Response to Reviewer #1's comments

(*Italic* indicates the manuscript text, *red* indicates revisions)

Comments 1:

Net primary productivity (NPP) of forests changes with the age. The relationship between NPP and age is crucial for quantifying the carbon sink of forests. The study investigates the species-specific relationships between NPP and forest age over subtropical China on the basis of different sources of field data. Overall, this manuscript is well-written. The topic is interesting. After some modifications, this manuscript is publishable.

Response:

Thanks for your positive feedback.

Comments 2:

In the calculation of dB, biomass in two different years is required. For the SPPCB dataset, are there biomass values in two different years available?

Response:

Thanks for your valuable comments. No, the survey date of the SPPCB samples covers from 2009 to 2019, but they were not resurveyed over time. For the SPPCB samples, we adopted a space-for-time substitution method and pairs of samples used to calculate the annual biomass change were restricted to the same forest species, located within 5 km of each other, and differing by no more than 3 years in stand age. Sections 2.2 and 2.3 were revised accordingly.

"***2.2. Data***

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The SPPCB field survey samples have previously been effectively used for constructing ten forest NPP–age relationships across China (Li et al., 2024a; Shang et al., 2023) and we only selected the 128 samples located in Fujian for the analysis. It records the sample location, survey time (from 2009 to 2013), forest cover type, age, forest aboveground and underground biomass (Li et al., 2024a). The ground survey size for each SPPCB sample was 1000 m^2 (600 m^2 for some plantations), closely approximating a 30-m resolution (Lin et al., 2023).

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"***2.3.1. Building NPP–age relationships for different forest species***

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where dB is the annual biomass change and c is the species-specific carbon content in biomass (see Table 1 for the constant values). Biomass was not directly provided in the NFI-I and NFI-II samples, but it could be calculated from the forest volume (V) using species-specific biomass regression equations. The coefficients for these regression equations are presented in Table 1 (Li et al., 2011; Wu et al., 2016). For the SPPCB samples, which were not resurveyed over time, annual biomass changes were estimated with the space-for-time substitution method (Ma et al., 2017; Liu et al., 2024). To reduce the influence of other factors and ensure that the observed biomass change is primarily attributed to stand age, pairs of samples used to calculate dB were restricted to the same forest species, located within 5 km of each other, and differing by no more than 3 years in stand age.

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Comments 3:

Are the values of variable C in equations (2) and (3) the same? Lf is the turnover of leaves per year. Equation (1) assumes that the NPP allocated into leaves is equal to the turnover of leaves for evergreen forests. It means that the foliage carbon does not change annually. This is true for mature evergreen forests. For young evergreen forests, this assumption is questionable to some extent. The foliage carbon of young evergreen forests increases year by year. The NPP allocated into leaves is larger than the turnover loss.

Response:

Thanks for your valuable comments.

Yes, the values of variable C in equations (2) and (3) are the same, representing the carbon content within biomass. For each forest species, its value was treated as a constant and is listed in Table 1 of the manuscript.

For Equation (1), the three terms on its right side—change in aboveground biomass (dB), leaf turnover (L_l), and fine root turnover (L_{fr}) are all dynamic and change with age. The age-related dynamics in L_l and L_{fr} are mainly reflected by the age-related dynamics of the annual maximum LAI.

The manuscript was revised accordingly.

*"**2.3.1. Building NPP–age relationships for different forest species***

The forest NPP was calculated from the three types of forest field samples, and it consisted of four components: total biomass increment, mortality, foliage turnovers, and fine root turnovers in the soil (Chen et al., 2002; He et al., 2012; Xia et al., 2019; Li et al., 2024a):

$$NPP = dB_c + M + L_f + L_{fr} \qquad (1)$$

where dB_c is the annual increment of total living biomass (including stems, branches, and coarse roots); M is mortality ignored in this study due to a lack of observations at the ground plots and its small proportion to NPP (Li et al., 2024a); L_l is the turnover of leaves per year; and L_{fr} is the turnover of fine roots per year in the soil. All three NPP components vary with stand age. Among them, the annual increment of total living biomass is the dominant contributor, whereas foliage and fine-root turnover are also indispensable parts of NPP (Li et al., 2024a; He et al., 2012).

The annual increment of total living biomass was calculated from the annual biomass change (dB) and the ratio of carbon content (Li et al., 2011; White et al., 2000; Wu et al, 2016; Xia et al., 2019):

$$dB_c = dB \times c \qquad (2)$$

where dB is the annual biomass change and c is the species-specific carbon content in biomass (see Table 1 for the constant values). Biomass was not directly provided in the NFI-I and NFI-II samples, but it could be calculated from the forest volume (V) using species-specific biomass regression equations. The coefficients for these regression equations are presented in Table 1 (Li et al., 2011; Wu et al., 2016). For the SPPCB samples, which were not resurveyed over time, annual biomass changes were estimated with the space-for-time substitution method (Walker et al., 2010; Blois et al., 2013). To reduce the influence of other factors and ensure that the observed biomass change is primarily attributed to stand age, pairs of samples used to calculate dB were restricted to the same forest species, located within 5 km of each other, and differing by no more than 3 years in stand age.

The turnovers of leaves and fine roots per year in the soil could be calculated as follows (Chen et al., 2002; He et al., 2012; Li et al., 2024a):

$$L_l = \frac{LAI}{SLA} \times t_l \times c \qquad (3)$$

$$L_{fr} = R_{fr,l} \times L_l \qquad (4)$$

where LAI is the annual maximum of leaf area index (LAI) obtained from the GLOBMAP Version 3 LAI product (Liu et al., 2012), SLA is the specific leaf area, t_l is the foliage turnover ratio, c is the species-specific carbon content in biomass (same as that in Equation 2), and $R_{fr,l}$ represents the ratio of carbon allocated to new fine roots to carbon in new leaves. The detailed values for the coefficients of SLA, t_l, and $R_{fr,l}$ for different forest species were provided in Table 2 (Li et al., 2024a; Li et al., 2007; White et al., 2000; Xie et al., 2022; Zhou et al., 2008). For HWB, SWB, OCF, and MF, t_l was assigned evergreen-species values because deciduous samples constitute only 2.23 % of the total samples. The age-related dynamics in L_l and L_{fr} are mainly reflected by the age-related dynamics of the annual maximum LAI (Li et al., 2024a; He et al., 2012)."

Comments 4:

Leaf area index changes seasonally. Is the annual maximum of LAI used in Equation (3)? Please clarify.

Response:

Thanks for your valuable comments. Yes, it is the annual maximum of LAI, and it was revised.

*"**2.3.1. Building NPP–age relationships for different forest species***

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where LAI is the annual maximum of leaf area index (LAI) obtained from the GLOBMAP Version 3 LAI product (Liu et al., 2012), ……"

Comments 5:

As shown in Table 2, the foliage turnover ratio is smaller than 1.0 for all species. Are these species all evergreen?

Response:

Thanks for your valuable comments. P. massoniana, C. lanceolata, and Eucalyptus are evergreen, and HWB, SWB, OCF, and MF are dominated by evergreen species with only a very small proportion of deciduous species in Fujian province. Among all samples used to build the NPP-age relationships, 97.77% were evergreen and only 2.23% deciduous. With such limited samples, reliable growth curves for deciduous types could not be derived. Therefore, we applied a foliage turnover ratio smaller than 1 for all seven forest species.

The manuscript was revised accordingly.

*"**2.3.1. Building NPP–age relationships for different forest species***

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The detailed values for the coefficients of SLA, t_l, and $R_{fr,l}$ for different forest species were provided in Table 2 (Li et al., 2024a; Li et al., 2007; White et al., 2000; Xie et al., 2022; Zhou et al., 2008). For HWB, SWB, OCF, and MF, t_l was assigned evergreen-species values because deciduous samples constitute only 2.23 % of the total samples.

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*"**4. Discussions***

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Third, the input coefficients for specific leaf area, foliage turnover ratio, and the ratios of the turnovers of fine roots and leaves to NPP used in calculating forest field NPP for diverse forest species may introduce uncertainties into the forest NPP–age relationships. Currently, these coefficients are primarily sourced from literature (Li et al., 2024a; Li et al., 2007; White et al., 2000; Xie et al., 2022; Zhou et al., 2008), with data originating from subtropical provinces in China such as Guangxi (Xie et al., 2022), Jiangxi (Li et al., 2007), and Guiyang (Zhou et al., 2011), as well as from other regions (White et al., 2000). Data from these regions may differ from those in subtropical

China, potentially leading to biases in the calculation of forest field NPP and final built NPP–age curves. Moreover, as deciduous samples constitute only 2.23 % of the total samples, HWB, SWB, OCF and MF were assigned evergreen foliage turnover coefficients. Therefore, future studies should prioritize local field measurements of these key coefficients, particularly for deciduous species, to refine the NPP–age relationships and to quantify the age-dependent carbon sequestration capacity of each species more accurately. "

Comments 6:

The period from 1901 to 1985 was used for the spin-up of the initial model parameters. What do you mean? Do model parameters change with time? It is better to change "the initial model parameters" into "carbon pools". What is the role of the BEPS model? It is not clear how the spin-up was implemented.

Response:

Thanks for your valuable comments and suggestions. The period from 1901 to 1985 was used to spin up the soil carbon pools, and it was revised. The 30 m NPP generated by the BEPS model for 2015 (Cao et al., 2025) was used as the input reference NPP.

More description about the model inputs, spin-up, and validations was added in section 2.3.2.

*"**2.3.2. Forest carbon modeling using the newly built NPP–age relationships***

The NPP–age relationships constructed for different forest species were integrated into the Integrated Terrestrial Ecosystem Carbon Cycle (InTEC) model for forest carbon modeling. To evaluate whether the forest species-specific NPP–age relationships can improve forest carbon modeling, the forest carbon modeling using the newly built NPP–age relationships was compared with that of using the China-wide NPP–age relationships (Shang et al., 2023; Li et al., 2024a). The InTEC model integrates multiple processes, including leaf photosynthesis (using the Farquhar biochemical model), soil carbon and nitrogen cycling, net nitrogen mineralization, and NPP–age relationships (Chen et al., 2000a, b). This model estimates forest carbon balance by accounting for atmospheric, climatic, and biological changes since the pre-industrial era. The impact of climate change on photosynthesis is modeled through changes in the growing season length and photosynthetic rate, while elevated CO_2 concentrations and leaf nitrogen content positively affect photosynthesis. Model inputs include spatially distributed data on climate, soil texture, nitrogen deposition, and vegetation parameters derived from remote sensing (Table 3). Climate, atmospheric composition, and soil data with resolutions coarser than 30 m were resampled to 30 m using nearest-neighbor resampling. Given the coarse resolution of the climate data, the empirical formulas embedded in the BEPS-TerrainLab model (Xie et al., 2023; Govind et al., 2009) were applied to adjust the resampled climate data using elevation, slope, aspect, and solar position, thereby mitigating the impacts of both resolution and topography. The 30 m NPP generated by the

Biosphere-atmosphere Exchange Process Simulator (BEPS) model for 2015, incorporating topographic effects (Cao et al., 2025), served as the reference NPP. The annual maximum LAI, originally from the 500-m GLOBMAP LAI V3 product, was downscaled to 30 m using the Reduced Simple Ratio (RSR) derived from Landsat data—an index used for LAI retrieval (Liu et al., 2012).

$$LAI_{30} = RSR_{30}/RSR_{500} \times LAI_{500} \quad (5)$$

$$RSR = \rho_{NIR}/(\rho_{NIR} + \rho_{SWIR1}) \quad (6)$$

where LAI_{30} and LAI_{500} are the annual maximum LAI at 30 m and 500 m resolution, respectively; RSR_{30} and RSR_{500} are the corresponding RSR at 30 m and 500 m resolution; ρ_{NIR} and ρ_{SWIR1} are Landsat surface reflectance in the near-infrared and short-wave infrared 1 bands.

Forest carbon modeling was conducted from 1986 to 2023 at a 30 m resolution. The period from 1901 to 1985 was used to spin up the soil carbon pools, reducing uncertainties in subsequent simulations. Specifically, the InTEC model assumes that the forest carbon cycle was in equilibrium before the Industrial Revolution, with NPP equaling heterotrophic respiration (Chen et al., 2000a, b). The model iterates using historical climate and atmospheric composition data, allowing the soil carbon pools to gradually adjust to a realistic and stable state, thereby reflecting long-term ecological dynamics prior to the study period (Chen et al., 2000a, b). Initializing the soil carbon pools in this way reduces the model's sensitivity to arbitrary initial conditions, yielding more robust and reliable transient simulation results.

The performance of forest carbon modeling was indirectly validated by comparing the modeled aboveground biomass (AGB) with the calculated AGB from forest field surveys or inventory data, since carbon flux measurements were not available in Fujian province. For each forest species, 20% of samples were randomly selected for validation. Both the SPPCB and NFI-I samples have a survey size closely approximating a 30 m resolution (Lin et al., 2023), while the NFI-I samples, though potentially larger than 30 m, were strictly screened and constrained to be located at the center of homogeneous forest polygons. Given the potential for significant AGB differences across different age groups, a stratified random sampling strategy was employed to select the validation samples. Specifically, validation samples were randomly selected within each 10-year age group to ensure adequate representation across all age groups. This approach ensured that the validation process was robust and representative of the full range of forest ages, thereby providing a comprehensive assessment of model performance across the entire age spectrum of the forest stands.

Table 3: Main Input Data of the InTEC Model. *LAI: Leaf area index; BEPS: Biosphere-atmosphere Exchange Process Simulator; DEM: Digital elevation model.*

Input data		Unit	Spatial resolution	Temporal resolution	Data source
Climate data	Precipitation	mm	0.5°	1901-2023	CRU TS 4.08
	Temperature	℃			
	Vapor pressure	hpa			

	Cloud amount	*%*			
Atmospheric composition data	*CO_2 concentration*	*mol mol^{-1}*	*Site scale*	*1960-2021*	*Mauna Loa*
	Nitrogen deposition	*10*gN m^{-2}yr^{-1}*	*1.27°×2.5°*	*1997-2013*	*(Gao et al., 2020)*
Vegetation data	*Forest cover types*	*/*	*30m*	*/*	*NFI-II*
	LAI	*m^2 /m^2*	*500m*	*2015*	*GLOBMAP LAI V3*
	Forest age	*year*	*30m*	*2015*	*NFI-II*
	Reference NPP	*10 gC m^{-2} yr^{-1}*	*30m*	*2015*	*BEPS (Cao et al., 2025)*
	NPP-age relationship curves	*/*	*/*	*/*	*This study*
Soil data	*Sand content*	*%*	*0.0083°*	*/*	*HDSW World Soil Database*
	Clay content	*%*	*0.0083°*	*/*	
	Soil depth	*100 m*	*0.0083°*	*/*	
Topographic data	*Latitude/longitude*	*degree*	*30m*	*/*	*/*
	DEM	*m*	*30m*	*/*	*http://www.gscloud.cn*
	Slope and aspect	*/*	*30m*	*/*	*Calculated from DEM*
	Topographic wetness index	*/*	*30m*	*/*	
	Water table depth	*m*	*30m*	*/*	

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