

***Interactive comment on “ Mortality as a key driver  
of the spatial distribution of aboveground biomass  
in Amazonian forests: results from a Dynamic  
Vegetation Model” by N. Delbart et al.***

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Answer to Reviewer 2 Rosie Fisher

Thanks a lot for your positive and useful comments. Please find our answers below. Of course we are willing to make more modifications if you think this is not sufficient.

Reviewer's comment : I think this is a nice piece of work and highlights a major issue presumably common to many Amazonian DVM simulations; that assumptions

C2615

of constant mortality across the Amazon basin are erroneous and will lead to errors in biomass, all other things equal. I think this paper is acceptable in its present form and would be maybe slightly improved with the minor corrections below. In addition, one aspect that I think is missing from the discussion is an exploration of the physiological or ecological mechanisms responsible for generating the observed NPP/mortality relationship. The interactions between climate, soil type and depth and ecosystem properties have been discussed in recent RAINFOR project publications (e.g. <http://biogeosciences-discuss.net/6/3993/2009/bgd-6-3993-2009.pdf> and <http://www.biogeosciences-discuss.net/6/3707/2009/bgd-6-3707-2009.pdf> ). While it might be slightly beyond our comprehension at this stage, it is worthwhile noting that we may, in the medium-term, want to simulate the linkages between climate, soil, mortality risk and competition such that the NPP-mortality relationships (and how they change with climate and CO<sub>2</sub>) can be predicted and these data used for validation, rather than parameterisation.

Answer : Many thanks for this suggestion and for having driven our attention to Quesada et al. 2009. This is very useful. We added the following paragraphs in the discussion, and the following figure C1 in the appendices.

“Soil type is an important factor influencing NPPAGW and residence, as shown in Fig. C1. For example, forests with low NPPAGW and long residence are favoured on older oxisol, whereas forests with high NPPAGW and short residence are favoured on entisol. Based on ground measurements, Quesada et al. (2009) analysed the impact of soil properties on the mortality rate and on NPPAGW. The mortality rate was found essentially influenced by the soil physical properties (topography, soil depth, structure), whereas NPPAGW was found primarily driven by fertility parameters, essentially phosphorus availability. The authors proposed that AGBW gradients can be explained by the ecosystem dynamics that is essentially driven by these soil properties. In Western Amazonia, poor soil physical properties (steep slope, shallow soils) favour high mortality rate, which favours early-successional species with low wood density, whereas

C2616

meanwhile the high phosphorus availability induces higher NPPAGW. On the contrary, on central Amazonia, ecosystems are less dynamic, with better soil physical properties and lower fertility inducing respectively a lower mortality rate and a lower NPPAGW. These two factors favour high wood density late-successional species, which ends up in higher AGWB. Eq. (7) is in line with this explanation, as long as physical properties and fertility properties co-vary, which appears to be the case from the soil properties measurements reported in Quesada et al. (2010). This strong influence of soil properties could be a key issue when modelling the future evolution of Amazonian forests under a climate change scenario, as soil type may limit the floristic composition change that we suggest to model through Eq. (7). However, this may also allow deriving maps of average residence, NPPAGW and thus AGWB from a soil type map.”

Specific Comments.

3:27. Change ‘One General Circulation Models’ to ‘One General Circulation Model’

Answer :done

4:1 ‘in line’, not ‘on line’.

Answer :done

4:6 ‘Most DVMs employ the concept of an average plant’. Some newer DGVMs (SIEB, LPJ-GUESS, ED) do not employ average plants, but have multiple average plants for each PFT.

The sentence is now : “Most DVMs employ the concept of an ‘average plant’ (but see e.g. Sato et al. 2007).”

Equations 1-4 all need units.

We rewrote as : “The amount of biomass allocated to each organ is calculated from the following equation:  $NPP_{organ} = f_{alloc-organ} \times NPP$  (1). with  $NPP_{organ}$  and  $NPP$  expressed in mass of carbon per time unit and surface unit, hereafter in

C2617

tonsC/ha/year, and  $f_{alloc-organ}$  being a dimensionless fraction ranging from 0 to 1. At year  $n$ , AGWB is given (in mass of carbon per surface unit, hereafter in tonsC/ha) by:  $AGWB(n) = AGWB(n-1) + NPPAGW(n-1) - mortality(n-1)$  (2) where mortality (in mass of carbon per time unit and surface unit, hereafter in tonsC/ha/year) equals (3), with residence (in years) being the time of residence of carbon in wood. Note that the inverse of residence is equal to the rate of mortality, i.e. the fraction of AGWB lost annually via mortality. Then, (4). Further details about the calculation of GPP,  $R_a$  and  $f_{alloc-organ}$  are provided in Krinner et al. (2005). The value of residence is prescribed and constant, set equal to 30 years for the tropical forest biome. Our objective is to test these assumptions for undisturbed tropical forests. Thus we fixed the length of the simulations ( $N_{years}$ ) to 206 years (from 1801 to 2006), after checking that biomass stores equilibrate after 100 years.”

10:2 insert ‘of’ after ‘testing’

Answer :done

10:13 Clarify here, just to make the reading smoother and to stress this point, that ‘total NPP is above + below ground NPP.

Answer :The paragraph was rewritten:

“Despite overestimation of NPPAGW (Fig. 2, Table 1), total NPP (above and below ground) was found to be underestimated by 25% (Fig. 3a). This is explained by the fact that the allocation fraction to above ground wood was overestimated (Fig. 3b, Table 1) in the model compared to empirical data (Aragão et al 2009, Chave et al. 2010). Allocation to below ground wood and to fruits was also overestimated (Fig 3b-c, Table 1). By contrast, allocation to leaves was underestimated by 34%, and allocation to fine roots by 84 % in ORCHIDEE. For none of the tested parameters was there either a significant correlation or a linear regression slope that is close to 1 (Table 1), showing the model cannot reproduce the observed spatial patterns. The simulated  $NPP_{leaf+fruit}$  is equal to 0.54 NPPAGW, whereas the ground measurements indicate

C2618

that  $NPP_{leaf+fruit} = 1.67 NPP_{AGW}$  on average.”

14: 2 Does Orchidee not have a stress-related mortality? Most DVMs use the sum of background and stress mortality rates. This needs clarifying slightly. Some reference to the work of Chao and Philips might be worthwhile in this paragraph.

Answer :In its current version ORCHIDEE has only a fixed mortality rate, whereas previously the mortality rate was deduced from a “vigor” parameter, thus mortality rate could increase in case of stress. A time-variable stress mortality rate is certainly necessary to simulate interannual variations in mortality rate, whereas a spatial-variable background mortality rate is necessary to reproduce spatial gradients. Our study is about this background mortality rate, but clearly we should work on the two types of mortality in ORCHIDEE.

The end of the second paragraph of the discussion section is now :

“Then, the background mortality rate as modelled by Eq. (7), which appears from our results necessary to reproduced regional variations in in AGWB, should be modulated by short term variations where mortality increases in case of adverse climate conditions in order to simulate temporal variations in AGWB. However, moderate and progressive decrease in precipitation may favour slow-growing species, with a low turnover rate and a high biomass. This point was ignored in previous Amazonian forest dieback simulations (Cox et al. 2004, Huntingford et al. 2008) and could be modelled through Eq. (7). Nevertheless, as indicated by the observations of current biome spatial distribution (Malhi et al. 2009b), forest might be replaced by savannah if a large decrease in precipitations is experienced in the future in the Amazonian region.”

14:30 This is very mysterious.Why can't light limitation be greater than water limitation? How can you simulate semi-arid/cold/nutrient limited systems like that?

Answer : Light limitation is calculated from the leaf area index value : the principle is that if the surrounding LAI is high, the plant must invest in the wood. This attempts to

C2619

replicate the need for the plant to grow higher to find the light. The light limitation is calculated as  $L = \max(\exp(-0.5 \cdot LAI), 0.1)$ . A smaller value indicates that light is more limiting. At LAI higher than 4.6, L would always be equal to 0.1. Water and nutrient limitations are calculated from soil temperature and moisture and are also given as number between 0.1 and 1 (again small values indicate high limitation). Then, neither nutrient nor water can become more limiting than light at LAI higher than 4.6, i.e. for all tropical evergreen forest PFT simulations. Thus, because water and nutrient cannot be more limiting than light for high LAI forests, allocation to wood never drops below the allocation to foliage or fine roots. In order to clarify this point, we modified the manuscript as follows :

“However, under the current formulation of the allocation pattern, limitation by water or nutrients cannot be larger than the limitation by light for high leaf area index forests. Thus excessive carbon is allocated to wood for our evergreen tropical forest simulations.”

15:1 To simulate the variations in AGWB in the Amazon, we must first understand what is driving them. This is commonly understood to be some combination of soil fertility and physical properties (Quesada). I can't see how we are going to explain the variations in NPP and mortality unless we somehow account for this.

Answer : Please see above.

15:24 “ but the constraint on  $NPP_{AGW}$  looks robust from our results”, needs a reference to whichever figure you are referring to.

Answer : Done (Fig 6b and 6d, ie former figures 5c and 5e).

20:3 I don't think it would be appropriate to extrapolate this (NPP-mortality) relationship into other systems in the manner described (capping lifespan at a maximum value for low productivity ecosystems). All the data used for fitting the relationship come from Amazon rainforests, whose productivity, by definition, never gets very low. In semi arid

C2620

ecosystems numerous other factors (water competition, fire, grazing) are important for biomass, and these are not represented by this dataset.

Answer : This is true. Actually we added this point for two reasons :

-There is no reason to think that residence can keep increasing exponentially when NPPAGW decreases. - We tested that keeping a fixed mortality rate does not prevent reproducing spatial variations in AGWB for boreal and temperate forests. However we have not tested for arid or semi-arid systems.

We remove this figure, and we replace in the text :

“Our results show clearly that an  $\alpha$  value of 1, which is equivalent to the mortality calculation as it is done in ORCHIDEE, cannot explain the patterns in the data for the Amazonian forests. However, we found that keeping  $\alpha$  equal to 1 does not prevent from reproducing spatial variations in AGWB for temperate and boreal forests biomes (not shown). In fact, as AGWB displays a hump-shaped variation with productivity when analysed over a range of biome types (Keeling and Phillips 2007), it is unlikely that Eq.(7) applies to many other biomes, if any.”

Fig5. This should really be 2 figures.

Answer : done

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C2621

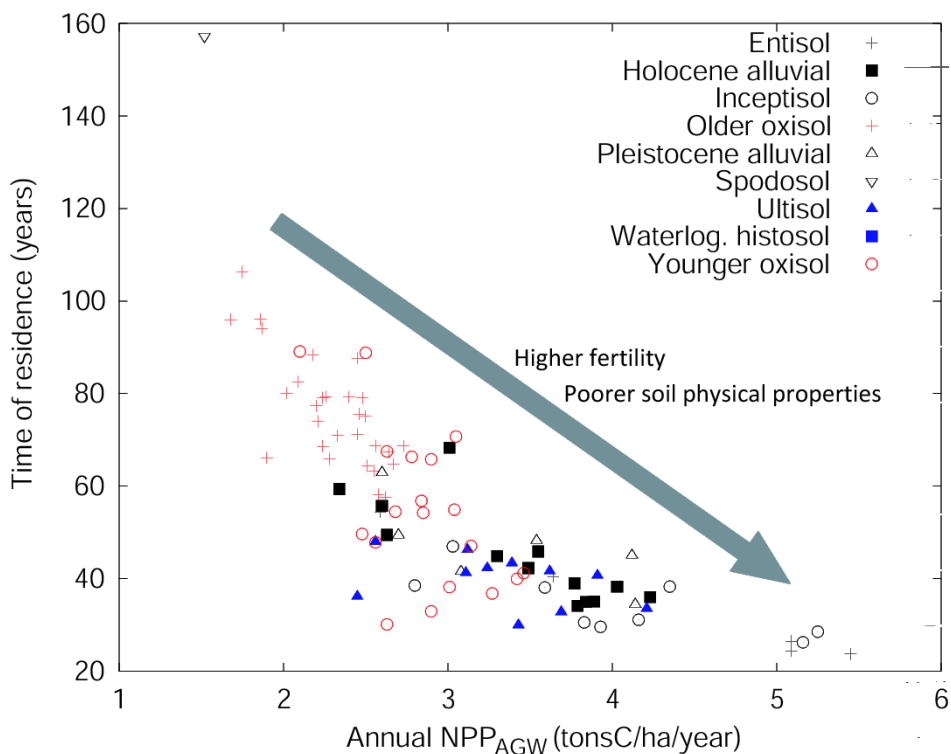


Fig. 1. figure C1

C2622