Summary of revisions:

We have made major revisions in response to the editor and the two reviewers. Specifically, we: (1) supplied a detialed description about field survey size and time of the SPPCB, NFI-I and NFI-II samples; (2) elaborated on the calculation of field-based NPP; (3) clarified all InTEC model inputs for AGB simulations and documented the harmonization of their spatial resolutions; (4) described the model spin-up procedure; (5) presented the method about the selection of validating field survey samples and the validation of the simulated AGB; (6) added the method about the comparison between the species-specific and China-wide NPP–age relationships; (7) incorporated a discussion on the varying spatial resolutions of model inputs; (8) added the definition of "forest species". Throughout the manuscript, we have also refined wording and added explanatory details to enhance clarity. Moreover, we have followed the reviewers' suggestions and provided feedback to the reviewers on a point-by-point basis (see responses below). All revisions are highlighted in *red* color in the manuscript.

Response to Editor's comments:

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

Comments E1:

Please follow the reviewers' suggestions carefully. Especially, please clarify the difference between the used data sets and the used models/equations.

Response:

Thanks for your helpful comments, and they were clarifed.

*"**Abstract.***

The relationship between net primary productivity (NPP) and forest age varies among forest species, yet there were no available NPP–age relationships established for various forest species in subtropical China for use in forest carbon modeling. This study explored the NPP–age relationships for seven forest species in subtropical China using field survey data from the Strategic Priority Project of Carbon Budget (SPPCB), National Forest Inventory (NFI) Type I (NFI-I), and Type II (NFI-II) data. Forest species included Pinus massoniana (P. massoniana), Cunninghamia lanceolata (C. lanceolata), Eucalyptus robusta (Eucalyptus), Other Coniferous Forests (OCF), Softwood Broadleaf (SWB), Hardwood Broadleaf excluding Eucalyptus (HWB), and Mixed Forests (MF). Based on these three datasets, we were able to derive subtropical forest species-specific NPP–age relationships using the Semi-Empirical Model (SEM). Implementation of these species-specific relationships in the process-based Integrated Terrestrial Ecosystem Carbon Cycle (InTEC) model markedly improved above-ground biomass (AGB) simulations for subtropical forests relative to simulations driven by the previously published China-wide NPP–age relationships. The greatest improvements were observed for P. massoniana, OCF, Eucalyptus, and SWB, where root-mean-square errors (RMSE) declined by 19.1–53.3%. These species-specific

NPP–age relationships therefore provide a robust, spatially explicit basis for forest carbon modeling and management in subtropical China."

Comments E2:

Furthermore, please clarify what has been used as validation data (was it measured or modeled).

Response:

Thanks for your helpful comments, and it was added.

*"**2.2. Data***

……

Given the limited availability of NFI-I and SPPCB samples, these data might be insufficient to effectively constrain the NPP–age curve in older forest age ranges. Consequently, we incorporated NFI-II polygons into our analysis. These polygons were rasterized into 30 m spatial resolution pixels using the nearest neighbor resampling method, and all pixels within a forest polygon shared the same attributes (Lin et al., 2023). The NFI-II samples were then created based on the dominance of forest species, requiring a proportion of 100% (with an adjustment to "higher than 80%" for C. equisetifolia and SWB due to their sample sizes) and the availability of relevant attribute records necessary for establishing forest NPP–age relationships (Lin et al., 2023). To ensure sample homogeneity and confirm that each sample is positioned at the center of the forest polygon, all adjacent 11×11 pixels were required to meet both criteria (Lin et al., 2023). Finally, NFI-II samples with old ages combined with the NFI-I and SPPCB samples (Fig. 1b and Fig. 2) were used to construct the forest NPP–age relationships. For each forest species, 80% of samples were randomly selected for building the NPP–age relationships, and the remaining 20% were used to validate the modeled aboveground biomass by the InTEC model with these relationships (see section 2.3.2 for details)."

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

……

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."*

Comments E3:

I suggest also to streamline the usage of the following terms in the manuscript and to define them clearly: 'forest type', 'forest species' and 'tree species'.

Response:

Thanks for your valuable comments. We have now consistently applied "forest species", and its definition was provided in the revised Introduction section.

*"**1. Introduction***

……

This study aims to explore forest NPP–age relationships for different forest species in subtropical China, with three objectives: (1) to comprehensively assess the impact of integrating NFI-II stand data on the construction of NPP–age curves; (2) to explore the NPP–age relationships of diverse forest species in subtropical China; and (3) to evaluate whether the forest species-specific NPP–age relationships can improve forest aboveground biomass modeling. Here, "forest species" denotes a functional–typological classification that groups individual tree species into ecologically and management-relevant categories rather than to biological species in the strict taxonomic sense. The forest species examined in this study include P. massoniana, C. lanceolata, Eucalyptus, Other Coniferous Forests except for P. massoniana and C. lanceolata (OCF), Softwood Broadleaf (SWB), Hardwood Broadleaf excluding Eucalyptus (HWB), and Mixed Forests (MF). Each species is defined by dominant taxa or shared functional or silvicultural traits, thereby enabling robust parameterisation of NPP–age relationships across heterogeneous subtropical forest stands. The resulting species-specific NPP–age relationships will provide scientific support for estimating forest carbon sequestration and formulating forest management strategies in subtropical China, contributing to enhanced understanding and management of forest carbon dynamics in this region."

Response to Reviewer #1's comments

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

Comments 1.1:

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 1.2:

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

……

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).

……"

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

……

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.

……”

Comments 1.3:

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 field 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):

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

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):

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

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) downscaled from the GLOBMAP Version 3 LAI product (see section 2.3.2 for details) (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 1.4:

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***

……

where LAI is the annual maximum of leaf area index (LAI) downscaled from the GLOBMAP Version 3 LAI product (see section 2.3.2 for details) (Liu et al., 2012), ……"

Comments 1.5:

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***

……

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.

……"

*"**4. Discussions***

……

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 1.6:

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-II 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*	*/*	

”

Response to Reviewer #2's comments

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

Comments 2.1:

Accurately establishing the relationship between Net Primary Productivity (NPP) and forest age is a crucial prerequisite for precisely simulating ecosystem carbon sequestration capacity. This study presents the first attempt to establish this relationship at the species scale, with a specific focus on improving NPP prediction accuracy for mature forests. Validation demonstrated that the NPP-age relationship based on the species scale effectively enhanced the accuracy of aboveground biomass (AGB) estimates simulated by the ecological model. This research holds significant scientific merit. The paper addresses an appropriate topic, features a rigorous experimental design, provides thorough argumentation, and maintains a well-structured presentation. It is recommended for acceptance after minor revisions.

Response:

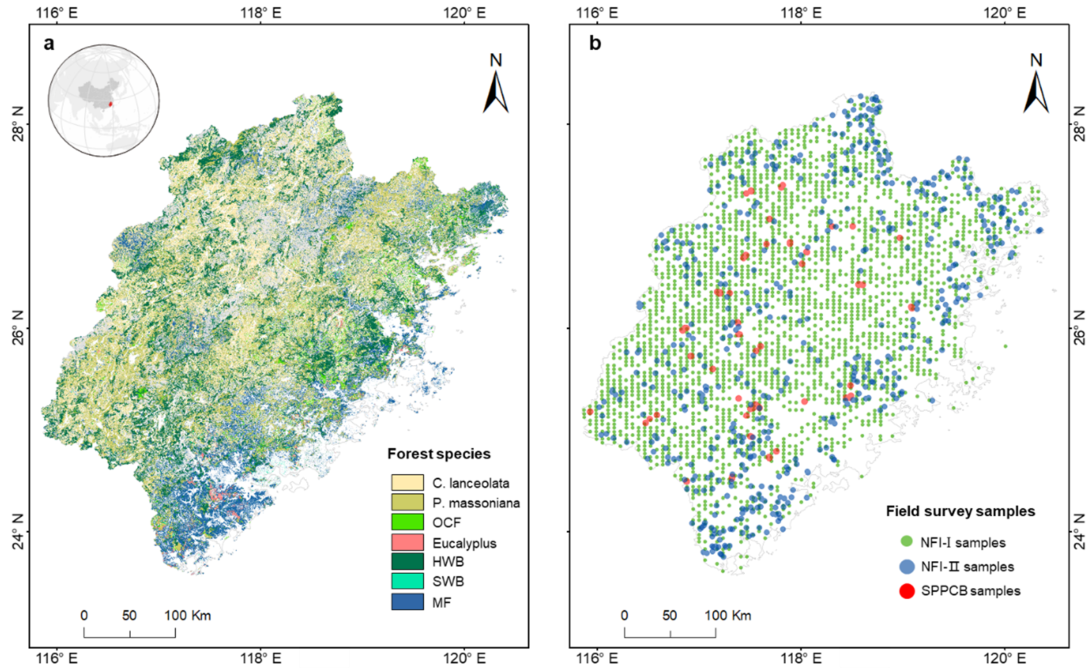
Thanks for your positive feedback.

Comments 2.2:

Figure 1a: Since the variable represented is categorical, the use of a color gradient is not recommended.

Response:

Thanks for your valuable comments. It was revised.



*"**Figure 1: The distribution of forest species in Fujian Province (a) and the distribution of NFI-I, NFI-II, and SPPCB field survey samples (b).** Different colours indicate different forest species, and the grey colour is for bamboo. P. massoniana: Pinus massoniana, C. lanceolata: Cunninghamia lanceolata, Eucalyptus: Eucalyptus robusta smith, HWB: Hardwood Broadleaf excluding Eucalyptus, SWB: Softwood Broadleaf, OCF: Other Coniferous Forests excluding P. massoniana and C. lanceolata, MF: Mixed Forests."*

Comments 2.3:

AGB Validation Data: The specifics of the AGB data used for validation need further clarification. This includes details on how the data was acquired and its spatial scale. Furthermore, regarding the InTEC model simulation, the grid size employed must be explicitly stated. This is particularly important given the vastly differing spatial resolutions of the model input data (Table 3). Clarify how these data were harmonized to a common scale for simulation. Additionally, address whether scale discrepancies exist between the model-simulated AGB and the ground-collected AGB, and if so, how these were reconciled.

Response:

Thanks for your valuable comments. Additional descriptions regarding the AGB validation, the resolution harmonization of model inputs, and the scale discrepancies between the simulated AGB and the ground AGB were added in sections 2.2 and 2.3.2.

A discussion on the varying spatial resolutions of model inputs was also included.

*"**2.2. Data***

……

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). NFI-I samples were obtained from China's 8th (2009-2013) and 9th (2014-2018) National Forest Inventories. Each NFI-I sample records various attributes, including survey time and location, dominant forest species, forest height, diameter at breast height (DBH), forest stock volume, average forest age, and so on. The ground survey size for each NFI-I sample is typically 667 m^2 (1 mu, a square of 25.82 m × 25.82 m), closely approximating a 30-m resolution. After screening for different forest species, a total of 2,746 samples were retained for each period.*

……"

*"**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-II 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."

*"**4. Discussions***

……

Last, the varying spatial resolutions of model inputs may affect the accuracy of model simulations. Downscaling LAI from 500 m to 30 m resolution using the RSR derived from Landsat data helps mitigate some scale-related impacts. However, in complex mountainous terrain, retrieving 30 m LAI may require consideration of additional factors, such as topography. Future research could focus on directly retrieving 30 m LAI based on Landsat data and Global Ecosystem Dynamics Investigation (GEDI) lidar data (Liang et al., 2025), thereby improving model accuracy. Besides, the empirical formulas embedded in the BEPS-TerrainLab V2.0 model (Xie et al., 2023; Govind et al., 2009) were also used to reduce the impacts of coarse resolution climate data. As higher-resolution remote sensing products and more ground climate data become available, it will *be possible to integrate higher-resolution climate data to further enhance the performance and reliability of the InTEC forest carbon modeling."*

Comments 2.4:

Lines 174-177: The content in these lines would be more suitably placed within the figure caption.

Response:

Thanks for your valuable comments. It was revised.

*"**Figure 3: NPP–age curves fitted by the SEM function for different forest species with and without using NFI-II samples.** The green and red lines depict the forest NPP–age curves with and without using NFI-II samples, respectively. Solid lines indicate the forest age ranges where field data are available, while dashed lines represent extrapolated curves beyond the field sample age range. The red and blue circles, with associated grey error bars, represent the average NPP values and their one standard deviation. The green and red lines depict the built forest NPP–age curves with and without using NFI-II samples. Solid lines indicate the forest age ranges where field data are available, while dashed lines represent extrapolated curves beyond the maximum age of the field samples. P. massoniana: Pinus massoniana, C. lanceolata: Cunninghamia lanceolata, Eucalyptus: Eucalyptus robusta smith, HWB: Hardwood Broadleaf excluding Eucalyptus, SWB: Softwood Broadleaf, OCF: Other Coniferous Forests except for P. massoniana and C. lanceolata, MF: Mixed Forest."*

Comments 2.5:

Lines 225-230: Several citations must be supplemented in this section.

Response:

Thanks for your valuable comments. They were added.

"This can be explained by the fact that hardwood species maintain stronger carbon absorption during later growth stages due to their higher wood density and longer lifespans (Luyssaert et al., 2008; Mun et al., 2020). In contrast, softwood species excel in rapid carbon sequestration during early stages but experience earlier and more significant productivity declines (Stephenson et al., 2014). Compared to C. lanceolate, P. massoniana shows a later peak NPP age and higher stabilized-to-peak NPP ratio, as P. massoniana supports prolonged carbon sequestration (Justine et al., 2017; Bai and Ding, 2024), while C. lanceolata prioritizes rapid early growth (Zhou et al., 2016)."

Comments 2.6:

Line 247 ("three previously built NPP–age curves for entire China"): Clarify the meaning of "three NPP-age curves". If this refers to curves for different forest cover types mentioned later, note that more than three types appear to exist. Additionally, it is recommended that the Methods section briefly describe how these prior China-wide NPP-age curves were constructed and explain the methodology used for their effective comparison with the relationship proposed in this study.

Response:

Thanks for your valuable comments and suggestions. They were added and revised.

*"**2.3.3. Comparison between the species-specific and China-wide NPP–age relationships***

The NPP–age relationships for seven forest species (referred to as species-specific curves) in Fujian province were compared with the built NPP–age relationships for entire China (shortened to as China-wide curves) (Li et al., 2024a). Previously, ten China-wide NPP–age curves were built by separating the southern and northern regions and five forest cover types (Li et al., 2024a): evergreen broad-leaved forests (EBF), evergreen needle-leaved forests (ENF), deciduous broad-leaved forests (DBF), deciduous needle-leaved forests (DNF), and mixed forests (MF). Only the southern-region ENF, EBF and MF curves were relevant to Fujian province, so the species-specific curves for C. lanceolata, P. massoniana and OCF were compared against the southern ENF curve, those for Eucalyptus, HWB and SWB against the southern EBF curve, and the MF curve against the southern MF curve. The intrinsic features of the species-specific and China-wide NPP–age curves and their performances within the InTEC carbon modeling were systematically compared."

*"**3.3. Comparison to the forest NPP–age curves built previously***

The normalized seven species-specific NPP–age curves were compared with three previously built China-wide curves (Fig. 6). The species-specific curves for C. lanceolata, P. massoniana and OCF were compared against the southern ENF curve, those for Eucalyptus, HWB and SWB against the southern EBF curve, and the MF curve against the southern MF curve. In general, the species-specific NPP–age curves constructed exhibit earlier peak ages and faster decline in old ages, particularly for Eucalyptus, C. lanceolate, OCF, and SWB."