Supplementary material S1: **The original bark beetle outbreak model of LandClim and the two-step integration into ORCHIDEE**

Table S1: Main equations of the three versions of the bark beetle outbreak model presented in this study. Subscript "org" refers to the original bark beetle outbreak model (BBO_{org}) as presented in Temperli et al. 2013. The subscript "imp" refers to the spatially implicit formulation of a simplified bark beetle outbreak model (BBO_{imp}), subscript "orc" refers to the bark beetle outbreak model in ORCHIDEE (BBO_{orc}). Subscript "p" represents a patch of 25x25m and "p_t "denotes the total number of patches. Subscript "lc" refers to landscape scale averages, and subscript "dc" represents the diameter classes in ORCHIDEE.

Process	Change in formulation	secondary equation
Susceptibility to drought	(1a) $SId_{org} = \sum_{p_t}^{p=1} \left(1 + e^{d1\times(DImax_p - d2)}\right)^{-1} \times \frac{1}{p_t}$ (1b) $SId_{imp} = \left(1 + e^{d1\times(DImax_{lc} - d2)}\right)^{-1}$ (1c) $SId_{orc} = \sum_{nac}^{ac=1} \left(1 + e^{d1\times((1-MOmax_{ac}) - d2)}\right)^{-1} \times \frac{Frac_{ac}}{ndc}$	$DImax_p = \max(DI, \dots, DI_{n-10})$ $DImax_{lc} = \sum_{pt}^{p=1} \frac{DImax_p}{p_t}$ $MOmax_{ac} = \max(MO, \dots, MO_{n-3})$
Susceptibility to windthrow	(2a) $SIw_{org} = \max\left(\frac{Bdw_p}{Bmax}, \frac{Bdw_k}{Bmax} \in D(p,k) < Dw\right)$ (2b) $SIw_{imp} = \frac{Bdw_{lc}}{Bmax}$ (2c) $SIw_{orc} = \frac{\frac{Litw_{sp}}{Bw_{sp}}}{Lit_{thres}}$	$Bdw_{lc} = \sum_{p_t}^{p=1} \frac{Bdw_p}{p_t}$ Lit_{thres} = *threshold of breeding substrate at whi windthrow susceptibility reaches its maxi*
Susceptibility to stem density	(3a) $SIra = \sum_{p_t}^{p=1} \left(a1 + \frac{1-a1}{1+e^{a2\times(Age_p - a3)}}\right) \times \frac{1}{p_t}$ (3b) $SIa_{imp} = \left(a1 + \frac{1-a1}{1+e^{a2\times(Age_{lc} - a3)}}\right)$ (3c) $SIr_{orc} = \left(a1 + \frac{1-a1}{1+e^{a2\times(RDI_{sp} - a3)}}\right)$	$RDI_{lc} = \sum_{p_t}^{p=1} \frac{RDI_p}{p_t}$
Susceptibility to patch purity	(4a) $SIs_{org} = \sum_{p_t}^{p=1} (s1 + (1-s1)/(1 + s2 \times e^{s3\times(Sh_p - s4)})^{s5^{-1}}) \times \frac{1}{p_t}$ (4b) $SIs_{imp} = (s1 + \frac{1-s1}{1+s2\times e^{s3\times(Sh_{lc} - s4)})^{s5^{-1}}})$ (4c) $SIs_{orc} = \left(1 + e^{s1*(sh_{sp} - s2)}\right)^{-1}$	$Sh_p = \frac{BA_{sp}}{BA_t}$ $Sh_{lc} = \sum_{p_t}^{p=1} \frac{Sh_p}{p_t}$ $Sh_{sp} = \frac{Frac_{deciduous}}{Frac_{spruce}}$
Susceptibility of trees to bark beetle infestation	(5a) $SI_{org} = \frac{SIw_{org}}{2} + \frac{SId_{org} + SIa_{org} + SIs_{org}}{6}$ (5b) $SI_{imp} = \frac{SIw_{imp}}{2} + \frac{SId_{imp} + SIa_{imp} + SIs_{imp}}{6}$ (5c) $SI_{orc} = SIw_{orc} \times Ww + SIr_{orc} \times Wr + SId_{orc} \times Wd + SIs_{orc} \times Ws$	$Risk_{orc} = \max\left(RI_{orc}, \dots, RI_{orc,n-3}\right)$ $Ws = 0.1;\ Wd = 0.1$ $Wr = \left(1 + e^{r1\times(Risk_{orc} - r2)}\right)^{-1} \times (1 - (Ws + Wd))$ $Ww = 1 - (Wr + Ws + Wd)$

Susceptibility of trees to mortality after bark beetle infestation	(6a) $SI_{p,co} = \max\left(SIw_{p,co}, \frac{SIa_{p,co} + SId_{p,co}}{2}\right)$ (6b) $SI_{p,co} = \max\left(SIw_{p,co}, \frac{SIa_{p,co} + SId_{p,co}}{2}\right)$ (6c) $SI_{ac} = SIr_{ac} \times Wr + SId_{ac} \times (1 - Wr)$	
Beetle pressure index	(7a) $BPI_{org} = Cbp \times SI_{org} \times \frac{GI + \frac{Bdb_{p,n-1}}{Bmax}}{2}$ (7b) $BPI_{imp} = Cbp \times SI_{imp} \times \frac{GI + \frac{Bdb_{imp,n-1}}{Bmax}}{2}$ (7c) $BPI_{orc} = Cbp \times SI_{orc} \times \frac{GI + \frac{Bdb_{pix,n-1}}{Bt \times Cst}}{2}$	
Risk index	(8a) $RI_{org} = SI_{org} \times BPI_{org}$ (8b) $RI_{imp} = SI_{imp} \times BPI_{imp}$ (8c) $RI_{orc} = SI_{orc} \times BPI_{orc}$	
Infested biomass by bark beetle	(9a) $Binf_{org} = 150 \times SI_{org} \times BPI_{org} + r_{beta}$ (9b)$Binf_{imp} = 150 \times SI_{imp} \times BPI_{imp}$ (9c) $Binf_{orc} = Bt \times Cst \times SI_{orc} \times BPI_{orc}$	$r_{beta} = random\ tern$
Killed biomass by bark beetle	(10a) $Bdb_{org} = \sum_{p}^{p=1} {}_{t} \sum_{nco}^{co=1} \frac{SI_{p,co} + BPI_{org}}{2} \times Binf_{p} \times \frac{BA_{sp,co}}{BA_{sp}}$ (10b) $Bdb_{imp} = \sum_{nco}^{co=1} \frac{SI_{lc,co} + BPI_{imp}}{2} \times Binf_{imp} \times \frac{BA_{lc,co}}{BA_{sp}}$ (10c) $Bdb_{orc} = \sum_{nac}^{ac=1} \frac{SI_{ac} + BPI_{orc}}{2} \times Binf_{orc} \times \frac{BA_{ac}}{BA_{sp}}$	Retrieving $Binf_{p}$ from $Binf_{org}$ is explained in Temperli *et al.* 2013