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Unraveling the growth determinism of Fagus sylvatica: a hybrid data-model approach

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The physiological processes underlying the limitation of forest growth are still under debate. Growth has long been considered as a carbone (C) limited process (Sala et al., 2012). As a matter of facts, a recent global meta-analysis has shown good agreements between assimilated C and forest productivity (Litton et al., 2007). Consequently, a majority of the process-based productivity models considers growth as a fraction of the net primary production (NPP) (Lacointe et al., 2000; Sitch et al., 2003. However, investigations at the stand scale report conflicting results (Rocha et al., 2006, Mund et al., 2010) and are not systematically consistent with a strict C limitation of growth, thus challenging the C-centric paradigm.

The mechanisms that potentially degrade the link between NPP and growth include: i) the direct effect of environmental factors on growth (Zweifel et al., 2006, Körner et al., 2003), ii) the temporal variability of the growth allocation coefficient, due either to ontogeny (Genet et al., 2009), or to the initial physiological state of the tree i.e. to the reaction to past conditions. Indeed, many dendrochronological and ecological studies have shown a correlation between growth and climatic factors of the previous years (e.g. Lebourgeois et al., 2005; Richardson et al., 2012).

In this work, we used a hybrid data model approach in order to assess the determinant of Fagus sylvatica stem growth along a spatial gradient across France. Despite they could brought essential insight on tree functioning, intra-specific studies across contrasted sites are still lacking in the current debate.

Standardized annual growth data series at the stand scale were calculated using circumference inventories and dendrochronological series on 17 plots of the RENECOFOR network. We used the process-based model CASTANEA, thoroughly validated in long term flux simulation across Europe (e.g. Delpierre et al. 2009), to simulate the annual NPP of the corresponding periods. We then investigated the dependency of annual growth on NPP, age and variables describing direct or indirect climatic conditions of the current (n) and the previous (n-1) year (e.g. simulated soil water content, sum of winter negative temperature, simulated growth phenology). Analyses were conducted as follows: first we used a Random Forest learning machine (RF) to select important variables and to obtain information on the form of the dependencies. We then formalized this information within the linear model framework to quantify the variability attributable to each factors and to conduct valid statistical tests.

RF analysis revealed that NPP was the most important variable explaining growth, with a quasi-linear partial effect. The 2 other selected variables quantified the hydric stress of year (n) and (n-1), and impacted growth with high threshold effects. Analysis of covariance then revealed that both hydric variables significantly affect the NPP-growth relationship. The retained variables explained 29% of the growth variability. Growth of F. sylvatica is under complex control, involving C assimilation, direct effect of water shortage and lagged response to past condition. We used these results to implement in the CASTANEA model a new conceptual allocation scheme, validated at regional scale.