Supplementary material for the manuscript

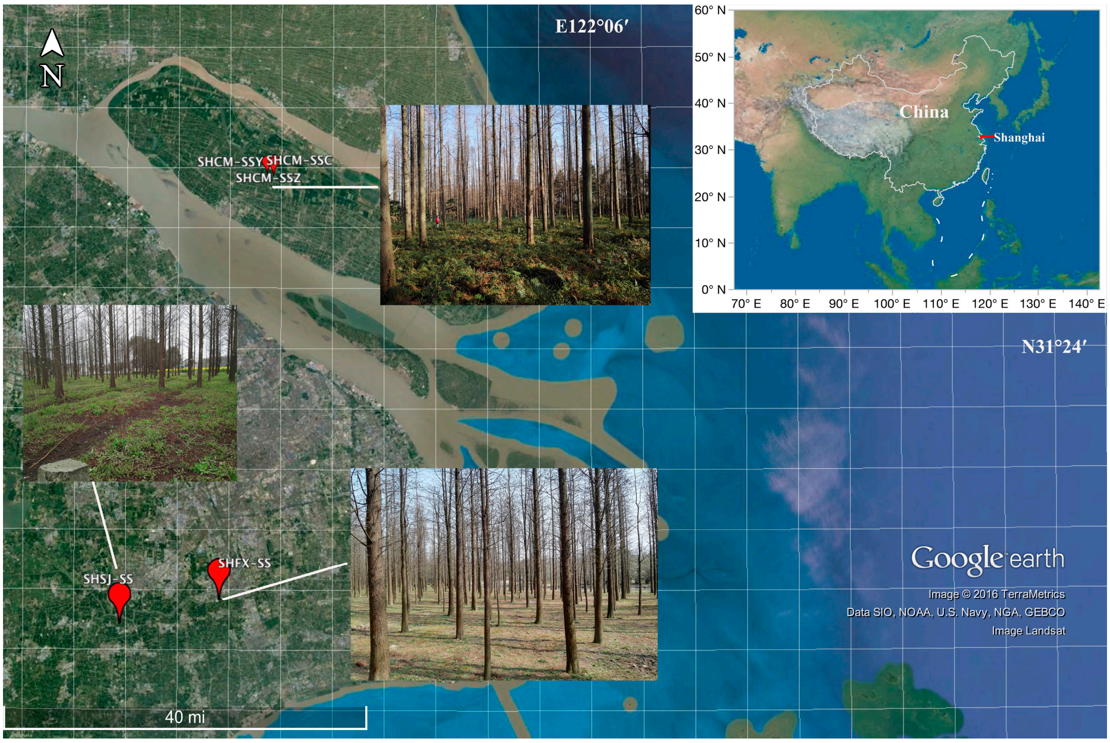

Figure S1 Study area of *M. glyptostroboides* plantations in SUFRN in Shanghai

Table S1 Description of *M. glyptostroboides* plantations plots in SUFRN

ID	County	Longitude	Latitude	SI (m)	Area (ha)	2016				2011			
						Age (year)	DBH (cm)	Height (m)	Density （stem ha^{-1}）	Age (Year)	DBH (cm)	Height (m)	Density （trees ha^{-1}）
1	Fengxian	121°22′52.25	30°59′04.96	12	0.06	17	10.2	10	3550	12	8.6	8.5	3550
2	Fengxian	121°22′52.24	30°59′03.78	16	0.06	17	10.4	13	2617	12	8.5	9.8	3017
3	Fengxian	121°22′51.32	30°59′02.36	14	0.06	17	11.5	13.3	2483	12	9.4	9.8	2767
4	Songjiang	121°19′06.58	30°94′31.18	10	0.06	23	19.1	14	933	18	14.6	11	967
5	Songjiang	121°19′04.75	30°94′31.05	10	0.06	23	18.2	14	1133	18	13.7	12.5	1133
6	Songjiang	121°19′02.30	30°94′31.00	10	0.06	23	16.9	14	1200	18	12.8	10.8	1500
7	Chongming	121°09′04.20	31°04′32.60	22	0.1	16	26.5	14.5	440	11	22.3	14.5	440
8	Chongming	121°09′04.19	30°04′32.50	22	0.1	16	19.4	13.5	880	11	15.8	10.1	880
9	Chongming	121°29′04.39	31°41′11.78	22	0.1	16	15.2	12	900	11	12.1	9.6	900
10	Chongming	121°29′06.17	31°41′26.82	12	0.1	25	21.8	20.7	760	20	20.7	17.5	760
11	Chongming	121°29′07.74	31°41′26.68	12	0.1	25	24.3	18	410	20	21.5	17.4	440
12	Chongming	121°29′06.39	31°41′26.48	12	0.1	25	22.7	17.7	640	20	20.4	16.4	640
13	Chongming	121°28′18.00	31°41′21.00	14	0.1	35	29.1	29	480	30	27.4	27	510
14	Chongming	121°28′21.00	31°41′19.00	16	0.1	35	30.7	29.3	410	30	28.7	28.4	440
15	Chongming	121°28′21.00	31°41′12.00	14	0.1	35	30.2	28.1	440	30	28.3	26.5	440

Table S2 The observed values for model evaluation

Stemwood biomass (Mg ha-1)			DBH (cm)			Top height (m)		
Age	Observed	Source	Age	Observed	Source	Age	Observed	Source
6	1.1	Fang et al., 1995	7	11.1	Gao et al.,1992	7	6.8	Gao et al.,1992
6	1.8	Fang et al., 1995	7	9.5	Gao et al.,1992	7	8.9	Gao et al.,1992
6	2.4	Fang et al., 1995	8	7.3	Xiao et al., 2010	8	5.4	Xiao et al., 2010
8	7.2	Xiao et al., 2010	11	15.8	SUFRN	11	14.5	SUFRN
8	6.4	Fang et al., 1995	11	12.1	SUFRN	11	10.1	SUFRN
8	8.9	Fang et al., 1995	12	16.6	Gao et al.,1992	11	9.6	SUFRN
8	10.9	Fang et al., 1995	12	11.4	Gao et al.,1992	12	11.4	Gao et al.,1992
10	21.4	Fang et al., 1995	12	8.6	SUFRN	12	12.3	Gao et al.,1992
10	22.6	Fang et al., 1995	12	8.5	SUFRN	12	8.5	SUFRN
10	26.1	Fang et al., 1995	12	9.4	SUFRN	12	9.8	SUFRN
11	48.5	SUFRN	15	16.3	Xiao et al., 2010	12	9.8	SUFRN
11	38.8	SUFRN	16	19.4	SUFRN	15	15.0	Xiao et al., 2010
11	19.5	SUFRN	16	15.2	SUFRN	16	14.5	SUFRN
12	31.0	SUFRN	17	10.2	SUFRN	16	13.5	SUFRN
12	30.6	SUFRN	17	10.4	SUFRN	16	12.0	SUFRN
12	25.5	SUFRN	17	11.5	SUFRN	17	10.0	SUFRN
12	36.3	Fang et al., 1995	18	19.5	Gao et al.,1992	17	13.0	SUFRN
12	32.7	Fang et al., 1995	18	14.6	SUFRN	17	13.3	SUFRN
12	41.5	Fang et al., 1995	18	13.7	SUFRN	18	14.4	Gao et al.,1992
12	68.5	Gao et al., 1992	18	12.8	SUFRN	18	16.3	Gao et al.,1992
14	51.5	Fang et al., 1995	20	12.4	Williams et al., 2003	18	11.0	SUFRN
14	43.9	Fang et al., 1995	20	12.4	Williams et al., 2003	18	12.5	SUFRN

14	55.8	Fang et al., 1995	20	20.7	SUFRN	18	10.8	SUFRN
15	50.6	Xiao et al., 2010	20	21.5	SUFRN	20	18.0	Williams et al., 2003
16	76.7	SUFRN	20	20.4	SUFRN	20	18.0	Williams et al., 2003
16	66.9	SUFRN	23	19.1	SUFRN	20	17.5	SUFRN
16	35.8	SUFRN	23	18.2	SUFRN	20	17.4	SUFRN
17	48.8	SUFRN	23	16.9	SUFRN	20	16.4	SUFRN
17	47.0	SUFRN	25	21.8	SUFRN	22	15.7	Gao et al.,1992
17	37.9	SUFRN	25	24.3	SUFRN	23	18.1	SUFRN
18	34.5	SUFRN	25	22.7	SUFRN	23	18.5	SUFRN
18	34.1	SUFRN	30	18.3	Chi, 2013	23	18.0	SUFRN
18	37.7	SUFRN	30	26.9	Xiao et al., 2010	25	20.7	SUFRN
18	110.7	Gao et al., 1992	30	27.4	SUFRN	25	18.0	SUFRN
20	68.7	SUFRN	30	28.7	SUFRN	25	17.7	SUFRN
20	44.0	SUFRN	30	28.3	SUFRN	27	24.7	Xie, 2007
20	55.6	SUFRN	32	17.9	Xie, 2007	30	24.3	Chi, 2013
23	68.0	SUFRN	35	29.1	SUFRN	30	22.5	Xiao et al., 2010
23	72.7	SUFRN	35	30.7	SUFRN	30	27.0	SUFRN
23	63.2	SUFRN	35	30.2	SUFRN	30	28.4	SUFRN
30	97.1	SUFRN	41	27.1	Williams et al., 2003	30	26.5	SUFRN
30	91.3	SUFRN	41	27.1	Williams et al., 2003	32	17.4	Xie, 2007
30	94.8	SUFRN	47	24.4	Williams et al., 2003	35	33.1	SUFRN
30	137.2	Xiao et al., 2010	47	24.4	Williams et al., 2003	35	34.0	SUFRN
30	144.5	Chi, 2013	48	25.1	Williams et al., 2003	35	35.0	SUFRN
32	198.6	Xie, 2007	48	25.1	Williams et al., 2003	41	27.3	Williams et al., 2003
35	107.3	SUFRN				41	27.3	Williams et al., 2003
35	108.6	SUFRN				44	31.5	Williams et al., 2003

35	105.7	SUFRN	44	31.5	Williams et al., 2003
			47	28.6	Williams et al., 2003
			47	28.6	Williams et al., 2003
			48	30.7	Williams et al., 2003
			48	31.1	Williams et al., 2003
			48	30.7	Williams et al., 2003
			48	31.1	Williams et al., 2003

The FORECAST model

FORECAST is a deterministic, management-oriented, stand-level forest growth and ecosystem dynamics simulator, which operates at annual time steps. The model simulates the dynamics of all forest carbon stocks required under the Kyoto Protocol (aboveground biomass, belowground biomass, litter, dead wood and soil organic carbon). It complies with the carbon estimation methods outlined by the IPCC (Penman et al. 2003). The model was designed to compare and contrast different management effects on forest productivity, stand dynamics and a series of biophysical indicators of non-timber values. The projection of stand growth and ecosystem dynamics is based on a representation of the rates of key ecological processes regulating the availability of, and competition for, light and nutrient resources. The rates of these processes are calculated from a combination of historical bioassay data (biomass accumulation in component pools, stand density, etc.) and measures of certain ecosystem variables (e.g., decomposition rates, photosynthetic saturation curves) by relating biologically active components (foliage and small roots) with calculations of nutrient uptake, capture of light, and net primary production (Blanco and González, 2010; Wang *et al*., 2013).

Using this internal calibration or hybrid approach, the model generates a suite of growth properties for each tree and plant species to be represented. These growth properties are subsequently used as a function of resource availability and competition. They include (but are not limited to) (1) photosynthetic efficiency per unit foliage biomass based on relationships between foliage biomass, simulated self-shading and net primary productivity after accounting for litterfall and mortality, (2) nutrient uptake requirements based on rates of biomass accumulation and literature- or field-based measures of nutrient concentrations in different biomass components at site of different qualities, and (3) light-related measures of tree and branch mortality derived from stand density input data in combination with simulated light profiles. Light levels at which foliage and tree mortality occur are estimated for each species. The model uses a mass balance approach to estimate how nutrients circulate in the ecosystem, and how their availability limits vegetation growth (trees, plants and bryophytes) together with available light in the canopy. Detailed descriptions of decomposition, tree uptake and biogeochemical cycles have been described before (Kimmins 1993, Kimmins et al. 1999, 2010).

Projection of stand growth and ecosystem dynamics is based upon a system of equations that links the rates of key ecological processes regulating the availability of, and competition for, light and nutrient resources with vegetation growth. The rates of these processes are calculated from a combination of historical bioassay data (biomass accumulation in component pools, stand density, etc., see (Kimmins et al. 1999) for a detailed description of input parameters needed) and measures of certain ecosystem variables (e.g. decomposition rates, photosynthetic saturation curves, etc.) by relating biologically active components (foliage and small roots) with calculations of nutrient uptake, capture of light, and net primary production. With the calibration data obtained from different sources, the model calculates the annual rates of different ecological processes (tree growth, litterfall production, mortality, etc.) that should had happened to produce the observed data on tree growth and density provided by the user. Therefore, for each plant species for which historical data are provided, the total net primary production (TNPP) that occurred for each annual time step (t) is calculated with Equation (1).

$$\mathrm{TNPPt} = \Delta\mathrm{biomasst} + \mathrm{litterfallt} + \mathrm{mortalityt} \qquad (1)$$

where Δbiomasst = the sum of the change in mass of all the biomass components of the particular species in time step t; litterfallt = the sum of the mass of all ephemeral tissues that are lost in time step t (e.g., leaf, branch, bark and reproductive litterfall, and root death); and mortalityt = the mass of plants that die in time step t. Change in biomass (Δbiomasst) in each time step is derived from a series of age–biomass curves created with empirical data (see a detailed description of the process in [Kimmins et al. 1999]). Litterfall is calculated using user-defined values based on empirical litterfall rates. For trees, mortality is derived from a series of age–stand density curves created with empirical data (for detailed descriptions on litterfall and mortality simulations in FORECAST, see (Kimmins 1993, Kimmins et al. 1999). For trees, mortality is calibrated through two different parameters: curves of historical stand density for different ages and the proportion of mortality that is due to non-interspecific competition factors. Together, both parameters allow simulating the endemic, low level mortality events caused by pests and diseases typical of coniferous forests. For plants (grasses and crops in these simulations) mortality is not simulated explicitly as no individual plants are simulated, but it is assumed to be included in the curves of biomass per area and age.

The model also estimates the Shade-Corrected Foliage N content (SCFN), which represents the amount of N in fully illuminated foliage that was required to produce the calculated historical TNPP, based on the empirical data. To estimate foliage shading, FORECAST simulates canopy foliage biomass as a “blanket” that covers the stand and that is divided in several layers of 0.25 m height, each of them increasingly darker from the top to the bottom of the canopy. Tree, understory, grasses or crop canopies are therefore simulated in the same way. The light absorbed by each layer is calculated based on the foliage biomass present in each time step and a user-defined empirical curve of foliage mass-proportion of full light (light absorption by foliage). Once an estimation of self-shading has been completed for a particular time step using the method described above, FORECAST calculates the equivalent N content after correcting for self-shading (SCFN, Equations 2 and 3).

$$SCFN_t = \sum_{i=1}^{n} (FN_{t,i} \times PLSC_i) \qquad (2)$$

$$FN_{t,i} = \text{foliage biomass}_{t,i} \text{ x foliar N concentration} \qquad (3)$$

Where $FN_{t,i}$ = mass of foliage N in the ith quarter-meter height increment in the live canopy at time t, $PLSC_i$ = photosynthetic light saturation curve value for the associated light level in the ith quarter-meter height increment in the live canopy, n = number of quarter-meter height increments in the live canopy at time t. The mean photosynthetic rate of the foliage in canopy level i is calculated by combining simulated light intensities in canopy level i with input data that define photosynthetic light saturation curves for the foliage type in question. Finally, the driving function curve for potential growth of a given species in FORECAST is the Shade-Corrected Foliar N Efficiency (SCFNE) calculated for each annual time step (t) with Equation 4:

$$SCFNEt = TNPPt / SCFNt \qquad (4)$$

When data describing the growth of a species on more than one site quality (defined as the combination of nutrient availability and climate conditions for a specific site, see [Kimmins 1993, Kimmins et al. 1999]) are provided, SCFNE function curves will be generated during the calibration stage for each site quality. To calculate the nutritional aspects of tree and plant growth, FORECAST requires data on nutrient concentration in each different tree organ. Nutrient dynamics in this study were restricted to N, the most limiting nutrient at these sites (Wei et al. 2012).

Net primary production in FORECAST is allocated among the different organs in the same ratios as the input data on biomass accumulation curves for each organ. If data are given for sites that differ in productivity, the model will simulate changing resource allocation strategies as the simulated nutritional site quality varies during a run of the model. Thus, empirically-observed variations in production allocation strategies on sites of different nutritional quality are used to guide the simulation of changing production allocation in response to simulated changes in nutritional site quality during the simulations.

Kimmins et al. (Kimmins et al. 2008) have shown how the combination of light and nutrient limitation is not enough to explain complex ecological patterns in simulated models, and they recommended including also understory vegetation. Therefore, a comparable but simpler (e.g. no data on bark, wood, mortality, etc.) set of data for understory vegetation must be provided to represent this ecosystem component. Lastly, data describing decomposition rates for various litter and humus types are required to simulate nutrient cycling. Decomposition rates are defined by the user (using values from empirical studies) and are affected by site quality, which in turn is defined depending on nutrient and water availability (Kimmins 1993, Kimmins et al. 1999). Litter is composed by a collection of different litter cohorts, each with its age and decomposition stage. Snags and logs are tracked by placing them into different categories depending on their original sizes (with slower decomposition rates for snags and for stems with larger sizes).

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