Dynamics of Desert Vegetation Productivity in China and Its Relationship with Hydrothermal Factors: A Postprint

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Abstract

To investigate the temporal changes in net primary productivity (NPP) of desert vegetation in China' s arid regions and its correlation with hydrothermal factors over the past 30 years, the CASA (Carnegie-Ames-Stanford Approach) model was employed to estimate the NPP of desert vegetation in China during the growing season from 1982 to 2015. Linear regression and GIS spatial analysis methods were utilized to analyze the spatiotemporal variation characteristics of NPP, and moving correlation coefficients were applied to examine the relationship between desert vegetation NPP and hydrothermal factors. Results indicate: The mean NPP per unit area is 42 g · m-2 · a-1, reflecting a relatively low overall NPP level. Spatially, it exhibits a distribution pattern with higher values in the northwest and eastern margins, and lower values in the central, southern, and mid-eastern regions. The annual total NPP of desert vegetation is 5.783×1013 g · a-1. Regarding interannual variation, the total NPP of desert vegetation in China increased at a linear rate of 1.64×1012 g · (10a)-1 (P=0.054) from 1982 to 2015, indicating an overall improvement in desert vegetation growth conditions. However, the total trend displayed staged variations: from 1982 to 1993, the total NPP exhibited an extremely significant increasing trend (1.25×1012g · a-1, P<0.01); from 1993 to 2006, the total NPP showed an extremely significant decreasing trend (-6.42×1011 g · a-1, P<0.01); and from 2006 to 2015, the total NPP increased slowly (1.70×1011g · a-1, P>0.05). From a spatial perspective, 47.65% of desert vegetation NPP demonstrated an increasing trend, mainly distributed across the Alxa Plateau, northern foothills of the Tianshan Mountains, western margin of the Tarim Basin, southeastern margin of the Qaidam Basin, southern foothills of the Altun Mountains, and Kunlun Mountains. In terms of temporal changes in the correlation between desert vegetation NPP and various climate factors, the moving correlation coefficient between NPP and temperature remained negatively correlated over time, while those with precipitation and aridity remained positively correlated. The moving

correlation coefficient between NPP and total solar radiation did not exhibit a significant changing trend over time. Overall, the correlation between desert vegetation and hydrothermal factors showed a further weakening trend during the study period, indicating that desert vegetation NPP has become increasingly insensitive to changes in climate factors.

Full Text

Dynamic State of Desert Vegetation Net Primary Productivity and Its Relationship with Hydrothermal Factors in China

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Abstract:
In this paper, the Carnegie-Ames-Stanford Approach (CASA) model was used to estimate the NPP of desert vegetation during its growing season from 1982 to 2015, and linear regression and GIS spatial analysis methods were applied to analyze the spatiotemporal variation of NPP. The purposes of the study were to explore the net primary productivity of desert vegetation and its correlation with water-heat factors in China' s arid regions over the past three decades. The sliding correlation coefficient method was used to analyze the relationship between NPP and water-heat factors. The results showed that: (1) The average NPP per unit area was 42 g·m ^{2}·a ^{1}, and the overall level of NPP was low. Spatially, it was higher in the northwestern and eastern margins but lower in the central, southern, and mid-eastern regions. (2) The average annual NPP of desert vegetation was 5.78×10^{13} g·a ^{1}. For interannual variation, the linear change rate of total NPP of desert vegetation was 1.64×10^{12} g·(10a) ^{1} (P=0.054) in China from 1982 to 2015. Desert vegetation generally improved, but the overall change trend was staged. The total NPP showed an extremely significant growth trend (1.25×10^{12} g·a ^{1}, P<0.01) during 1982-1993, significantly decreased from 1993-2006 (-6.42×10^{11} g·a ^{1}, P<0.01), and increased slowly during 2006-2015 (1.70×10^{11} g·a ^{1}, P>0.05). From the perspective of spatial change, 47.65% of desert vegetation NPP showed an increasing trend, mainly distributed in the Alashan Plateau, northern piedmont of the Tianshan Mountains, western marginal zone of the Tarim Basin, southeastern marginal zone of the Qaidam Basin, southern piedmont of the Altun Mountains, and Kunlun Mountains. (3) From the perspective of temporal changes in correlation between desert vegetation NPP and climatic factors, the sliding correlation coefficient between NPP and temperature was negatively correlated with time,

but positively correlated between NPP and precipitation and dryness index. There was no significant temporal variation in the sliding correlation coefficient between NPP and total solar radiation. In general, the correlation between desert vegetation and water-heat factors was further weakened during the study period, indicating that desert vegetation NPP became increasingly insensitive to changes in climatic factors.

Keywords: net primary productivity; desert vegetation; climatic factors; sliding correlation; hydrothermal factors

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1.2.2 CASA Model

The Carnegie-Ames-Stanford Approach (CASA) model was employed to estimate NPP of desert vegetation from 1982 to 2015. The model utilizes NDVI data from the Global Inventory Modeling and Mapping Studies (GIMMS) at a spatial resolution of 8 km × 8 km and a temporal resolution of 15 days. The simple ratio SR(x,t) is calculated as:

$$SR(x,t) = \frac{SR(x,t) - SR_{\min}}{SR_{\max} - SR_{\min}} = \min[0.95] \quad (3)$$

where SR(x,t) represents the simple ratio at location x and time t, SR is 1.08, and SR ranges from 4.14 to 6.17. SR(x,t) is derived from NDVI(x,t) as:

$$SR(x,t) = \frac{1 + NDVI(x,t)}{1 - NDVI(x,t)}$$

The average NPP per unit area was 42 g·m 2·a 1. Areas with NPP below 50 g·m 2·a 1 accounted for 79.65% of the study region, primarily distributed in extremely arid zones such as the Taklamakan Desert interior, Badain Jaran Desert, and Tengger Desert. Areas with NPP between 50-100 g·m 2·a 1 accounted for 11.05%, mainly in relatively humid regions such as the northern Tianshan piedmont and western Tarim Basin margins. Overall, areas with NPP between 0-100 g·m 2·a 1 comprised 90.70% of desert vegetation, indicating generally low productivity [Figure 2: see original paper].

2.2 Temporal Variation of NPP

From 1982 to 2015, the average annual NPP of desert vegetation was 5.78×10^{13} g·a 1, with a linear trend of 1.64×10^{12} g·(10a) 1 (P=0.054). The interannual variation exhibited distinct stages: extremely significant increase during 1982–1993 (1.25×10^{12} g·a 1, P<0.01), significant decrease during 1993–2006 (-6.42×10^{11} g·a 1, P<0.01), and slow increase during 2006–2015 (1.70×10^{11} g·a 1, P>0.05) [Figure 3: see original paper]. The average annual NPP trend was 0.09 g·m 2·a 1 (P<0.05), with spatial differences in significance levels.

Spatially, 47.65% of desert vegetation showed increasing NPP trends, concentrated in the Alashan Plateau, northern Tianshan piedmont, western Tarim Basin margins, southeastern Qaidam Basin margins, and southern Altun and Kunlun Mountains piedmont. Decreasing trends accounted for 25.02%, mainly in the central Taklamakan Desert, Badain Jaran Desert, and Tengger Desert [Figure 4: see original paper].

2.3 Relationship Between NPP and Climate Factors

Climate data showed significant increasing trends in temperature [0.491°C $\cdot$ $(10a)^{1}$, $P<0.01$] and solar radiation [60.461 MJ $\cdot$ $(10a)^{1}$, $P<0.01$], while precipitation increased slightly [5.576 mm $\cdot$ $(10a)^{1}$, $P<0.05$] [Figure 5: see original paper]. The dryness index ranged from 0.63 to 1.04, with 17 stations showing values >10, indicating arid to extremely arid conditions.

The sliding correlation analysis revealed that the correlation between NPP and temperature weakened over time, becoming negative. Conversely, correlations with precipitation and dryness index strengthened, becoming positive. The correlation with solar radiation showed no significant temporal variation [Figure 6: see original paper]. During 1982–1998 and 1986–2002, NPP was significantly positively correlated with temperature ($P<0.05$). During 1987–2003, correlations with precipitation and dryness were significant ($P<0.05$). During 1996–2012, 47.65% of the area showed significant positive correlations between NPP and precipitation/dryness ($P<0.01$), while 32.20% showed significant negative correlations with temperature ($P<0.01$).

3. Discussion

The correlation between desert vegetation NPP and hydrothermal factors weakened during the study period, suggesting decreasing sensitivity to climate change. Temperature and precipitation were the primary factors influencing NPP, but their effects varied spatially. In extremely arid regions, precipitation was the main limiting factor, while in semi-arid regions, temperature played a more important role. The weakening correlation may be attributed to vegetation adaptation to climate change and human activities such as ecological restoration projects.

The spatial distribution of NPP was closely related to hydrothermal conditions. Areas with NPP >100 $g \cdot m^{2} \cdot a^{1}$ were mainly distributed in regions with relatively abundant precipitation or water supply, such as mountain piedmont and river basins. The increasing NPP trends in the Alashan Plateau and Tianshan Mountains piedmont were associated with increased precipitation and temperature, while decreasing trends in the Taklamakan Desert interior reflected extreme aridity and limited water availability.

4. Conclusions

(1) The average NPP of desert vegetation in China was $42\ g \cdot m^{\ 2} \cdot a^{\ 1}$, with low overall productivity. Spatially, NPP was higher in northwestern and eastern margins and lower in central, southern, and mid-eastern regions.

(2) The total NPP showed a staged change trend: rapid increase during 1982–1993, significant decrease during 1993–2006, and slow increase during 2006–2015. Overall, 47.65% of desert vegetation showed increasing trends.

(3) The correlation between NPP and climate factors weakened over time, with NPP becoming increasingly insensitive to climatic changes. Temperature and precipitation were the main influencing factors, but their effects varied across regions.

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Note: Figure translations are in progress. See original paper for figures.