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Carbon dynamics and its responses to environmental drivers of desert steppe in Inner Mongolia, China

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1 Introduction

Arid and semi-arid ecosystems are playing an important role in defining the interannual trends and variability of the terrestrial carbon (C) cycle, mostly driven by the high turnover of organic C in these ecosystems[1]. The high turnover rate increases the uncertainty of C budget estimates and reduces the stability of C sequestration in these ecosystems.

Although many rangeland management policies have improved ecosystem conservation, the complexity of these ecosystems and their relationships with climate change have created long-term feedbacks that govern the dynamics of the of C stock, making the impacts uncertain[2,3].

Inner Mongolia's temperate desert steppe is one of the most sensitive vegetation types among the world's semi-arid and arid ecosystems It therefore provides an excellent context for analyzing the impact of environmental change on C sequestration.

Therefore, the long-term adaptive response to environmental changes of the processes and potential driving mechanisms in Inner Mongolia's desert steppe ecosystems is of great significance for arid and semi-arid ecosystems, as well as global carbon cycle changes.

2 Study area

In our study, we focused on a temperate desert steppe located in the southern part of the Mongolian Plateau, which is a transition zone between deserts and steppes in Inner Mongolia, northern China (Fig. 1). The study area is at the limit of the East Asian Summer Monsoon, and is therefore influenced by a combination of the monsoon climate and the temperate continental climate. The mean annual temperature ranges mainly from 3.5 to 8.5℃, and the mean annual precipitation ranges from 140 to 265 mm. The precipitation occurs mainly (85%) between May and September and reaches a maximum in August, and the growing season is from April to October.

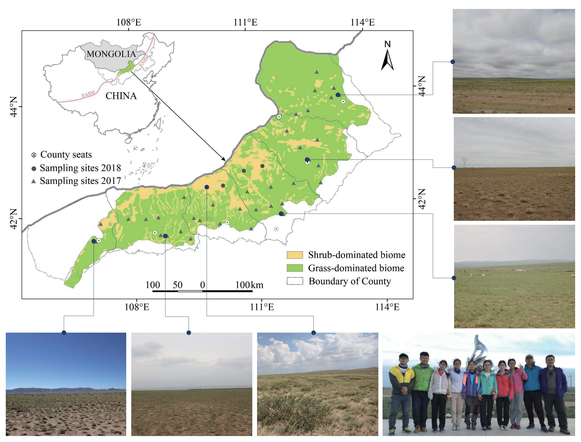

Figure 1. Distribution of sampling sites in the temperate desert steppe ecosystem of Inner Mongolia.

3 Model description

We chose the TECO-R model for our study[4]. TECO-R is an ecological process model that combines inversion analysis with genetic algorithms.

TECO-R contains two submodels: a light-use efficiency (LUE) scheme based on the Carnegie-Ames-Stanford Approach (CASA) and the Vegetation And Soil Carbon Transfer (VAST) model[5]. These submodels (respectively) simulate the ecosystem's net primary productivity (NPP) and the large-scale dynamics of terrestrial C pools.

We constructed a framework that combined data on the local conditions of the desert steppe with the TECO-R algorithms (Fig. 2). The anthropogenic activity accounted for by the model was rotational grazing, and we used grassland and shrub terrestrial biomes in the model of the desert steppe region. The calculations performed by TECO-R for the desert steppe, including assimilation of the field observations and spatially explicit satellite data to synthesize information in the model.

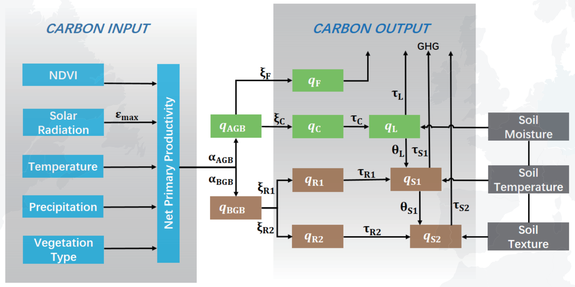

Figure 2. Framework for the structure of the TECO-R model for Inner Mongolia's desert steppe and its simulation parameters.

4 Result

The total C stock of the desert steppe ecosystem in our study area was 288.29±10.35 Tg.

The soil C storage to a depth of 50 cm accounted for 92.3% of the total ecosystem stock for the grassland biome, versus 87.9% for the shrub biome.

The soil carbon density of grassland biome is 1.29 times that of shrub biome.

Table 1. The average C stock and C density in the desert steppe ecosystem for the two biomes and total region.

Desert steppe	No. of sites/plots	Area (×10⁴ km²)	C pool	C density to a depth of 50 cm (g C m²)	C stock (Tg C)
Grassland biome	35/105	8.74	q_{BMC}	215.92±4.88	18.86±0.43
			q_{SOC}	2634.88±98.57	230.16±8.61
			Total	2850.79±102.05	249.02±8.91
Shrub biome	10/30	1.79	q_{BMC}	266.14±7.61	4.79±0.14
			q_{SOC}	1927.99±77.86	34.68±1.40
			Total	2194.13±82.95	39.47±1.49
Total region	45/135	10.53	q_{BMC}	224.49±5.29	23.65±0.56
			q_{SOC}	2512.31±94.57	264.64±9.96
			Total	2736.81±98.26	288.29±10.35

The ecosystem C (q_{ECO}) in stdudy area showed an overall increasing trend, at 27.75 g C m^{-2} yr^{-1}, with the highest rates in the southeastern part of the study area.

This rate averaged 33.54 g C m^{-2} yr^{-1} for the grassland biome and 25.74 g C m^{-2} yr^{-1} for the shrub biome.

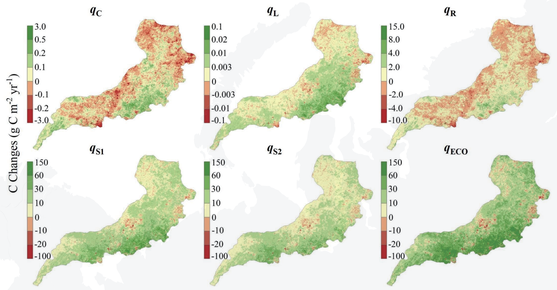

Figure 3. Changes in the C density for different C pools throughout the study area.

The precipitation and temperature increase rate during outside the growing season was higher than that during the growing season.

The SPEI drought index trend showed that drought was common in the central and southeastern parts.

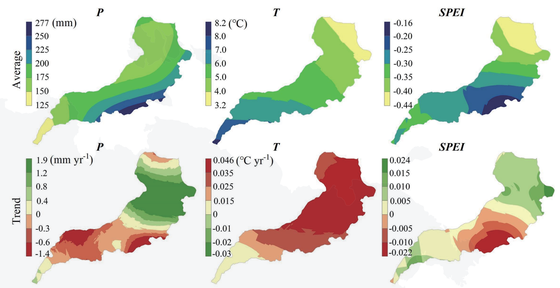

Figure 4. Spatial distribution of average annual and the trends of precipitation (P), temperature (T) and SPEI.

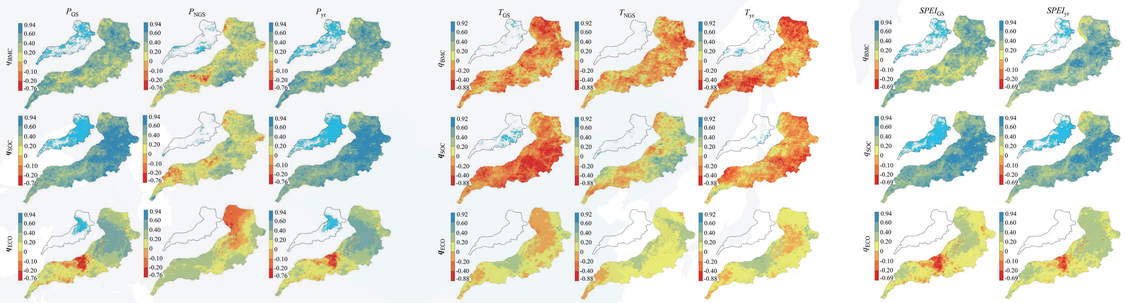

Figure 5. Spatial pattern of the correlation (Pearson's r) between precipitation, temperature, and SPEI with the C pools in the vegetation biomass (q_{BMC}), in soil organic C (q_{SOC}), and in the whole ecosystem (q_{ECO}) for different time scale.

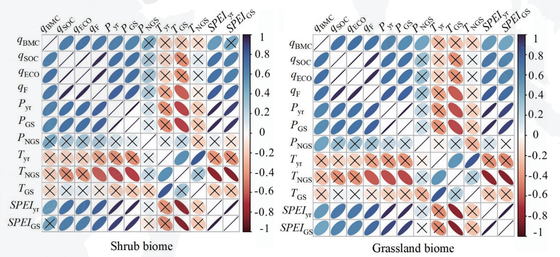

Figure 6. Summary of the correlations (Pearson's r) among the C pools and the environmental variables from 2000 to 2017.

Reference

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5 Conclusion

The desert steppe ecosystem C stock totaled 288.29 Tg C and with increasing trend of 3.09 Tg C yr^{-1}, and 91.6% C is stored in soil.

The desert steppe ecosystem was functioning as a C sink, and SOC is positively correlated with precipitation and temperature in spatial distribution.

The increasing precipitation and temperatures outside the growing season affected the drought stress experienced by plants during the growing season.

The C storage was higher for the grassland biome than the shrub biome, and the grassland biome was more sensitive to climate change, whereas the shrub biome was more drought tolerant.

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