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The Dataset Curation of Vegetation Net Primary Productivity and Climate Impacts in China in the Following Century

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Abstract: Ecosystem model simulation is one of the most important methods for studying the impacts of climate change on ecosystem. Presently, most ecosystem models predict an increasing net primary productivity (NPP) in most regions of the globe, however, interannual changes in NPP and its stability at long time scales of nearly 100 years have rarely been studied under future climate scenarios. The interannual NPP with a spatial resolution of 0.1° was simulated for the terrestrial ecosystem of China for the period from 2006 to 2019, through an ecosystem process model carbon exchange between vegetation, soil and atmosphere-remote sensing (CEVSA-RS) using RCP4.5 and RCP8.5 climate scenarios data from the Regional Climate Model Version 4 (RegCM4.6) and Coupled Model Intercomparison Project Phase 5 (CMIP5). Then the dataset described here was produced and includes the interannual trends, multi-year averages, and stability data for the period from 2006 to 2099, but also in time periods: the early period (2006–2035), the middle period (2036–2065), and the far period (2066–2099), each under the RCP4.5 and RCP8.5 climate scenarios. This dataset has scientific and practical application potential for climate change mitigation and research and adaptation actions.

Keywords: NPP; CEVSA-RS model; future climate scenarios; stability

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1 Introduction

Vegetation net primary productivity (NPP) characterizes the rate of atmospheric carbon fixation and biomass accumulation through photosynthesis[1]. It is the primary basis for studying the response of global terrestrial ecosystem to climate change[2]. Climate factors driving changes in carbon sinks are highly heterogeneous in time and space[3], and resulting fluctuations in productivity can have an impact on carbon fixation[4]. How to cope with the rising temperatures, changing precipitation patterns, and determine the degree of stabilization of NPP under global change is an important research topic today.

Ecosystem model simulation is one of the most important methods used to study the response of terrestrial ecosystem to climate change[5, 6], which is usually categorized into climate statistical models, remote sensing parameter models and ecological process models[7, 8]. Ecological process models based on small-scale, fine-tuned experimental analyses, can more accurately predict future changes from ecosystem mechanistic simulation. By combining these predictions with remote sensing parameter models, model-data fusion can be accomplished in order to produce a more accurate simulation of ecosystem carbon dynamics[9–12]. Considering effects from hydrology, atmospheric carbon dioxide, land cover and land use change, species composition and nitrogen deposition on the carbon cycle of terrestrial ecosystem, those effects can be more accurately simulated, which can greatly improve the accuracy and precision of models to simulate the responses of terrestrial ecosystem to climate change, and has been considered an important research field for future model improvements[13]. The remote sensing-driven ecosystem process model (CEVSA-RS), has high accuracy in simulating ecosystem productivity[14, 15]. The model provides the methodological basis for diagnosing the historic dynamics of carbon cycles and predicting future responses to climate scenarios for terrestrial ecosystem by opening or closing remote sensing-driven submodule.

The dataset described here incorporated a future climate that was simulated based on different GHG emission scenarios in CMIP5. However, the two scenarios selected, RCP 4.5 and RCP8.5, are important because the RCP4.5 simulates a balanced economic development model as the "better situation" of climate change if the measures will be implemented to effectively mitigate climate change, while RCP8.5 represents the "worst situation" climate change without taking any effective measures.

Therefore, in the dataset described here, vegetation NPP was simulated through the CEVSA-RS model. The simulation considered the two climate scenarios of RCP 4.5 and RCP8.5 for the terrestrial ecosystem in China. The annual NPP were output for the period from 2006 to 2099. Then the average, trend and stability of the NPP were calculated for the different periods and shared openly for public access. The stability of NPP is defined as the inverse of the coefficient of variation. As we know, there are few open datasets available on the interannual stability of NPP for Chinese terrestrial ecosystem. Therefore, opening this dataset should provide an opportunity for the further understanding of carbon cycles, carbon sink management, ecological restoration and development of responsive of policies.

2 Metadata of the Dataset

The metadata of the dataset[16] described here are summarized in Table 1.

Table 1 Metadata summary of the dataset of Stability of vegetation net primary productivity and climate impacts in China in the following century

Items	Description
Dataset full name	Stability of vegetation net primary productivity and climate impacts in China in the following century
Dataset short name	RCPsNPPChina
Authors	Chen, X. 0009-0006-4886-3974, Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, chenx.20s@igsnrr.ac.cn Wang, J. B. 0000-0001-5169-6333, Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, jbwang@igsnrr.ac.cn He, Q. F. 0009-0009-9554-4812, College of Tourism and Geography, Jiujiang University, 2051936579@qq.com Wang, C. Y. 0000-0002-9960-5530, Qilu Normal University, 1871302580@qq.com Ye, H. 0000-0003-0278-5406, College of Tourism and Geography, Jiujiang University, fever2cn.huiye@outlook.com
Geographical region	3°51′N–53°33′N，73°33′E–135°05′E
Years	2006–2099
Spatial resolution	0.1°
Data format	.tif
Data size	4.26 KB (compressed)
Data files	A total of 16 raster data files, including multi-year average, trends, and stability of NPP in different periods under the RCP4.5 and RCP8.5 scenarios
Foundations	National Natural Science Foundation of China (31861143015, 31971507); Chinese Academy of Sciences-Qinghai Provincial People's Government Sanjiangyuan National Park Joint Research Program (LHZX-2020-07)
Data publisher	Global Change Research Data Publishing & Repository, http://www.geodoi.ac.cn
Address	No. 11A, Datun Road, Chaoyang District, Beijing 100101, China
Data sharing policy	***Data*** from the Global Change Research Data Publishing & Repository includes metadata, datasets (in the *Digital Journal of Global Change Data Repository*), and publications (in the *Journal of Global Change Data & Discovery*). ***Data*** sharing policy includes: (1) ***Data*** are openly available and can be free downloaded via the Internet; (2) End users are encouraged to use ***Data*** subject to citation; (3) Users, who are by definition also value-added service providers, are welcome to redistribute ***Data*** subject to written permission from the GCdataPR Editorial Office and the issuance of a ***Data*** redistribution license; and (4) If ***Data*** are used to compile new datasets, the 'ten per cent principal' should be followed such that ***Data*** records utilized should not surpass 10% of the new dataset contents, while sources should be clearly noted in suitable places in the new dataset[17]
Communication and searchable system	DOI, CSTR, Crossref, DCI, CSCD, CNKI, SciEngine, WDS/ISC, GEOSS

3 Methods

3.1 Data Acquisition Methods

The model input for this data uses the 2006–2099 climate scenario data for terrestrial ecosystem in China[18, 19]. These data are based on the HadGEM2-ES data scenarios in the Regional Climate Model version 4 (RegCM 4.6) and CMIP5, of which the medium (RCP4.5) and high (RCP8.5) emission climate scenario data are used. The original data had a spatial and temporal resolution of 0.25° and 3 h, including air temperature, precipitation, cloudiness, and relative air humidity, respectively, which were processed to a time step of 10 days and a spatial resolution of 0.1° for model input.

The vegetation classification was from Chinese land cover (ChinaCover) remote sensing data in 2010. The ChinaCover data was based on Landsat TM/ETM, HJ-1 satellite data, and field survey data. Its original data having a spatial resolution of 30 m, and the accuracy of the first-level classification at the national scale of 94% and the accuracy of the second-level classification of 86%[20, 21]. Its secondary classification was merged, and spatially resampled to obtain the model input data with a spatial resolution of 0.1°. The detailed model inputs and outputs are shown in Table 2.

In this work, the national terrestrial ecosystem climate scenario data for 2006–2099 under medium- and high-emission climate scenarios were used to simulate the NPP data under different future climate scenarios using the 2010 Chinese land cover remote sensing data, based on the satellite-based remote sensing-driven CEVSA-RS model.

Table 2 List of input and output data of the model

Data type	Indicators	Time resolution	Spatial resolution	Unit
Input meteorological data	Temperature (Tas)	10 days	0.1°	℃
	Precipitation (Prc)	10 days	0.1°	mm
	Relative humidity (Hum)	10 days	0.1°	%
	Cloud fraction (Clo)	10 days	0.1°	%
Input land use data	Land cover data (ChinaCover in 2010)	Year (2010)	0.1°	dimensionless
Output Variables	Net primary productivity of vegetation (NPP)	Year	0.1°	$g\ C{\cdot}m^{-2}{\cdot}a^{-1}$
	Mean, trend and Stability of NPP	Year	0.1°	dimensionless

3.2 Data Processing

The annual NPP data are subjected to calculating average, trend and stability for the different periods, and the data processing specifically includes the following parts:

(1) The trend analysis is based on linear regression and its slope was calculated with the following Equation:

$$Slope = \frac{n\sum_{i=1}^{n}(i \times X_i) - \sum_{i=1}^{n} i \sum_{i=1}^{n} X}{n\sum_{i=1}^{n} i^2 - \left(\sum_{i=1}^{n} i^2\right)} \tag{1}$$

where, *Slope* is the slope of the linear regression equation at the pixel scale, X_i is the NPP in the *i*-th year; *n* is the length of the period.

(2) Stability of a system was defined as remaining unchanged or changes regularly, and the coefficient of variation itself expresses volatility [20], so the absolute value of the inverse of the coefficient of variation is usually used to quantify the stability, and the calculation Equation is as follows:

$$S_{X(i,j)} = \left| \frac{M_{X(i,j)}}{STD_{X(i,j)}} \right| \tag{2}$$

where, S_X, M_X and STD_X denote the stability, mean and standard deviation of the NPP for a given time series. The *i* stands for the *i*-th period, and *j* stands for the *j*-th pixel.

4 Data Results and Validation

4.1 Data Composition

This dataset consists of a total of 16 raster data files, including the average, trend, and stability raster data of NPP in four periods under the RCP4.5 and RCP8.5 scenarios [22, 23]. The four periods are defined as the whole period from 2006 to 2099, the near-term from 2006 to 2035, the mid-term from 2036 to 2065, and the far-term from 2066 to 2099. In the file name, the periods were formatted as 200620999, 20062035, 20362065, and 20662099 respectively.

(1) RCP45 represents the RCP4.5 climate scenario and RCP85 represents the RCP8.5 climate scenario;

(2) npp_mean represents the NPP mean in the specific period;

(3) npptrend20062099 represents the NPP trend at the pixel scale from 2006 to 2099;

(4) P20062099 represents the significance level of the NPP trend at the pixel scale from 2006 to 2099;

(5) R220062099 represents the coefficient of determination of the NPP trend at the pixel scale from 2006 to 2099;

(6) stable20062035 represents the multi-year stability for the near-term, where 20062035 represents the near-term from 2006 to 2035.

Notes on units:

(1) NPP: g C·m^{-2}·a^{-1};

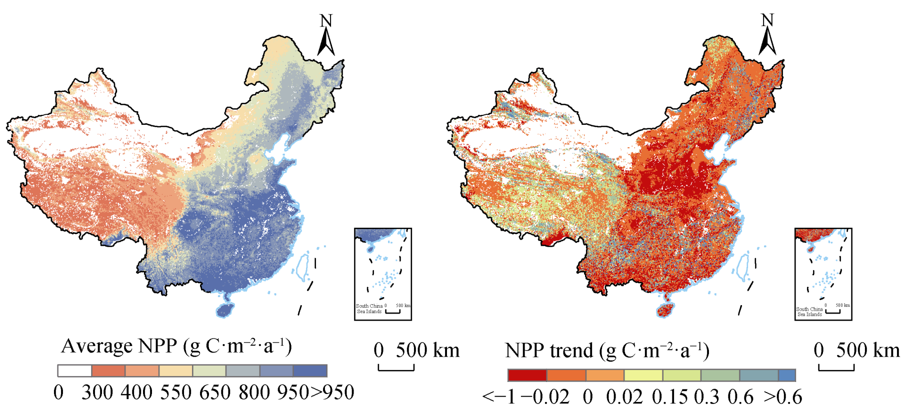
(2) NPP stability: dimensionless;

(3) NPP trend: g C·m^{-2}·a^{-1};

(4) Significance level, coefficient of determination: dimensionless.

4.2 Data Products

The dataset also presents the spatial pattern of NPP and its trends and its stability under the two future climate scenarios. The NPP of China's terrestrial ecosystem from 2006–2099 generally had a spatial pattern of "high" in the east, "low" in the west, "high" in the south and "low" in the north (Figure 1). Among them, under the RCP4.5 scenario, the total NPP reached 4.41 Pg C·a^{-1} for the whole terrestrial ecosystem of China, and it was slightly higher under the RCP4.5 scenario compared with that under the RCP8.5 scenario. NPP showed a spatial variation but was more similar within the same climate zones, such as the total NPP of 0.57 Pg C·a^{-1} in the Tibetan Plateau zone, which was the region with the lowest total



(a) Average NPP in 2006–2099

(b) NPP trend in 2006–2099

Figure 1 Map of the the average NPP and its trend under the RCP4.5 scenario in 2006 to 2099 over the terrestrial ecosystem in China

NPP among the four major climate zones in China. The tropical-subtropical monsoon zone had the highest total NPP among the four zones with 2.09 Pg C·a^{-1}.

The NPP showed a decreasing trend over most climate zones except for the Tibetan Plateau (Figure 1). The inter-annual changes are shown in figure 2, which illustrates that the total NPP shows a significant decreasing trend in both the RCP4.5 scenario and the RCP8.5 scenario for the future 94-years, from 2006 to 2099 (Figure 2). The decreasing rate for the medium-emission scenario will be greater than that in the high-emission scenario. Moreover, it is worth noting that the change in total NPP will turn around in the 2060s, from an increasing to a decreasing trend.

Figure 3 shows the spatial distribution pattern of NPP stability in the different periods. NPP stability for the Tibetan Plateau region shows higher values in 2006–2099, while the temperate monsoon region and the temperate continental climate region show lower values. NPP stability in 2006–2035 (near-term) shows higher values in south China and lower values in north China. NPP stability in the period 2036–2065 (medium-term) also shows higher values in the south and lower values in north China. But the stability is relatively higher in the medium-term compared to that in the near term in south China. In the period 2066–2099 (far-term), NPP stability is relatively lower with a large number of regions having very low NPP stability.

4.3 Data Validation

The model was extensively validated and evaluated based on ChinaFLUX observations in previous studies. The modelled GPP can explain 58%–94% of the seasonal variations in GPP observations from the eddy covariance towers on grassland, in forest and on cropland[14]. Meanwhile, it showed good consistence with the remote sensing-based GPP product (MYD17A2H) of MODIS[14]. The validations and evaluation indicate that the CEVSA-RS model has high reliability in the GPP estimation[16].

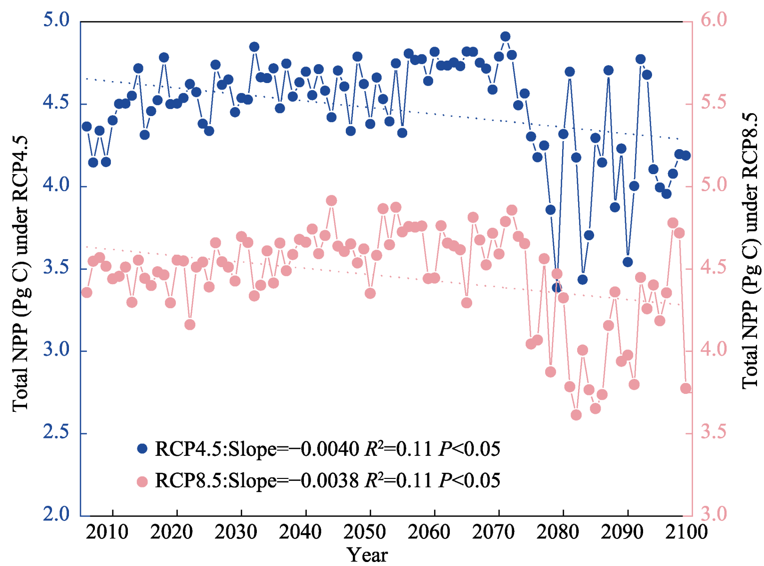


Figure 2 Map of the inter-annual changes for the total NPP of the terrestrial ecosystem in China from 2006–2099

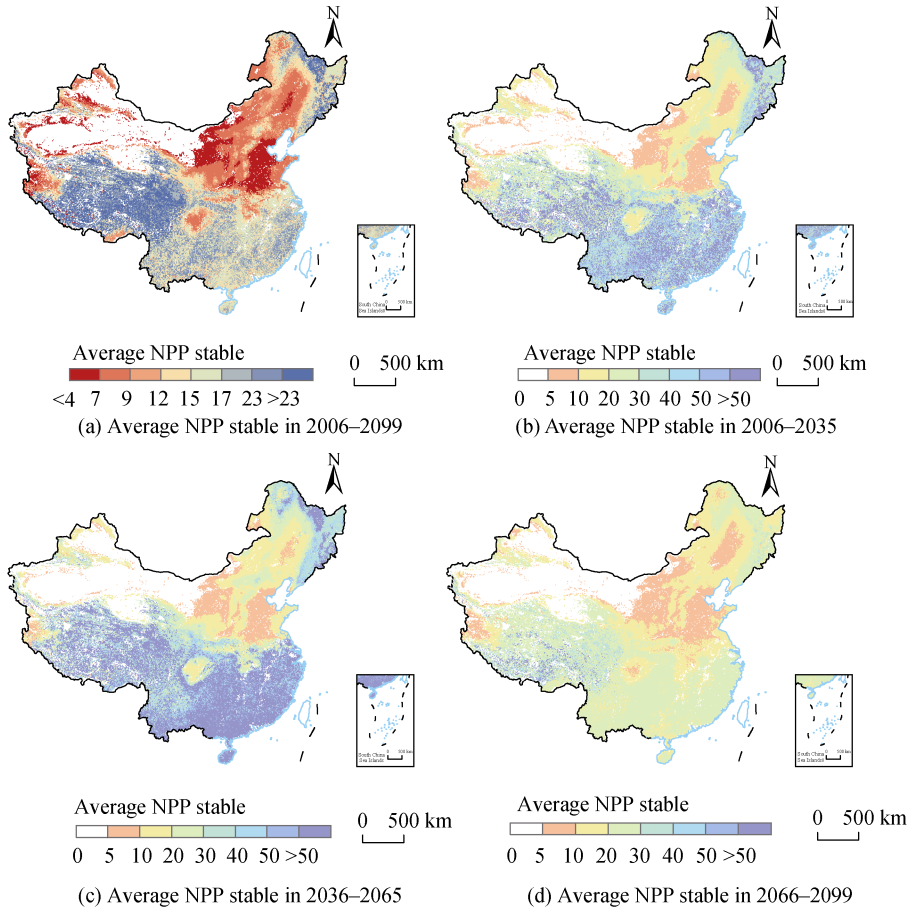


Figure 3 Map of the NPP stability in Chinese terrestrial ecosystem at different time periods under the RCP4.5 scenario

5 Conclusion

This dataset includes not only the CEVSA-RS model based NPP under the two future climate scenarios, but also its mean, trend and stability in the near, medium, and long term. It can be used to assess the total NPP for different sub-regions, and also to assess the degree of stability of NPP in response to climate change. The CEVSA-RS model has been evaluated on its performance to quantify carbon flux in different ecosystem, which demonstrated the reliability of the data in this study. These data present the spatial-temporal changes in NPP and its mean, trend and stability under climate change scenarios, which can be applied in research on ecological conservation and restoration, dual-carbon actions, and climate change mitigation and adaptation by considering regional and decadal differences.

Author Contributions

Wang, J. B. did the overall design for the development of the dataset; Chen, X. collected and processed the NPP stability data; Ye, H. and He, Q. F. collected and processed the NPP data; Wang, J. B. designed the models and algorithms; Wang, C. Y. did the data validation; and Chen, X. and Watson A. E. wrote the data paper.

Conflicts of Interest

The authors declare no conflicts of interest.

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