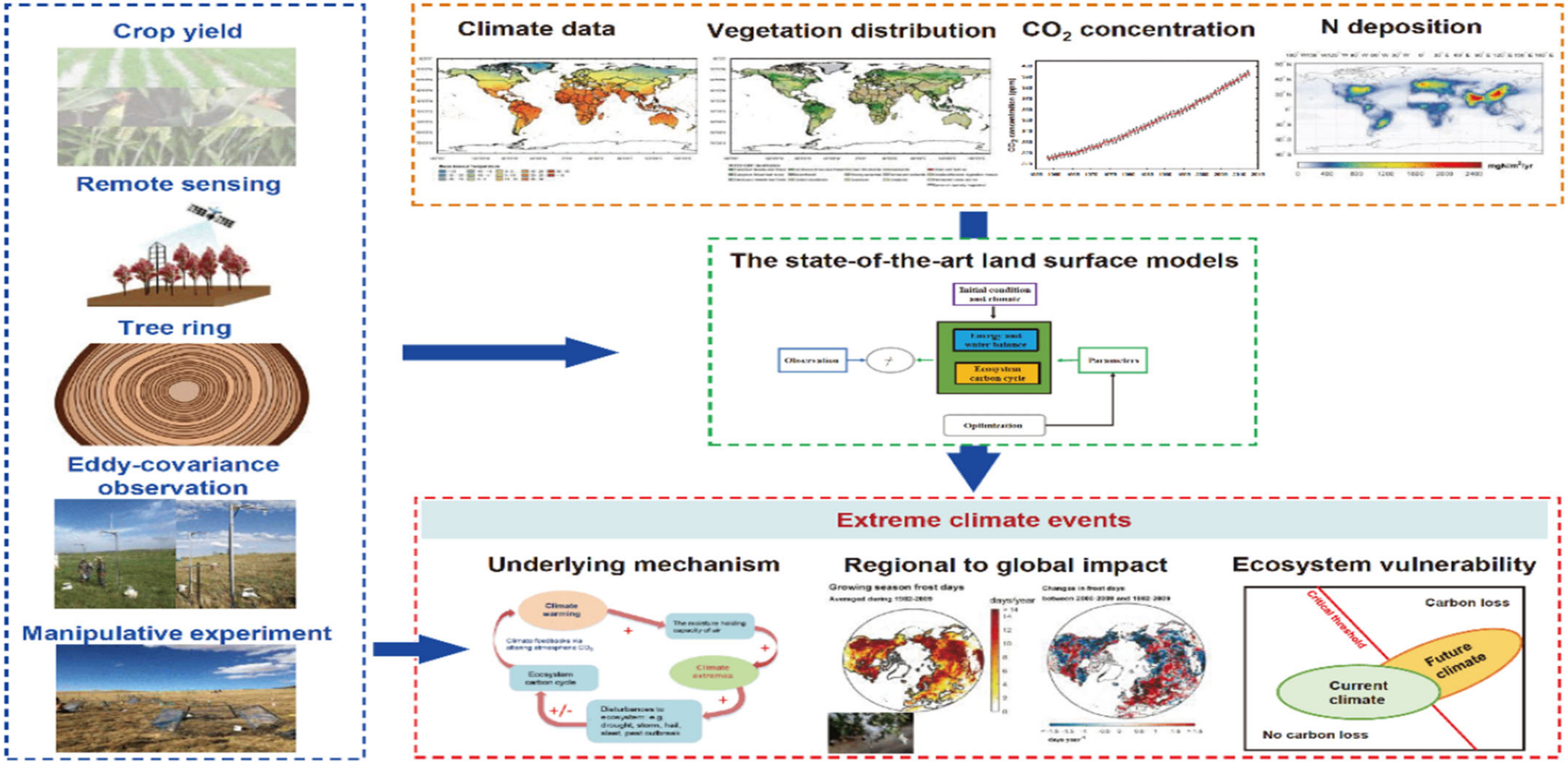


Figure 3 Schematic diagram of the research framework for investigating the impact of extreme climatic events on the terrestrial carbon cycle, which jointly uses multi-source ground and satellite observations and land surface models.

Piao, S., Zhang, X., Chen, A., Liu, Q., Lian, X., Wang, X., Peng, S. and Wu, X., 2019. The impacts of climate extremes on the terrestrial carbon cycle: A review. Science China Earth Sciences, pp.1-13.

land management change

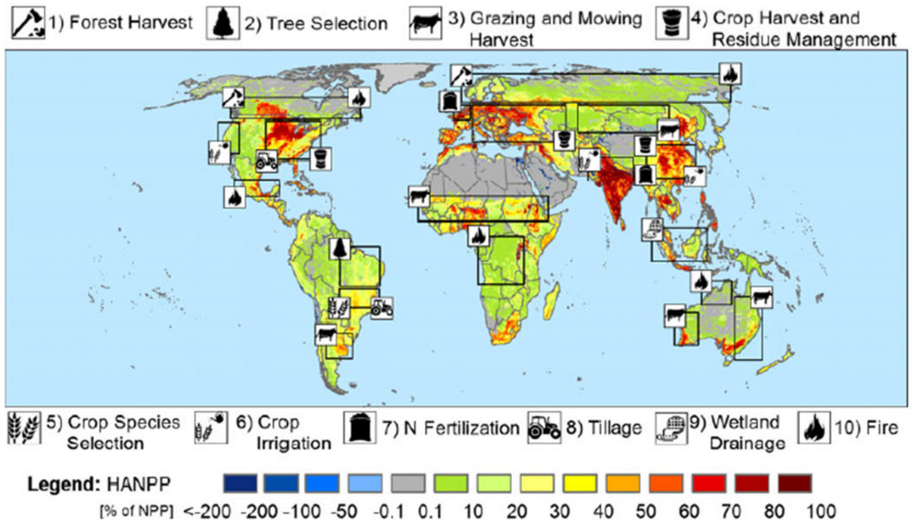


Fig. 1 The ten selected management activities and a selection of geographic regions where these activities play an important role. The background map displays the human appropriation of net primary production (Haberl *et al*., 2007; Copyright 2007 National Academy of Sciences, USA), that is the ratio between annual potential net primary production (NPP) and NPP remaining in ecosystems after harvest. Negative values indicate areas where due to management NPP remaining in ecosystems surmounts the hypothetical potential NPP.

1. a good knowledge base exists (cropland harvest and irrigation)
2. sufficient knowledge on biogeochemical and biophysical effects exists but robust global data sets are lacking (forest harvest, tree species selection, grazing and mowing harvest, N fertilization)
3. with severe data gaps concomitant (crop species selection, artificial wetland drainage, tillage and fire management and crop residue management, an element of crop harvest).

Erb, K.H., et al., 2017. Land management: data availability and process understanding for global change studies. *Global change biology*, *23*(2), pp.512-533.

double-cropping systems

1. DC system

- Planting twice on a certain cropland during a calendar year. DC systems are widely used to enhance crop production worldwide.

- There are two transition (harvest-sowing) periods in the DC systems. In order to obtain sufficient growth periods and guarantee the yield, DC systems generally require strict control over the time of harvest and sowing.

2. Hypothesis

- in theory, extreme events that occur during the transition may have an impact on the entire crop growth period.

Study area

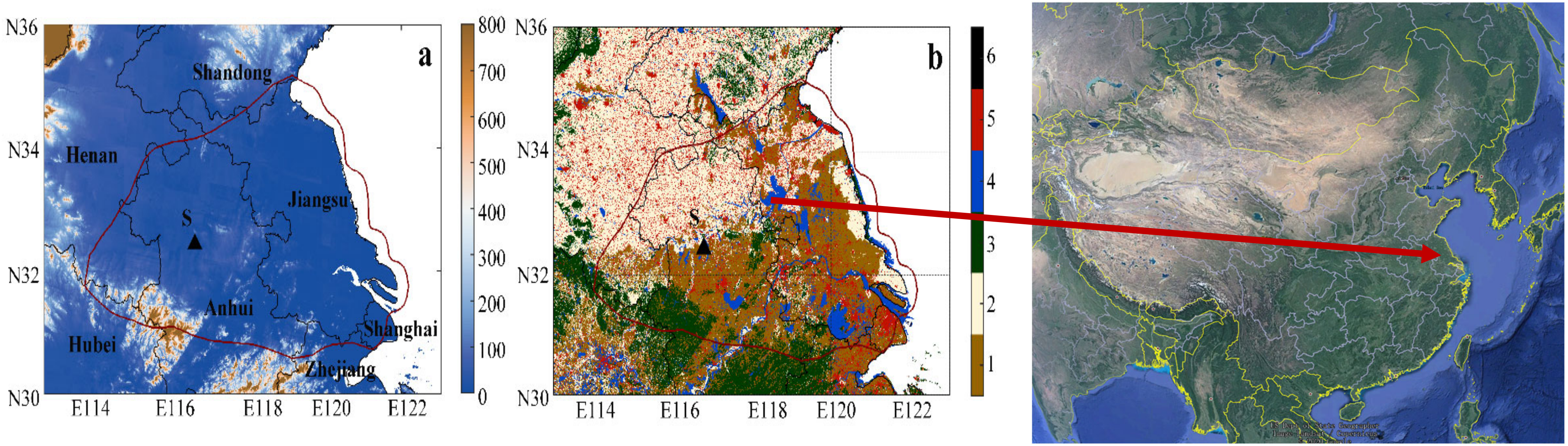
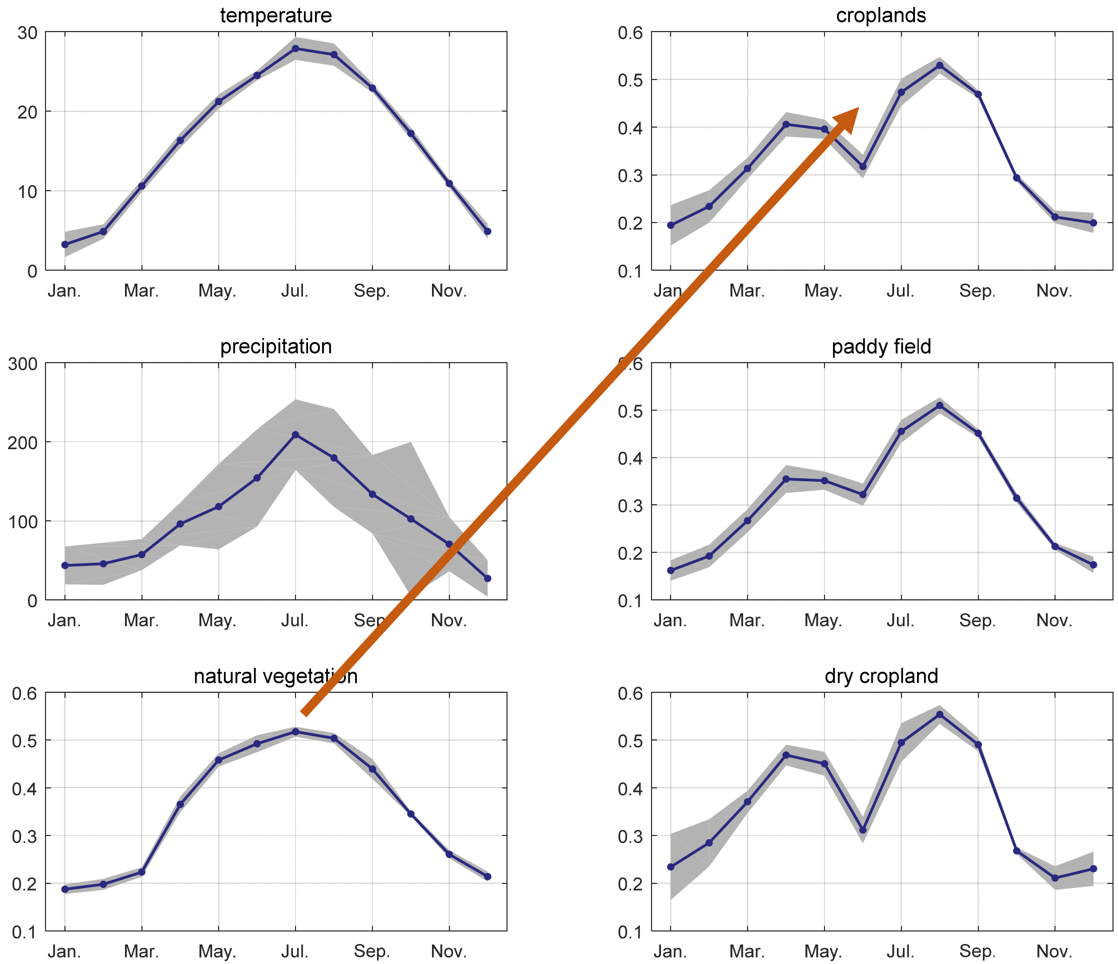
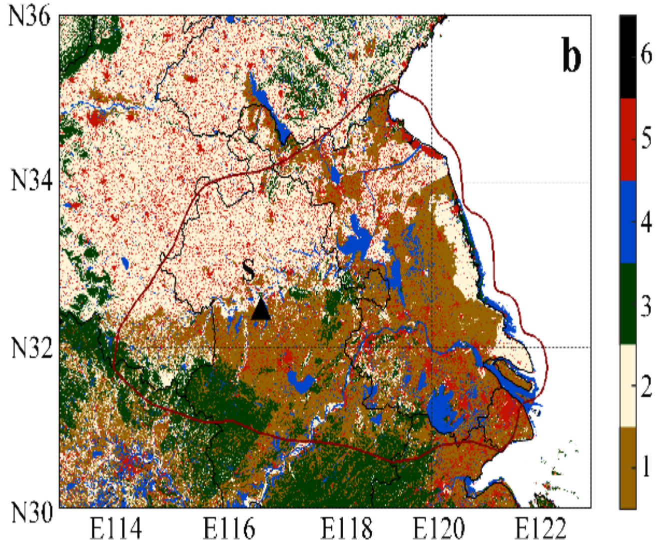


Figure 1, topography (a), land cover (b) of the study area. More details of the legend of land cover type are listed in Table1. The extension of precipitation extreme events is illustrated by red line. Letter S indicates the eddy flux site in Shouxian National Climate Observatory.

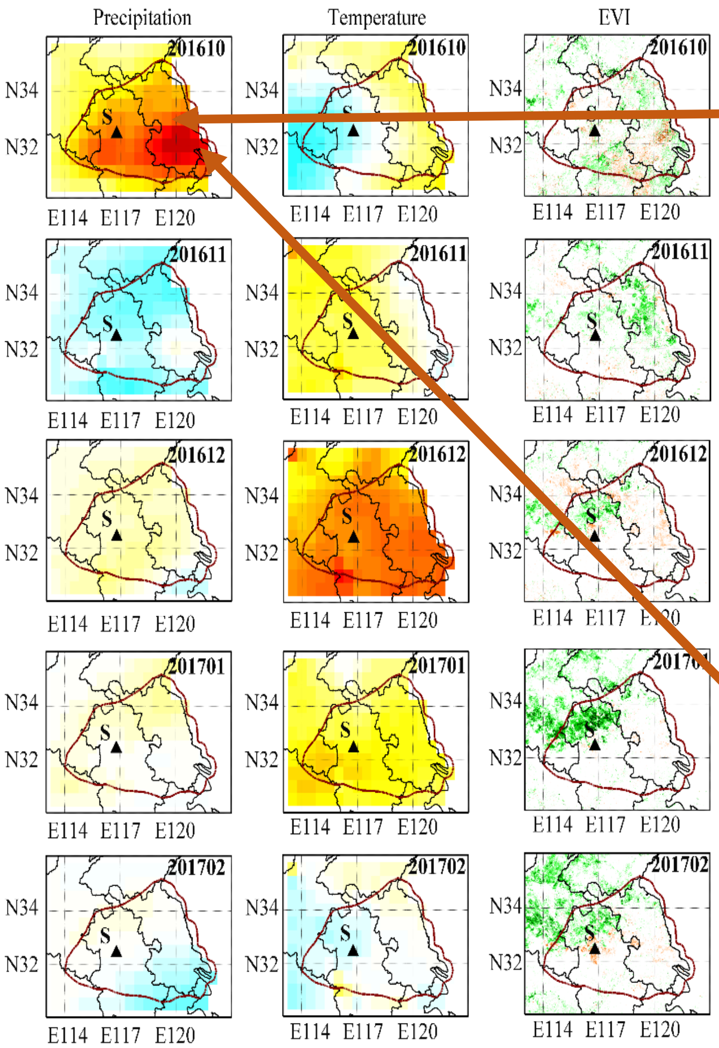
Study area





A very typical DC region. the seasonal cycles of monthly temperature (a), precipitation (b) and EVI of natural, croplands, paddy field and dry cropland (c-d). Blue curve lines are the averages of each month with standard deviations indicated by grey areas.

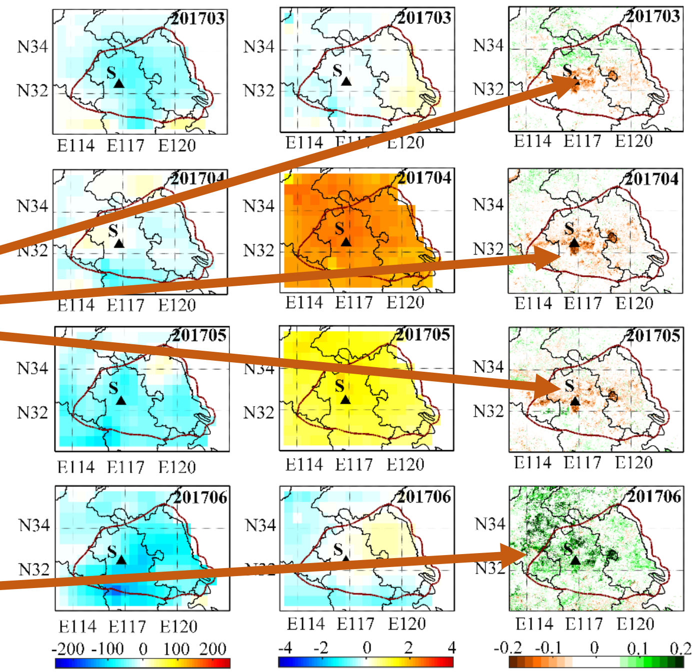
Waterlogging triggered by heavy rain and its impact

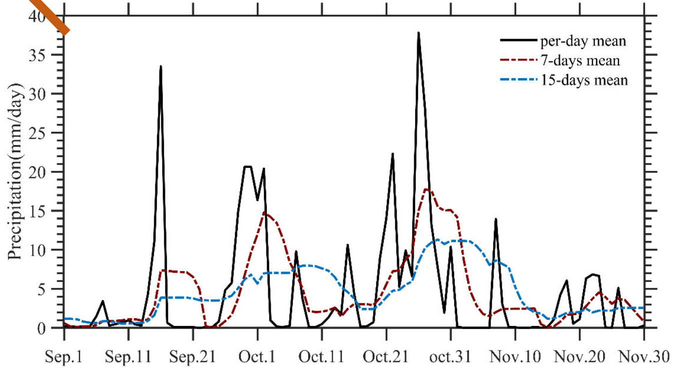


Waterlogging disasters were triggered by an extreme precipitation event occurred in October 2016,

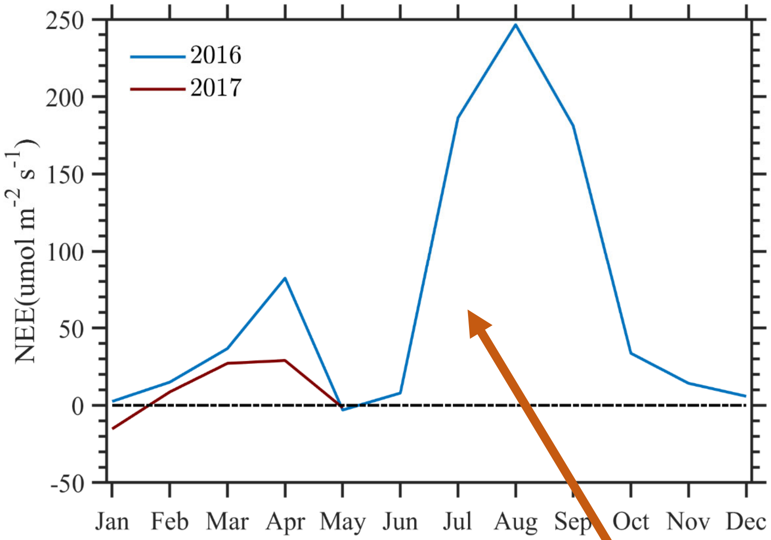
The lack of sowing led months negative EVI anomalies, especially from March to May 2017.

The influence of vegetation indicated by EVI was ended in June 2017 when summer crops were planted.



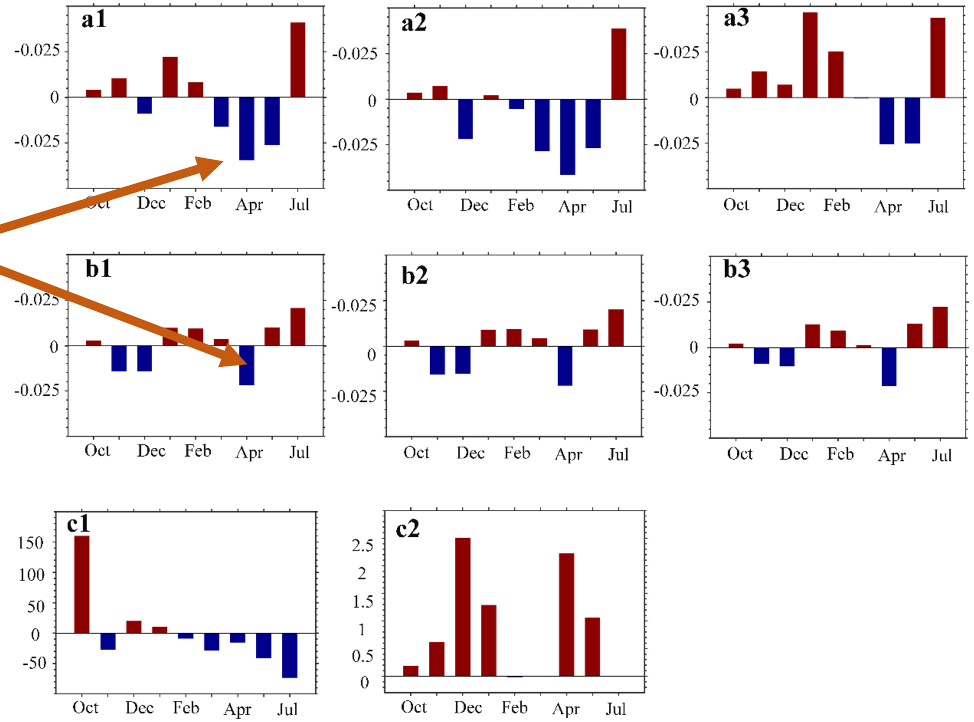


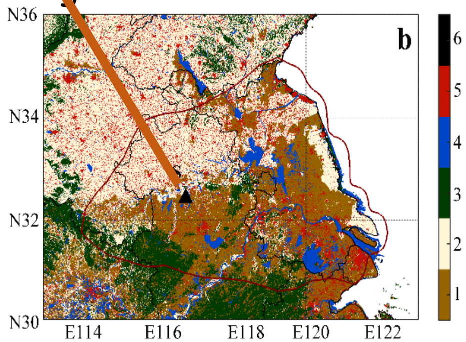
Waterlogging triggered by heavy rain and its impact



monthly NEE (net ecosystem exchange) records based on an eddy flux tower in the Shouxian National Climate Station during 2016-2017.

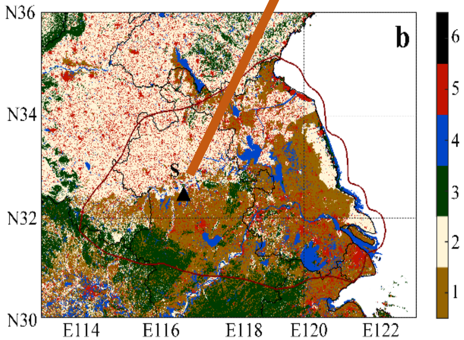
The impacts on natural vegetation and crops are totally different.





monthly anomalies of regional averaged EVI, precipitation and temperature. a1-a3 (left column of panels) indicate EVI anomalies of all croplands, paddy croplands, dry croplands. b1-b3 (middle column of panels) indicate EVI anomalies of natural vegetation, woodlands and grasslands. c1-c2 (right column of panels) indicate the precipitation and temperature anomalies.

seeing is believing



we conducted a field trip to the Shouxian Observatory where the eddy flux tower is located. The date was 29 March 2017.

seeing is believing

Crop conditions inside and outside the station. a) and b) were taken inside the station, which located in the field of view in FigS2c above. c) and d) were taken in north of the station, which located in the field of view in FigS2d above. The short green plants are **winter wheat** and the plants with yellow flowers are **rapeseed**. The date was 29 March 2017.

Future perspective

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Changes in the Potential Multiple Cropping System in Response to Climate Change in China from 1960–2010

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LETTER

Response of double cropping suitability to climate change in the United States

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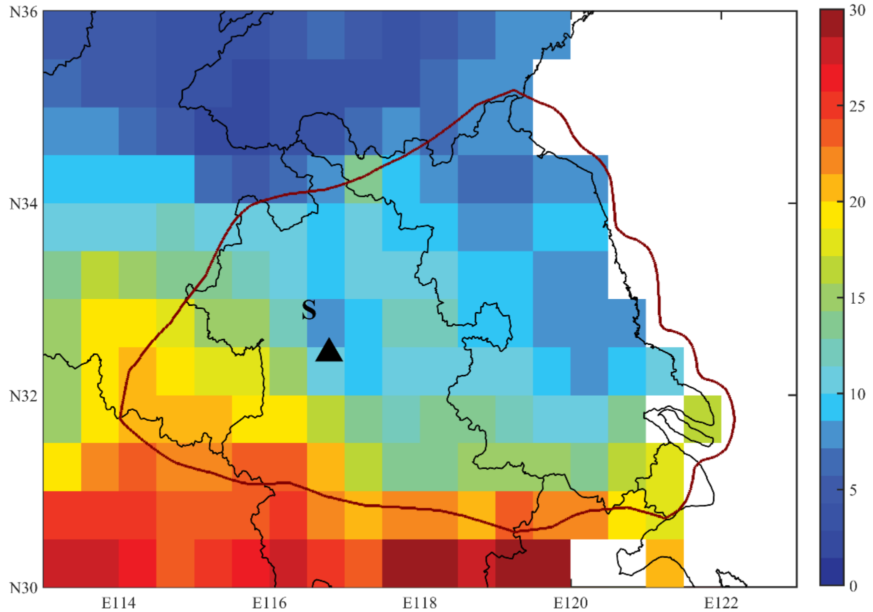

the frequency (in percentage %) of precipitation i
October exceeds 100mm during 2015-2100. Th
frequency was calculated based the average frequenc
of 14 models listed in Table 2.

With global warming, the area suitable for DC systems has expanded and is expected to continue to expand. Using latest CMIP6 results, we selected 14 models outputs during the standard period of 2015 – 2100 under SSP2-4.5. As illustrated here, spatial distribution of the probability of precipitation exceeding a threshold of 100 mm in October.

Thanks for your time!