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RESEARCH ARTICLE

Evaluating the grassland net primary productivity of southern China from 2000 to 2011 using a new climate productivity model

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Abstract

Grassland is the important component of the terrestrial ecosystems. Estimating net primary productivity (NPP) of grassland ecosystem has been a central focus in global climate change researches. To simulate the grassland NPP in southern China, we built a new climate productivity model, and validated the model with the measured data from different years in the past. The results showed that there was a logarithmic correlation between the grassland NPP and the mean annual temperature, and there was a linear positive correlation between the grassland NPP and the annual precipitation in southern China. All these results reached a very significant level (P<0.01). There was a good correlation between the simulated and the measured NPP, with R^2 of 0.8027, reaching the very significant level. Meanwhile, both root mean square errors (RMSE) and relative root-mean-square errors (RRMSE) stayed at a relatively low level, showing that the simulation results of the model were reliable. The NPP values in the study area had a decreasing trend from east to west and from south to north, and the mean NPP was 471.62 g C m^{-2} from 2000 to 2011. Additionally, there was a rising trend year by year for the mean annual NPP of southern grassland and the tilt rate of the mean annual NPP was 3.49 g C m^{-2} yr^{-1} in recent 12 years. The above results provided a new method for grassland NPP estimation in southern China.

Keywords: grassland NPP, estimation model, annual precipitation, mean annual temperature, southern China

1. Introduction

Grassland is one of the major biological communities in the world. It takes more than 40% of the total land area on the planet, playing an important role in the global biogeochemical cycle and energy transformation process (Chen and Zhang 2000). The impacts of the climate on grasslands are quite complicated. On one hand, different types of grasslands have their own spatial distributions controlled by temperature and precipitation; on the other hand, the rise in temperature will alter some processes in the ecosystem (such as evapotranspiration, decomposition and photosynthesis), placing a significant impact on biological community productivity (Niu 2001). The net primary productivity (NPP) is an indicator that measures the production capacity of the plant community in the natural conditions. The changes of NPP directly reflect the responses of ecosystems to environmental climate conditions, therefore it can be used as a research index in the study of relationship between ecosystem function and climate changes (Gu *et al.* 2007).

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It has an important theoretical and practical significance for evaluating the environment quality of terrestrial ecosystem, regulating the ecological process and estimating the terrestrial carbon sink to master the interannual variation rule of terrestrial NPP (Lei *et al.* 2015; Hou *et al.* 2007; Mao *et al.* 2010; Zhang *et al.* 2011; Xu *et al.* 2012).

There are different estimation methods to calculate grassland NPP. Most of the methods are based on the establishment of the model. An estimation model demonstrates more exceeding advantages than any other methods in the study of global, regional and other large scales, becoming an important way in the macro-ecological research of grasslands. Therefore, in order to provide theoretical and technical support for grasslands' ecological improvement and recovery, some researchers use a grassland NPP estimation model for dynamic monitoring and forecasting (Shi *et al.* 2008). Many domestic and foreign scholars carried out a large number of studies on impacts of climate change to the ecosystem processes, including grassland productivity and grassland C circulation. Although many scholars have studied the influences on the national or regional scale (Cao and Woodward 1998; Fang *et al.* 2001; He *et al.* 2007; Li *et al.* 2008; Gao *et al* 2013; Zhao *et al.* 2013; Ouyang *et al.* 2014; Pachavo and Murwira 2014), the research on relationships between the grassland NPP and climate factors in southern China was rarely conducted. Grassland resources are abundant in China, with an area of nearly 400 million ha. There are about 60 million ha of grasslands located in southern China, near 1/6 of the area of total grasslands in China. As the grassland in northern areas are continuously suffering from deterioration and desertification, the ecological system of grassy hills and slopes in southern China are becoming increasingly important. The study of relationship of NPP and climatic factors, together with their dynamic simulation, will put significant meanings on the effective management and reasonable utilization of grasslands in southern China, and the promotion of global change research.

2. Materials and methods

2.1. Research area

The grassy hills and slopes in southern China were chosen as the research object. The central position of the region was in about 110°0′E, 27°30′N, covering 17 provinces/autonomous regions including Yunnan, Guizhou, Sichuan, Guangxi, Jiangxi, Anhui, etc. The total area reached about 60 million ha, containing multiple territories including hilly and mountainous area. The grasslands of southern China were mainly composed of typical grassland, wetland grassland, lowland meadow and upland meadow. The layouts of southern grasslands were scattered and staggered distribution with forest land and cultivated land, and they mostly located in all kinds of sloping fields. The most regions of southern grasslands were managed with grazing and some regions with enclosure and cutting. The climate characteristics in this area were high temperature and rainy in summer, and mild temperature and rainy in winter, with the frost-free period being more than 300 days all year around. The annual mean precipitation was between 800–1 600 mm and the annual mean temperature was greater than 15°C in most areas, suitable for the grass growth (Xu *et al.* 2004).

2.2. Data acquirement and processing

NPP data acquirement In July of 2009, 2010 and 2011, 66 sample plots were investigated in several provinces including Anhui, Guizhou, Sichuan, etc. Large quadrates were set in each representative sample plot (10 m×10 m), and five small squares (1 m×1 m) were set on corners and in the center of large quadrates. Above-ground biomass and the latitude and longitude information were investigated in each small quadrate, with an average level calculated after sampling. Every 2.2 g dry matter was converted into 1 g carbon, leading to the grass NPP in each sample area, represented in the form of carbon (g C m^{-2}).

Climate data acquirement The mean month temperature and month precipitation data from year 2000 to 2011 were acquired from ground stations of China Meteorological data sharing service system (http://cdc.cma.gov.cn/) (Fig. 1). By using geographic information system (GIS) interpolation tool, Kriging interpolation (it is a good interpolation method for meteorological data) was applied to those meteorological data according to the latitude and longitude information of each station, followed by the application of image projection transformation to the data which was all then converted to latitude and longitude network projected raster image with a spatial resolution of 1 000 m. Finally, the temperature and precipitation information was extracted according to the latitude and longitude corresponding to the investigation points.

2.3. Model establishment and validation

Modeling methods According to statistical analysis on the relationships between measured NPP and precipitation and temperature, the model's preliminary structure was put forward. Then the nonlinear fitting algorithm was applied to the model parameter for optimization and determination.

Model validation In order to verify the reliability of simulation results, both root mean square errors (RMSE) and