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What are the functional mechanisms underlying forest decline? A case study on a European beech (Fagus sylvatica L.) stand.

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The ongoing climate change is altering the precipitation patterns (abundance and frequency) of most parts of the world. The consequences of these changes on forests are already visible through frequent declines. A lot of them can be linked to the occurrence of long and/or repeated drought periods. Although forest decline could severely impact the nutrient and water cycles, their underlying functional causes are not well understood. Two main hypotheses have been proposed to explain the mechanisms of decline at the tree level:

• Carbon reserves deficit (“carbon starvation”)
• Loss of water transport (“hydraulic failure”)

Although hydraulic failure has been observed in a wetland species decline (poplar), our understanding of forest decline is still lacking in many species. Our study concerns a widespread species, European beech (Fagus sylvatica L.). A severely declining mature beech plot in the Fontainebleau state forest (France) was followed. This decline can be related to repeated droughts, enhanced by unfavorable soil conditions (sandy soil with very low extractible soil water). For the first time to our knowledge, an integrative in situ functional approach coupling both hydraulic and carbon, but also nitrogen functioning was developed. More precisely, pre-dawn and midday water potentials, “native” embolism, and embolism vulnerability of branches, radial tree growth, carbon and nitrogen reserves concentrations, were measured on healthy and declining trees.

Our results showed that under normal climatic conditions (summer 2012), pre-dawn and midday water potentials were the same for healthy and declining trees throughout the season. Their losses of hydraulic conductivity (“native” embolism) were not significantly different, even at the end of the summer. Moreover, the embolism vulnerability curves also showed no significant difference (50% loss of hydraulic conductivity at around - 3MPa). Concerning C and N reserves concentrations, we showed that seasonal variations were the same for healthy and declining trees. However, starch concentration was significantly lower before budburst in 2010 growth units and recent xylem rings in declining trees. These deficits in short distance storage compartments could lead to an altered spring growth. Indeed, radial growth rate and duration were drastically lower for declining trees.

Finally, the observed beech decline cannot be attributed to either hydraulic dysfunction or nitrogen starvation. Concerning carbon functioning, the carbon reserves of declining trees were far from being exhausted. Despite a lower net carbon assimilation at the tree level (reduced leaf area index), trees maintain similar carbon and nitrogen reserves content, radial growth being apparently the adjusted variable.