Impact of prolonged drought on rainfall use efficiency across China in the early 21th century

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INTRODUCTION

Net Primary Productivity (NPP)

- NPP is the rate at which all the plants in an ecosystem produce net useful chemical energy. As the foundation of energy flow and nutrient cycle for organisms, NPP plays an important role in the global carbon balance, and alterations in ecosystem NPP greatly affect CO^2 exchange between the land and the atmosphere. The interaction of NPP with climate has been a key focus of ecological study in recent years.

Rainfall use efficiency (RUE)

- RUE is the ratio of NPP to precipitation, has been suggested an effective integrating measure for evaluating the response of NPP to spatial and temporary changes in precipitation.

Prolonged drought

- Increased aridity and persistent droughts are projected in the 21st century for most of Africa, southern Europe and the Middle East, most of the Americas, Australia and Southeast Asia. China suffered from a series of severe droughts during the first decade of the 21st century. The drought in China in 2010 was the most severe in the last 50 years and was considered to be a 'once in a century drought' .
- Sala et al. (2012) reported that current-year drought explained only a small proportion of the variation in annual ANPP, and the previous year drought contributed significantly to changes in ANPP.

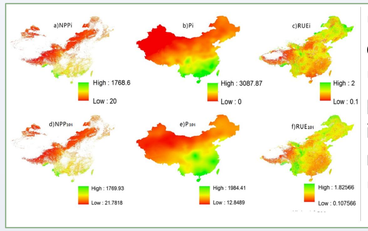
OBJECTIVES

❖Investigate the relation between the variation of annual NPP and precipitation.

❖Determine the impact of prolonged drought on NPP and RUE.

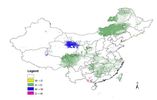
❖Based on the patterns of RUE change with the prolonged drought, create an empirical model on RUE change with previous- and current-year PDSI.

DATA AND METHODS



- The annual NPP is derived from MODIS global data set (MOD17A3) at 1-km resolution over the time period from 2001 to 2010
- The annual precipitation (P)is derived from 726 meteorological stations across China, provided from Climate Database of China Meteorological Administration (CMA), and is interpolated at 1-km resolution using a kriging method based on the digital elevation model
- RUE=NPP/P

Biome map: Four types of biomes - Needleleaf Forest, Broadleaf Forest, Woody Savannas and Grassland were selected from the biome map of China, generated from the MODIS land cover product (MOD12Q1). This analysis was limited to these four distinct biomes, and four biomes combined.



Drought type: Based on the PDSI from years 2000 to 2010, all the cells were divided into wet years and dry years based on a threshold T, where T_{dry} is the threshold for the bottom 25th percentile of PDSI for 11-year record and T_{wet} equals zero. Then for each year, a map was derived with each cell classified into one of the four categories on drought type based on the current and previous-year drought type.

Definitions:(using NPP as an example):

$NPP_{i=year}$, $NPP_{i,j=biome}$, $NPP_{i,j,k=drought\ type}$: NPP values in a certain year, biome and drought type.(i=10i means the average value over the entire 10-year period 2001-2010).

$\overline{NPP_{i=year}}$, $\overline{NPP_{i,j=biome}}$, $\overline{NPP_{i,j,k=drought\ type}}$: the bar signifies the mean of all the values within the time periods i or 10i.

$$\Delta\overline{NPP_i}=\overline{NPP_i}-\overline{NPP_{10i}} \qquad \text{Normalized } \Delta\overline{NPP_i}=\Delta\overline{NPP_i}/\overline{NPP_{10i}}$$

$$\text{Normalized } \Delta\overline{NPP_{j,k}}=\sum_{i=2001}^{2010}\left(\left(\left(\overline{NPP_{i,j,k}}-\overline{NPP_{10i,j,k}}\right)/\overline{NPP_{10i,j,k}}\right)\times C_{i,j,k}\right)/\sum_{i=2001}^{2010} C_{i,j,k}$$

Where $C_{i,j,k}$ is the number of pixels in a certain year, biome and drought type.

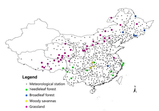
Modeling method:

Based on a previous study reporting that RUE was affected by the current-year drought, we assumed that $\text{normalized } \Delta\overline{RUE_i}$ was function of current-year PDSI :

$$\text{Normalized } \Delta\overline{RUE_i}=a+b\times PDSI_i \qquad (1)$$

However, the previous-year drought also affect the RUE, we derived a logical relation between $\text{normalized } \Delta\overline{RUE_i}$ and both previous- and current-year PDSI:

$$\text{Normalized } \Delta\overline{RUE_i}=a+b\times PDSI_i+c\times PDSI_{i-1} \qquad (2)$$



Modeling calibration dataset: A subset of all the data was extracted for model calibration. The location of calibration dataset was chosen from the 726 meteorological sites. 54 sites were associated with the dominant biome by visual interpretation with Google Earth. We averaged the RUE and PDSI data over an area of 3km*3km (3*3 pixels) based on the coordinates for each site.

RESULTS AND DISCUSSION

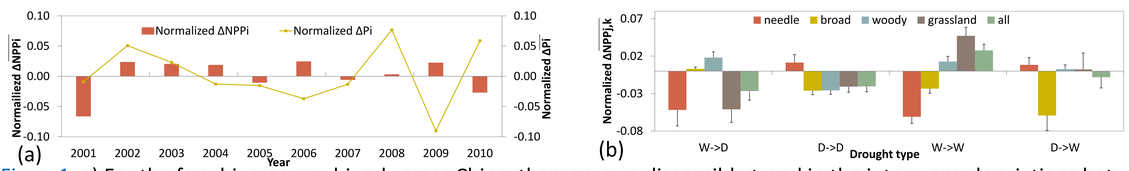


Figure1. a) For the four biomes combined across China ,there was no discernible trend in the inter-annual variations between NPP and precipitation. b)For each biome and all biomes combined, normalized $\Delta\overline{NPP_{j,k}}$ had different relations with drought.

RESULTS AND DISCUSSION

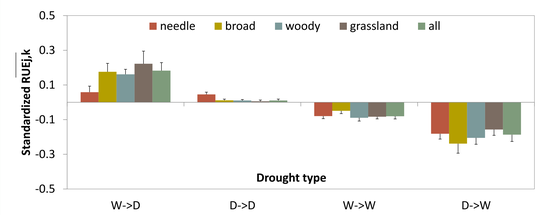
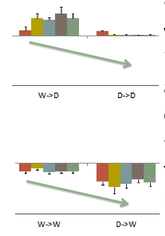


Figure 2. For each biome and all biomes combined, Normalized $\Delta\overline{RUE_{j,k}}$ showed a significantly declining trend with the variations in previous- and current-year drought.



- Normalized $\Delta\overline{RUE_{j,k}}$ was positive in dry year and decrease when the previous-year is dry year because of the biome resilience and the resilience decrease with prolonged drought.
- The legacy effects result from transitions from dry to wet years or the reverse (W->D, D->W). The legacy effects from wet year made that the NPP was higher than normal year and lower because of the dry year legacy effects.

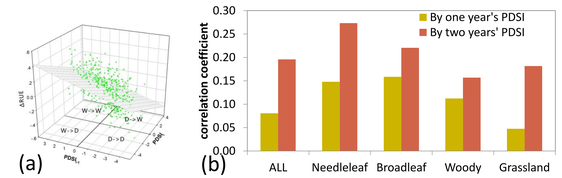


Figure 3. a) Based on the trend of RUE, we created the model of normalized $\Delta\overline{RUE_i}$ by previous- and current-year PDSI: $\text{Normalized } \Delta\overline{RUE_i}=-0.0109+(-0.0537PDSI_i)+0.0419PDSI_{i-1}$

b) The correlation coefficient (R^2) of the normalized $\Delta\overline{RUE_i}$ model by current-year PDSI (Eq. 1) and by two-years PDSI (Eq. 2).

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