Forest responses to simulated elevated CO_2 under alternate hypotheses of size- and age-dependent mortality

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Supplementary Figures

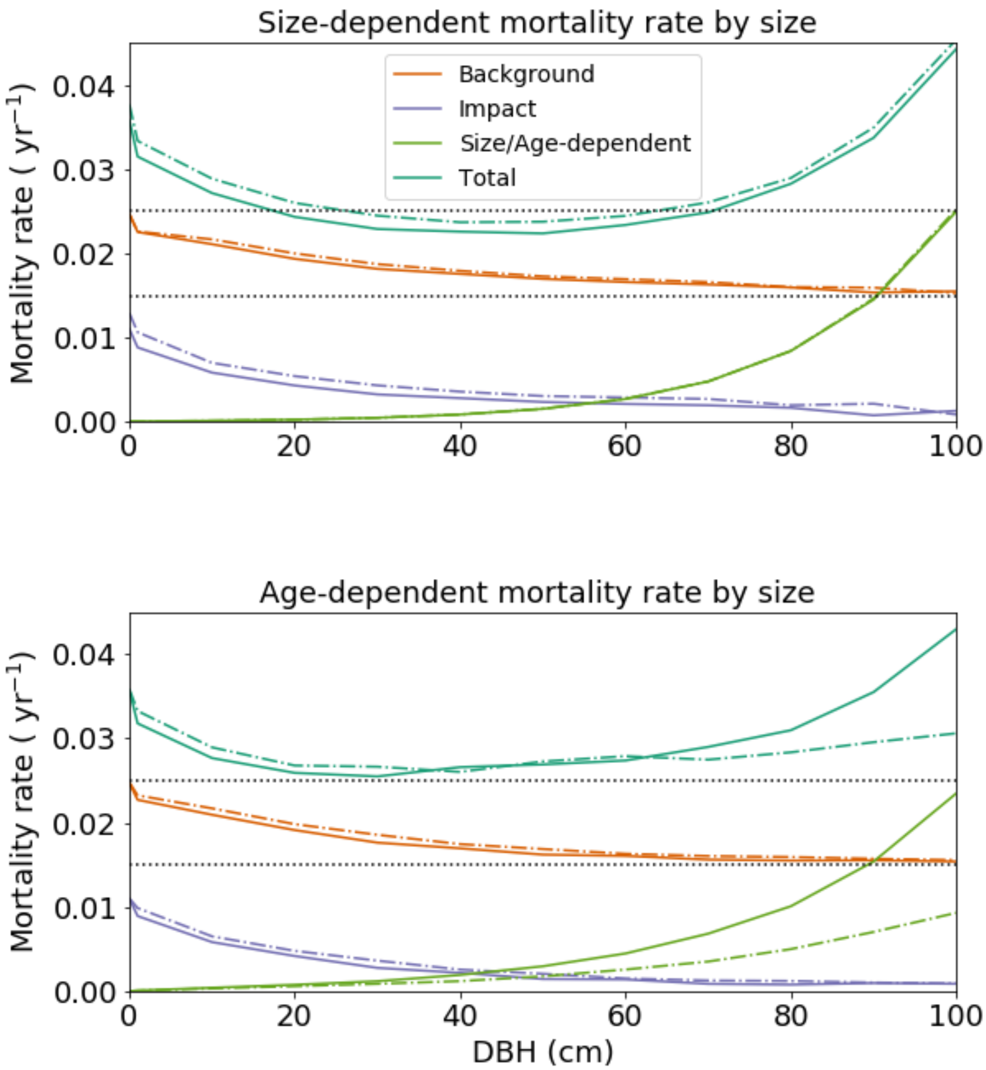

Figure 1: Mortality terms against DBH. Dashed horizontal lines show the background mortality rates in they understory (top dashed line) and canopy (lower dashed line). Solid lines are in control runs with constant wNPP, dotted curves show each mortality term following ewNPP. The orange lines show how background mortality is reduced at larger sizes due to a greater proportion of canopy versus understory cohorts. Conversely, impact mortality decreases with size as this term only affects understory cohorts which tend to be smaller. Size and age dependent mortality increase with DBH. Size-dependent mortality does not change following ewNPP, whereas age dependent mortality at a given DBH is reduced following eNPP because plants are faster growing and therefore younger for the same size.

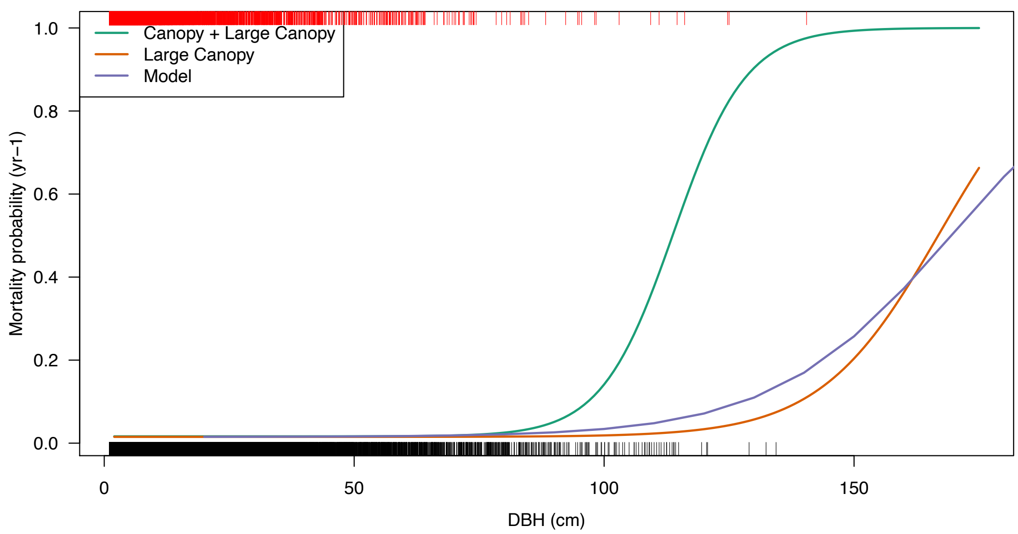

Figure 2: Modelled size-dependent mortality compared to observed mortality at Barro Colorado Island, Panama. Rugs show survival (black, bottom axis) and mortality (red, top axis) during the 2010 to 2015 census interval against DBH in cm. The green and orange curves show the basal area weighted mean survival curve for species assigned to the large-canopy cluster (purple) and both the canopy and large-canopy clusters (green) from Johnson et al., 2018. The purple line shows the model we used in simulations presented in the rest of the manuscript.

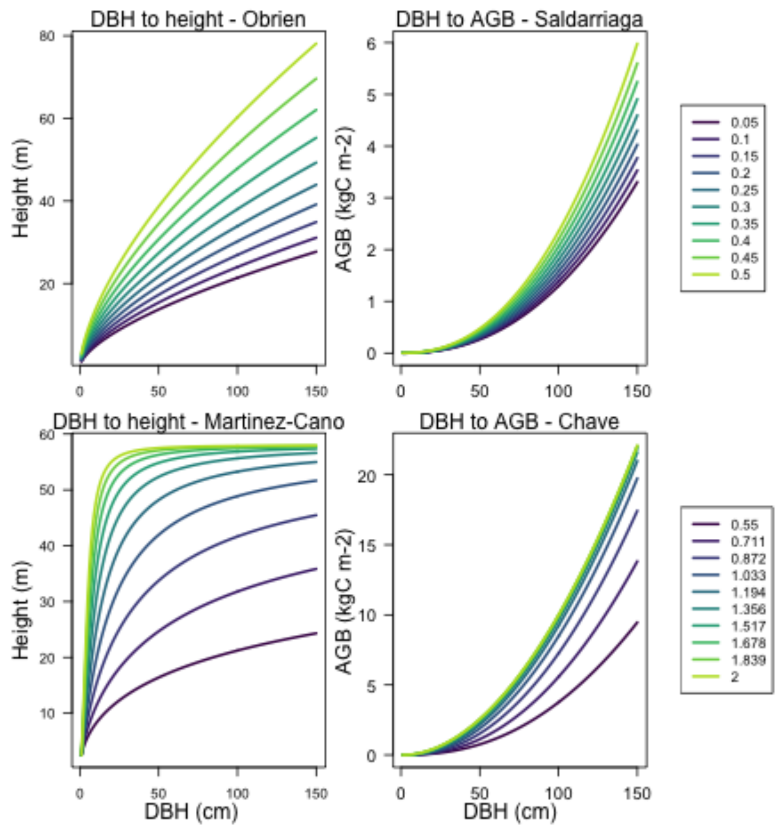

Figure 3: Parameterisation of the DBH to height and DBH to AGB allometric equations in the allometry sensitivity analysis. In top panels the p_2 parameter in DBH to height allometry eq.5 was altered from 0.05 to 0.5. Resulting heights were used to calculate AGB using eq.7. In bottom panels the p_2 parameter in DBH to height allometry eq.8 was altered from 0.55 to 2.0 and these heights were used to calculate AGB using eq.9.

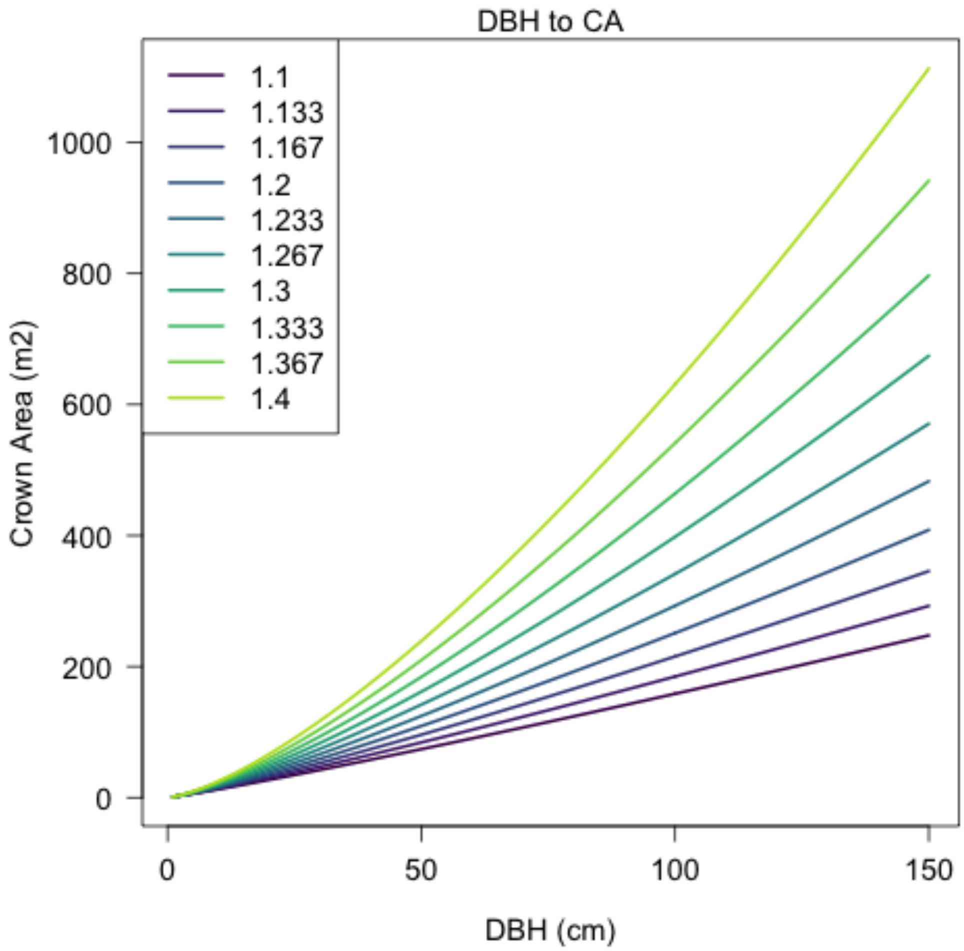

Figure 4: Parameterisation of the DBH to crown area allometric equation in the allometry sensitivity analysis. The $d2bl_{p2}$ parameter ranged from 1.1 to 1.4.

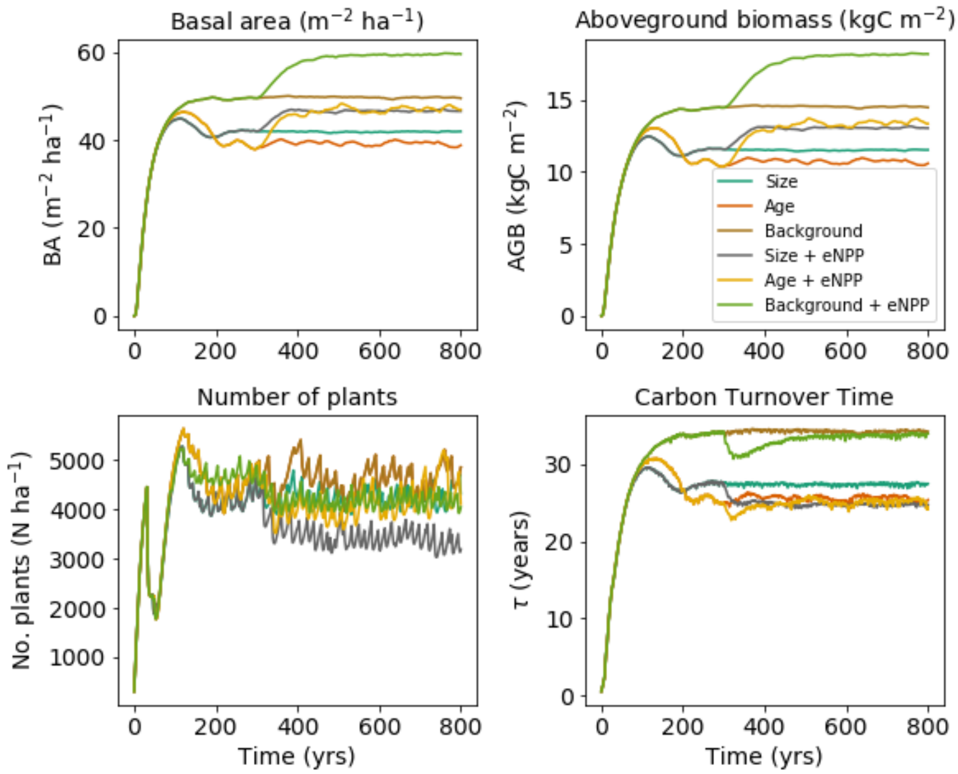

Figure 5: Absolute changes in basal area, aboveground biomass, number of plants and carbon turnover time in the one PFT simulations with background, size or age dependent mortality.

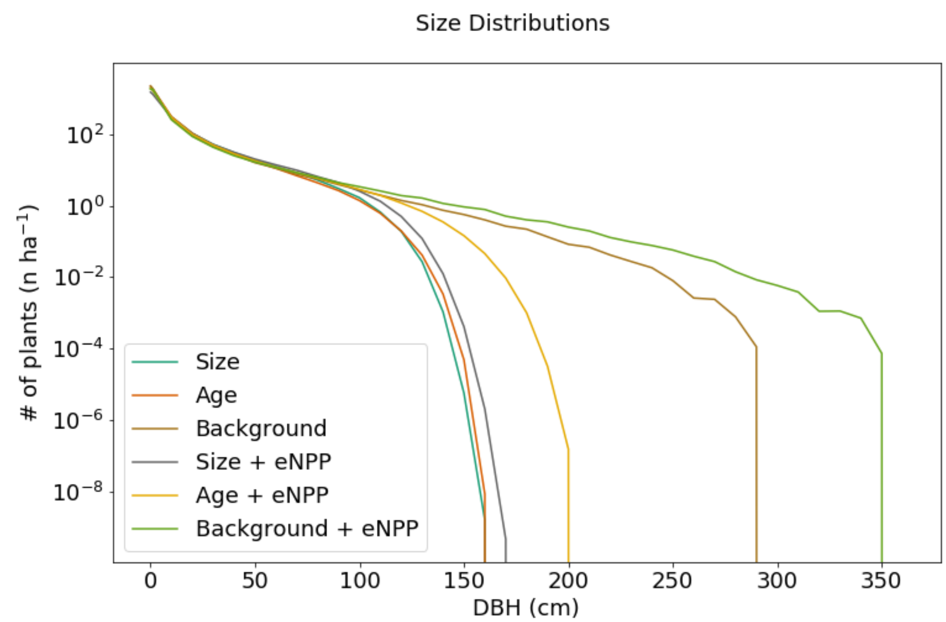

Figure 6: Size distributions for one PFT simulations. Results show the mean number of trees per ha over the last 400 years of simulations in the size-dependent, age-dependent, and just background mortality simulations with both constant NPP and eNPP in each case. The y-axis is logged, but the x-axis is linear to emphasise differences in the larger size classes.

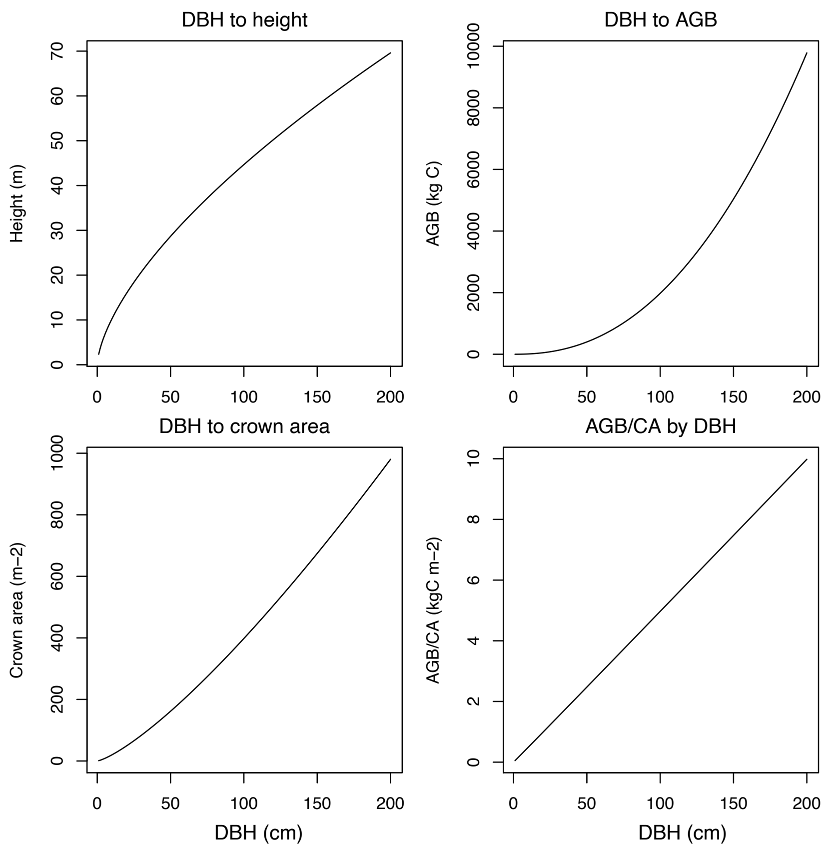

Figure 7: Allometries used in FATES simulations. DBH to height, aboveground biomass (AGB), crown area (CA) and AGB per unit CA. As DBH increases AGB per unit of crown area increases.

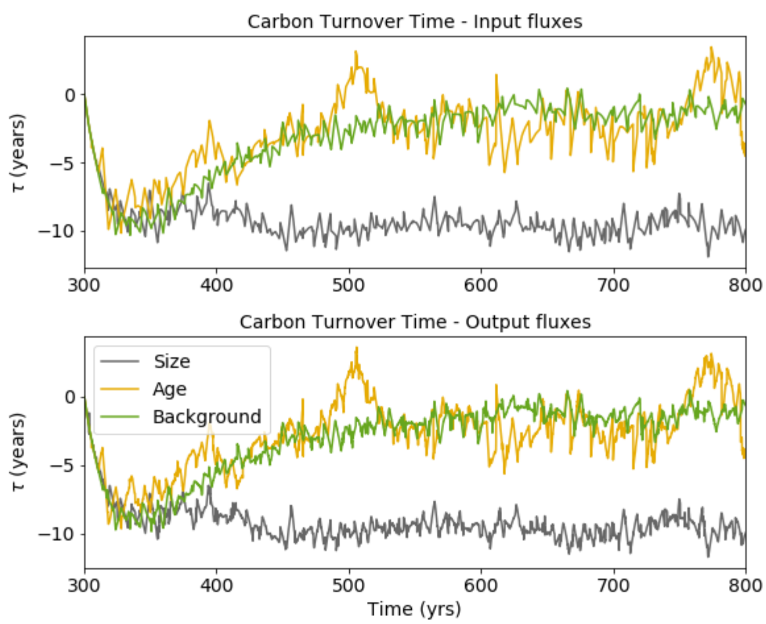

Figure 8: Carbon turnover calculated using input (NPP) and output (mortality) fluxes. The top panel is what is presented in the main results, but given the equilibrium assumption, results can only be evaluated at steady state. However, these results show that τ is expected to initially decrease under all mortality scenarios, regardless of the method used to calculate it.

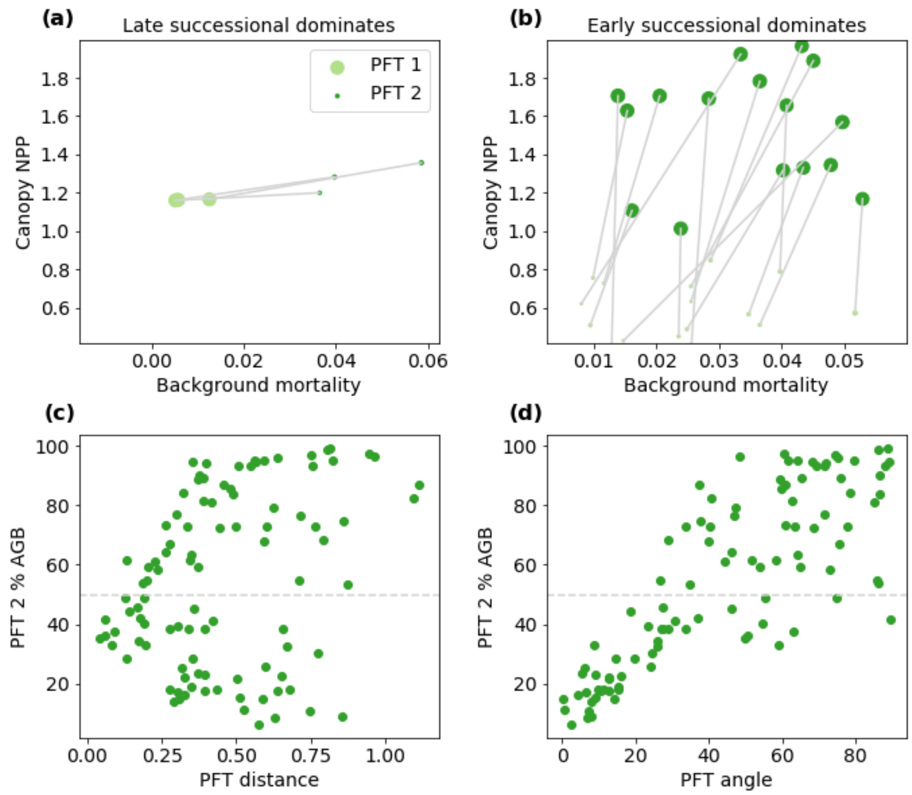

Figure 9: Coexistence of PFT pairs. Top panels show the position of PFT pairs in parameter space where the late successional PFT (PFT 1) (left) or early succesional PFT (PFT 2) (right) makes up greater than 80% of plot AGB (prior to eNPP). Bottom panels show the percentage of plot AGB in the early successional PFT against the angle and distance between PFTs in each pair. Early successional PFTs dominate when the difference in NPP between PFTs is greater than the difference in mortality (high angle) (top right, bottom right). Late successional PFTs dominate when differneces in mortality are large relative to differences in NPP between PFT pairs (small angles) (top left, bottom right). PFTs are more equal when the demographic distance between them is small (bottom left). As they become more demographically different one or the other starts to dominate AGB. These results are for size-dependent mortality.

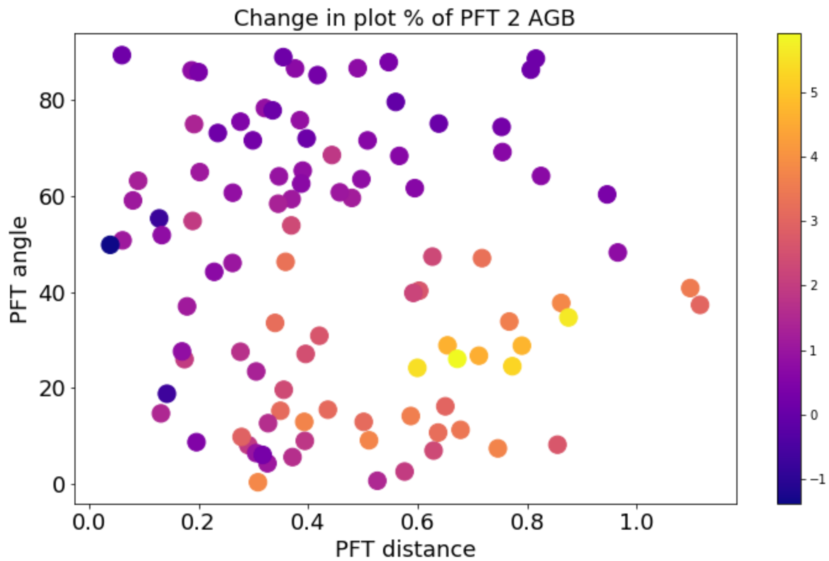

Figure 10: Change in the percent AGB of the early successional PFT (PFT 2) following the increase in NPP. The early successional PFT was able to increase most following simulated eNPP when the distance between PFT pairs was intermediate and the angle between PFT pairs was low. The early successional PFT decreased in plot AGB when the angle between PFTs was high. These results are for size-dependent mortality.

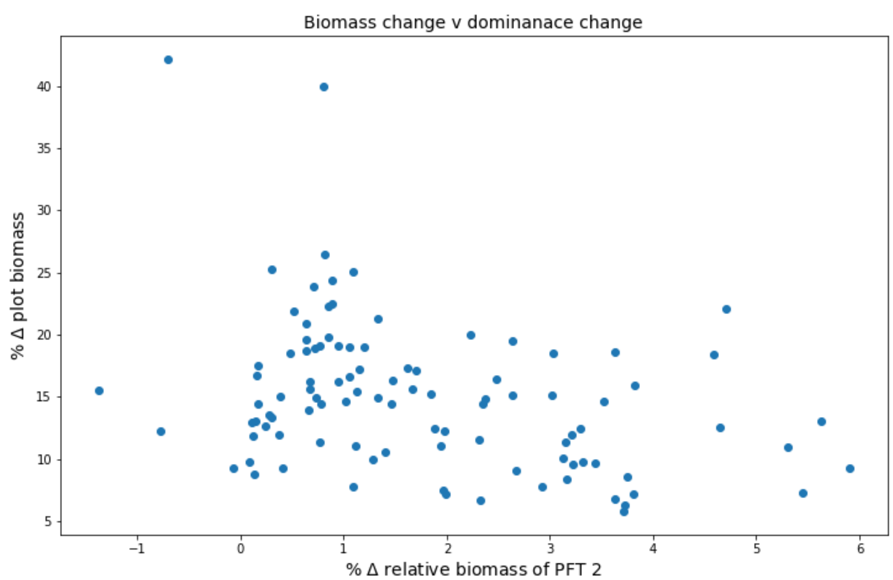

Figure 11: Change in biomass of PFT2 relative to PFT1 in response to eNPP, against plot level change in AGB. Negative numbers on the x axis show ensemble members where the relative proportion of plot AGB in PFT 2 (early successional) was higher in the constant simulation than in the ewNPP simulation. Results show that in most cases, the early successional PFT increased in dominance in response to eNPP, but this lead to smaller overall increases in plot level biomass, due to the higher background mortality of the early successional PFT.

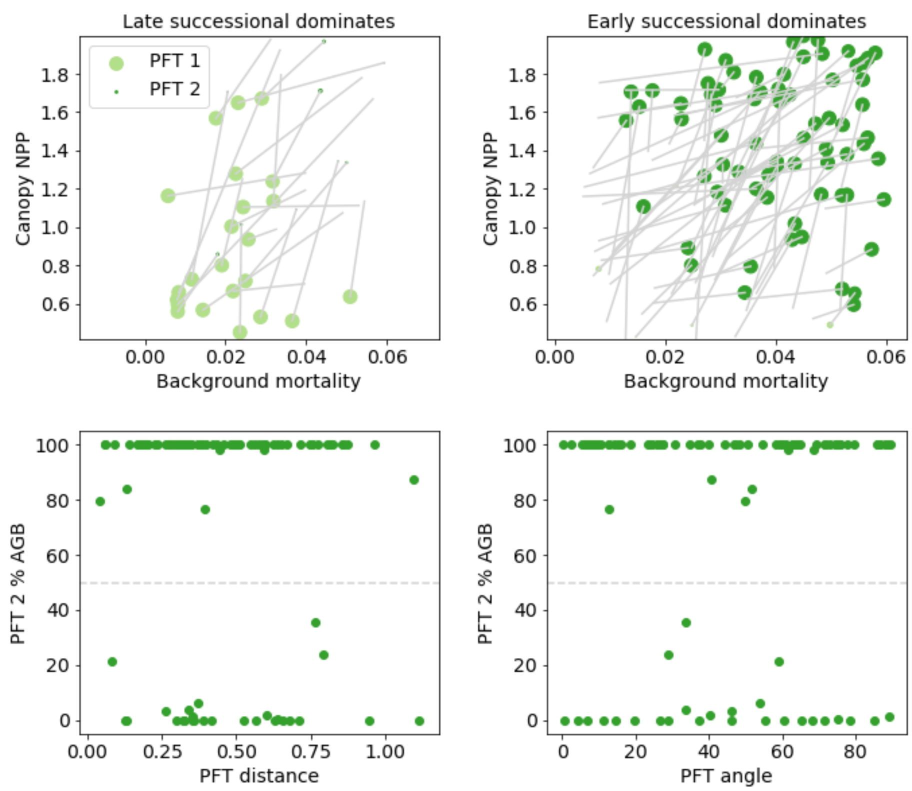

Figure 12: Co-existence of PFT pairs with size-dependent mortality according to demographic parameterisation, when recruitment is based on existing PFT AGB. Top panels slow the position of PFT pairs in demographic space, defined by rates of background mortality and canopy NPP. Top left show PFT pairs where the relatively more late-successional PFT dominates, and top right shows PFT pairs where the relatively more early successional PFT dominates. Bottom panels show the percent of AGB of the early successional PFT as a function of the distance between PFTs in demographic space (left) and the angle between them (right). Assigning PFT identity to recruits based on existing proportions of PFTs in the plot resulted in far less co-existence than when both PFTs were able to recruit at each time step.

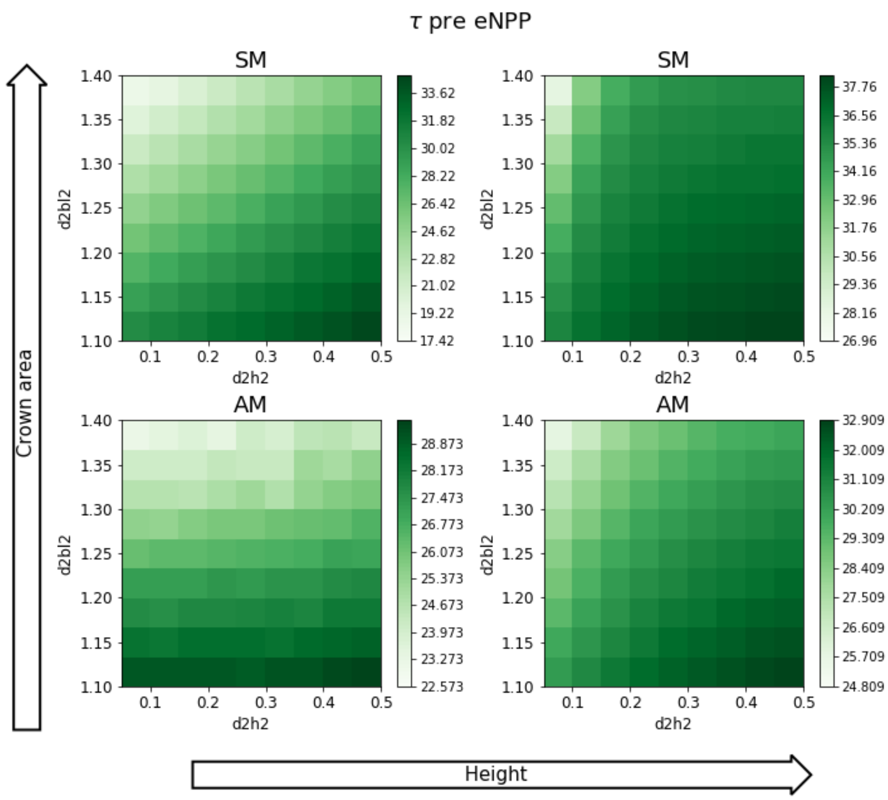

Figure 13: τ for each set of allometries (eqs.5 and 7 LHS, eqs.8 and 9 RHS) with size-(SM) and age-dependent (AM) mortality, prior to the increase in NPP.

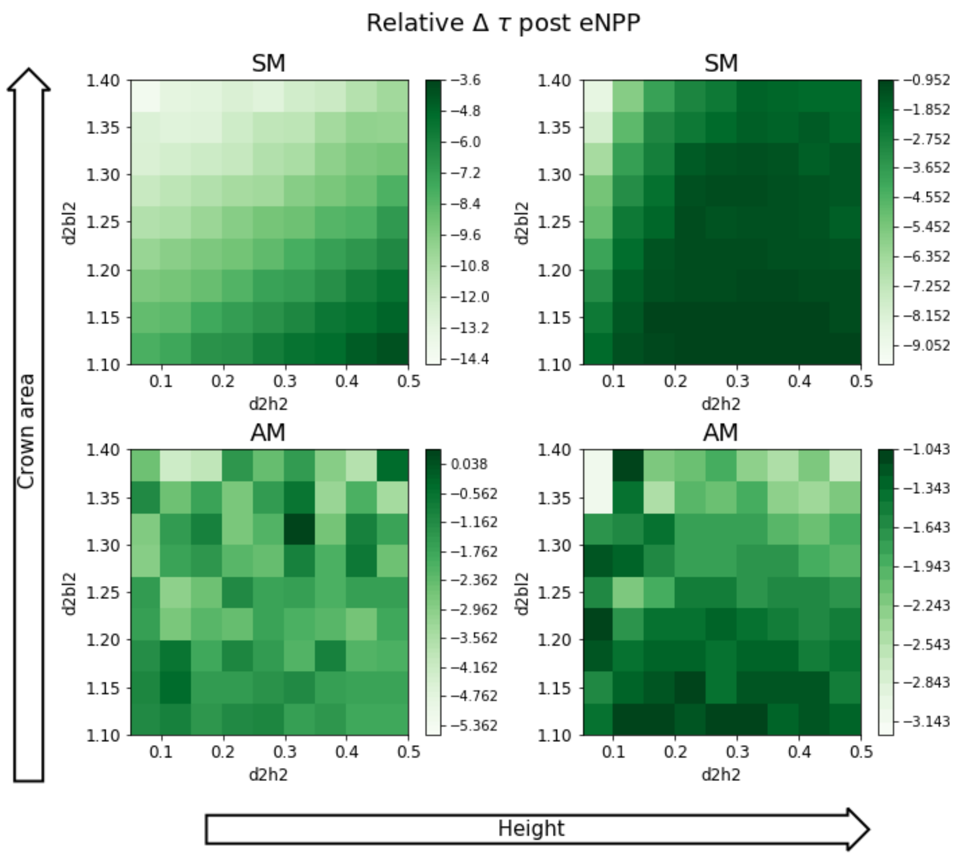

Figure 14: Change in τ for each set of allometries (eqs.5 and 7 LHS, eqs.8 and 9 RHS) with size-(SM) and age-dependent (AM) mortality, after the increase in NPP.

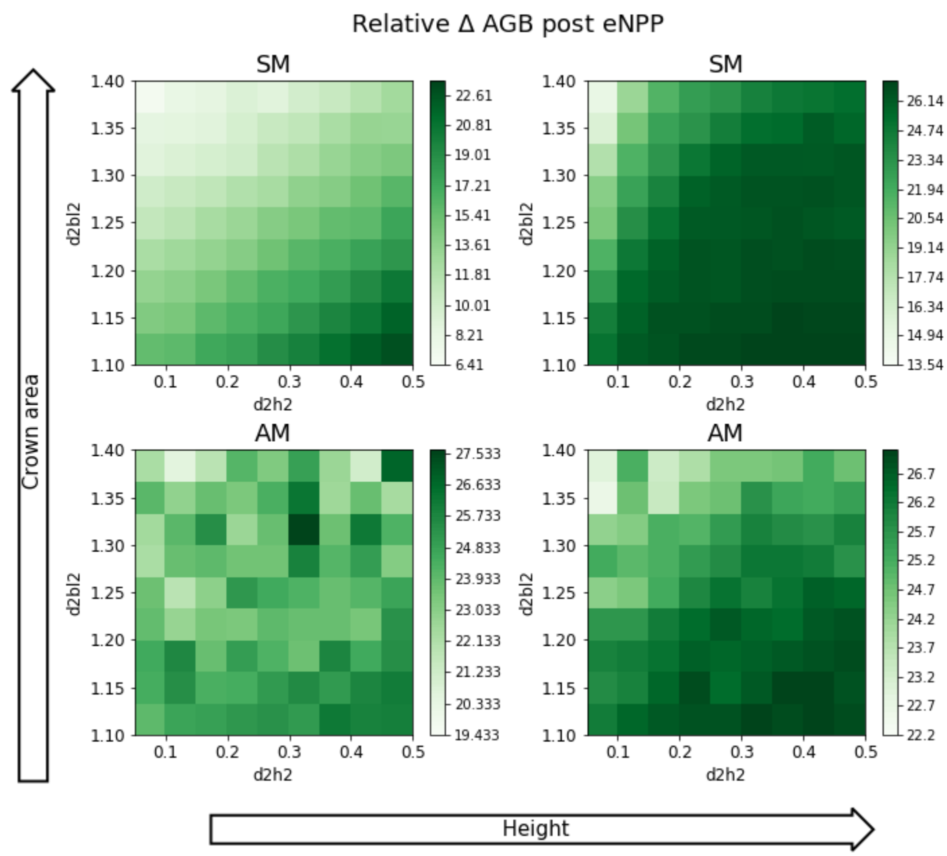

Figure 15: Change in AGB for each set of allometries (eqs.5 and 7 LHS, eqs.8 and 9 RHS) with size-(SM) and age-dependent (AM) mortality, after the increase in NPP.

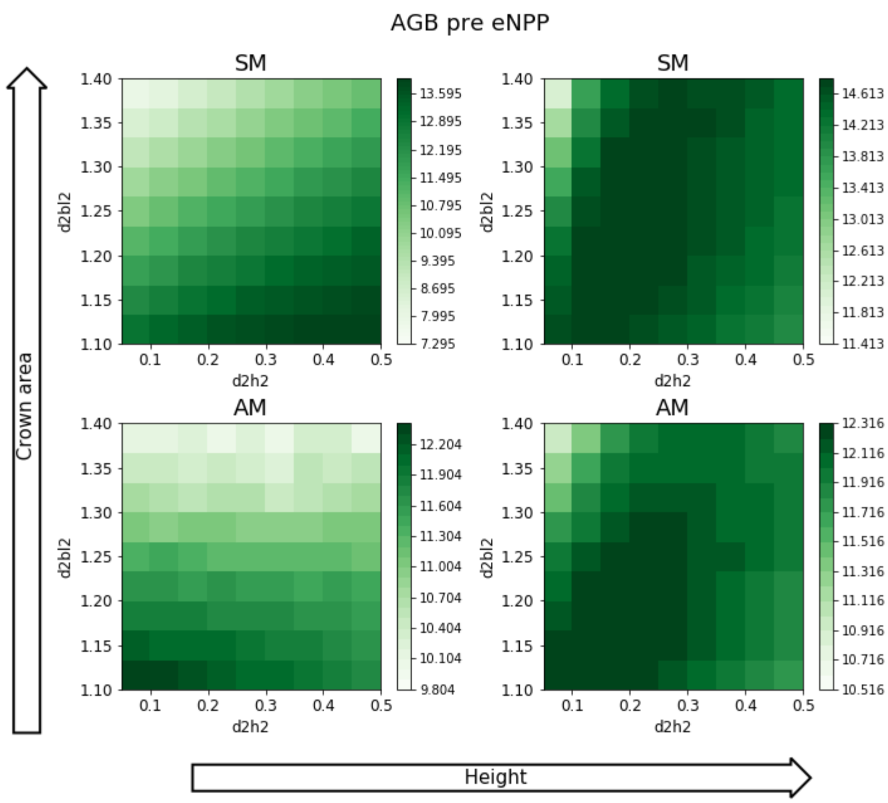

Figure 16: AGB for each set of allometries (eqs.5 and 7 LHS, eqs.8 and 9 RHS) with size-(SM) and age-dependent (AM) mortality, prior to the increase in NPP.

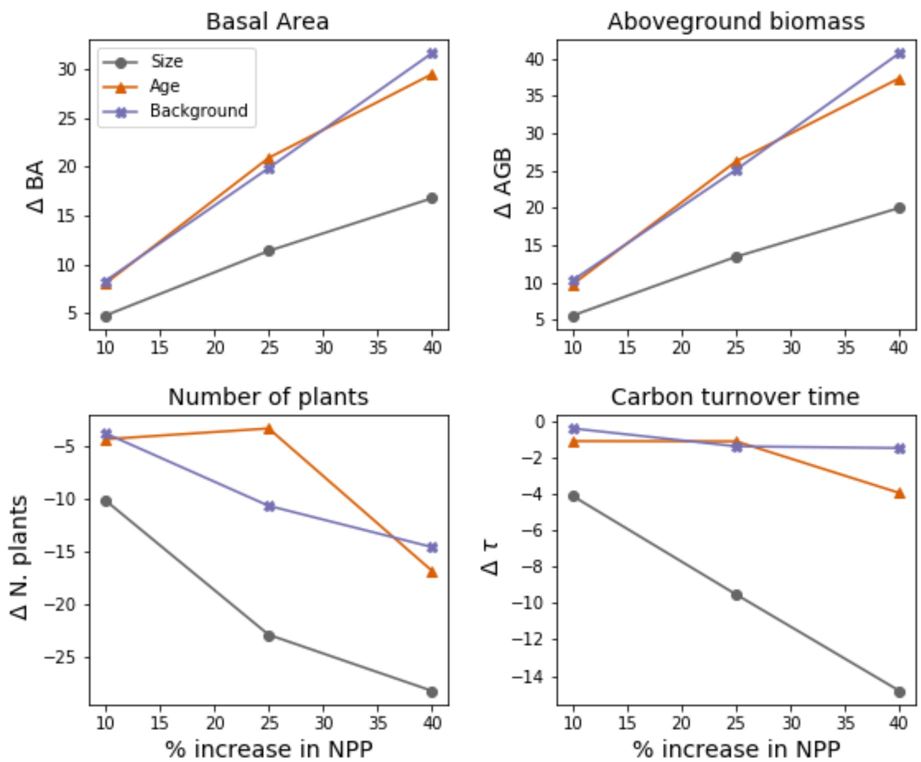

Figure 17: Sensitivity of background, size-, and age-dependent mortality simulations to increases in NPP. Results show the relative change in basal area, aboveground biomass, number of plants and carbon turnover time in simulations with 10%, 25% and 40% increases in NPP, relative to a control run with constant NPP.

Tables

	Mort_s	Mort_a
Canopy mortality	0.015	0.015
Understory mortality	0.025	0.025
Canopy NPP	0.700	0.700
Understory NPP	0.050	0.050
Recruitment	0.020	0.020
p	170.000	280.000
r	0.056	0.040

Table 1: PFT parameters in single PFT simulations. mort_s and mort_a are size- and age-dependnet simulations respectively.

	Mort_s PFT 1	Mort_s PFT 2	Mort_a PFT 1	Mort_a PFT 2
Canopy mortality	0.005 - 0.06	0.005 - 0.06	0.005 - 0.6	0.005 - 0.6
Understory mortality	0.025	0.050	0.025	0.050
Canopy NPP	0.4 - 2.0	0.4 - 2.0	0.4 - 2.0	0.4 - 2.0
Understory NPP	0.031	0.031	0.031	0.031
Recruitment	0.020	0.020	0.020	0.020
p	195.000	195.000	280.000	280.000
r	0.055	0.055	0.040	0.040

Table 2: PFT parameters in paired PFT simulations. mort_s and mort_a are size- and age-dependnet simulations respectively. In both size- and age-dependent mortality scenarios, PFT 1 is the relatively more late succesional PFT than PFT 2. For each PFT pair, canopy mortality and canopy NPP were drawn from a uniform distribution with bounds given in the table. Pairs with higher canopy NPP or lower canopy mortality in PFT 1 were discarded.