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RESEARCH PAPER

Modeling the interannual variation and response to climate change scenarios in gross and net primary productivity of *Pinus elliottii* forest in subtropical China

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Abstracts: In this study, the BIOME-BGC model, a biogeochemical model, was used and validated to estimate GPP (Gross Primary Productivity) and NPP (Net Primary Productivity) of *Pinus elliottii* forest in red soil hilly region and their responses to interannual climate variability during the period of 1993–2004 and climate change scenarios in the future. Results showed that the average total GPP and NPP were 1941 g C $m^{-2}a^{-1}$ and 695 g C $m^{-2}a^{-1}$, and GPP and NPP showed an increasing trend during the study period. The precipitation was the key factor controlling the GPP and NPP variation. Scenario analysis showed that doubled CO_2 concentration would not benefit for GPP and NPP with less than 1.5% decrease. When CO_2 concentration fixed, GPP responded positively to precipitation change only, and temperature increase by 1.5°C with precipitation increase, while NPP responded positively to precipitation change only. When CO_2 concentration was doubled and climate was changed, GPP and NPP responded positively to precipitation change, and GPP also responded positively to temperature increase by 1.5°C with precipitation change.

Key Words: carbon storage; slash pine forest; BIOME-BGC model; gross primary productivity (GPP); net primary productivity (NPP); climate change

Gross primary productivity (GPP) is the total C gain by the system via net photosynthesis and is defined as the sum of daily gross photosynthesis and daily foliar respiration. Net primary productivity (NPP) represents the net C accumulation by the stand and is determined as the difference between GPP and the sum of the maintenance (R_m) and growth (R_g) of respiration components[1]. NPP is an important component of the global carbon cycle and a key variable in ecosystem study. It plays a key role in understanding carbon exchange between biota and atmosphere, currently under climate change conditions caused by increase in atmospheric CO_2 concentration. Many models have been developed to study the responses in terms of primary productivity[2–9] including MIAMI model[2], Chikugo model[10] and model based on satellite remote sensing[11]. Now the terrestrial biogeochemical model used to estimate GPP and NPP is very popular because the model can describe the detail process of plant growth accurately.

The BIOME-BGC model, one biogeochemical model, can be used to simulate fluxes and storage of water, carbon and nitrogen for terrestrial biomes ranging from single stand to global scales. The model requires general information about the site stands (climate data, elevation, plant ecophysiological parameters, etc.) to estimate daily carbon fluxes and storage. In this study, interannual variation and response to climate change scenarios in GPP and NPP of the *Pinus elliottii* forest in subtropical China were studied with the BIOME-BGC model based on climate data during 1985–2004 in Qianyanzhou Ecological Station (QYZ station). This study can offer scientific basis in assessing eco-environmental effects of vegetation restoration and improving management of man-made forests.

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1 Study area

Qianyanzhou Ecological Station (26°44′52″N, 115°03′47″E) is situated in the middle of Jiangxi Province, Southeast China. The terrain of the area is mainly hilly, with elevation about 100 m. The climate is typical subtropical monsoon humid, with mean annual rainfall around 1487 mm, temperature around 18.0°C, active accumulated temperature (⩾0°C) is 6523°C, active accumulated temperature (⩾10°C) is 6015°C, annual sunshine time is 1406 h, percentage of annual sunshine is 43%, total solar radiation is 4349 MJ m^{-2}, and frostless period is 323 d.

The area is dominated by diverse conifer species, with the presence of some deciduous species to increase land productivity. Most of the trees were planted in 1985. Among the conifer species, slash pine (*Pinus elliottii* Engelm.), masson pine (*Pinus massoniana* Lamb.) and Chinese fir (*Cunninghamia lanceolata* (Lamb.) Hook.) are by far the most common, but other broad-leaved species can also be found such as Chinese sweetgum (*Liquidambar formosana* Hance) and Chinese Chestnut (*Castanea mollissima* Blume). The understory layer is generally characterized by the presence of young trees of the main dominant species and shrubs of different species (e.g., *Loropetalum chinense* (R. Br.) Oliv. and *Quercus fabri* Hance). The plants cover about 76 % of the land surface. According to the investigation in 1999, the average DBH (diameter at breast height), height and density of slash pine forest were 16.3 cm, 12.2 m and 1736 trees/hm^2, respectively.

2 Methods

2.1 BIOME-BGC model

The BIOME-BGC model was developed following the FOREST-BGC model[12,13], which had been originally applied to coniferous forest stands. The latest version of the BIOME-BGC model was version 4.1.2. BIOME-BGC uses at least 3 input files each time it is executed: (1) the initialization file, which provides general information about the simulation, including description of site latitude, longitude, elevation, soil depth, soil texture, plant type, CO_2 concentration, and input and output file sets; (2) the meteorological data with day step, e.g., daily air temperature, maximum and minimum air temperature, precipitation, solar radiation, vapor pressure deficit and daylength; (3) the ecophysiological parameters of the vegetation, about 44 parameters in all, e.g., leaf parameter, C:N of fine roots, stomatal conductance, canopy light extinction coefficient, canopy average specific leaf area, and fraction of leaf N in Rubisco. All parameters used in this paper were shown in Table 1, where there were 38 ecophysiological parameters. Six of them were measured in *P. elliottii* forest in the study site: C∶N of leaves, 68.3 (kgC/kgN); C∶N of fine roots, 118 (kgC/kgN); C∶N of live wood, 179 (kgC/kgN); canopy light extinction coefficient, 0.5053 (DIM); canopy

Table 1 Parameters of *P. elliottii* forest in BIOME-BGC model

Parameter	Unit	Value		Unit	Value
Site parameter					
Effective soil depth	m	1.0	Clay percentage	%	25
Sand percentage	%	40	Site elevation	m	86
Silt percentage	%	35	Site shortwave albedo	DIM	0.18
Ecophysiological parameter					
Transfer growth period as growth fraction	Prop.	0.3	Litterfall as fraction of growing season	Prop.	0.3
Annual leaf and fine root turnover fraction	1/a	0.26	Annual live wood turnover fraction	1/a	0.7
Annual whole-plant mortality fraction	1/a	0.005	Leaf litter lignin proportion	DIM	0.33
Annual fire mortality fraction	1/a	0.005	Fine root labile proportion	DIM	0.34
New fine root C: new leaf C	ratio	1.4	Fine root cellulose proportion	DIM	0.44
New stem C: new leaf C	ratio	2.4	Fine root lignin proportion	DIM	0.22
New live wood C: new total wood C	ratio	0.076	Dead wood cellulose proportion	DIM	0.7
New root C: new stem C	ratio	0.31	Dead wood lignin proportion	DIM	0.30
C:N of leaves	kgC/kgN	68.3	Canopy water interception coefficient	1/LAI/d	0.05
C:N of leaf litter	kgC/kgN	130	Canopy light extinction coefficient	DIM	0.5053
C:N of fine roots	kgC/kgN	118	Canopy average specific leaf area	m^2/kgC	12.08
C:N of live wood	kgC/kgN	179	Fraction of leaf N in Rubisco	DIM	0.033
C:N of dead wood	kgC/kgN	710	Maximum stomatal conductance	m/s	0.0065
Leaf litter labile proportion	DIM	0.39	Cuticular conductance	m/s	6×10^{-5}
Leaf litter cellulose proportion	DIM	0.28	Boundary layer conductance	m/s	0.09
Leaf water potential: start of conductance reduction	MPa	–0.7	Vapor pressure deficit: start of conductance reduction	pa	610
Leaf water potential: complete conductance reduction	MPa	–2	Vapor pressure deficit: complete conductance reduction	pa	3100

DIM: dimensionless; LAI: leaf area index