

Rate of tree carbon accumulation increases continuously with tree size

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Thus, large, old trees do not act simply as senescent carbon reservoirs but actively fix large amounts of carbon compared to smaller trees; at the extreme, a single big tree can add the same amount of carbon to the forest within a year as is contained in an entire mid-sized tree. The apparent paradoxes of individual tree growth increasing with tree size despite declining leaf-level and stand-level productivity can be explained, respectively, by increases in a tree's total leaf area that outpace declines in productivity per unit of leaf area and, among other factors, age-related reductions in population density.

Although the results of a few single-species studies have been consistent with this assumption, the bulk of evidence cited in support of declining growth is not based on measurements of individual tree mass growth. Instead, much of the cited evidence documents either the well-known age-related decline in net primary productivity (hereafter 'productivity') of even-aged forest stands (in which the trees are all of a similar age) or size-related declines in the rate of mass gain per unit leaf area (or unit leaf mass), with the implicit assumption that declines at these scales must also apply at the scale of the individual tree. Declining tree growth is also sometimes inferred from life-history theory to be a necessary corollary of increasing resource allocation to reproduction. On the other hand, metabolic scaling theory predicts that mass growth rate should increase continuously with tree size, and this prediction has also received empirical support from a few site-specific studies. Thus, we are confronted with two conflicting generalizations about the fundamental nature of tree growth, but lack a global assessment that would allow us to distinguish clearly between them.

In absolute terms, trees 100 cm in trunk diameter typically add from 10 kg to 200 kg of aboveground dry mass each year (depending on species), averaging 103 kg per year. This is nearly three times the rate for trees of the same species at 50 cm in diameter, and is the mass equivalent to adding an entirely new tree of 10–20 cm in diameter to the forest each year.

Our data set included many natural and unmanaged forests in which the growth of smaller trees was probably reduced by asymmetric competition with larger trees. To explore the effects of competition, we calculated mass growth rates for 41 North American and European species that had published equations for diameter growth rate in the absence of competition. We found that, even in the absence of competition, 85% of the species had mass growth rates that increased continuously with tree size, with growth curves closely resembling those in Fig. 2. Thus, our finding of increasing growth not only has broad generality across species, continents and forest biomes (tropical, subtropical and temperate), it appears to hold regardless of competitive environment.

Our calculated 52-fold greater average mass growth rate of trees 100 cm in diameter compared to those 10 cm in diameter falls within this range. Thus, although growth efficiency often declines with increasing tree size, increases in a tree's total leaf area are sufficient to overcome this decline and cause whole-tree carbon accumulation rate to increase.

The rapid growth of large trees indicates that, relative to their numbers, they could play a disproportionately important role in these feedbacks. For example, in our western USA old-growth forest plots, trees 100 cm in diameter comprised 6% of trees, yet contributed 33% of the annual forest mass growth.

Teilweise Übersetzung mit DeepL:

Alte Bäume als effektivste Kohlenstoffsinken

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...In absoluten Zahlen ausgedrückt, fügen Bäume mit einem Stammdurchmesser von 100 cm in der Regel zwischen 10 kg und 200 kg oberirdischer Trockenmasse pro Jahr hinzu (je nach Art), im Durchschnitt 103 kg pro Jahr. Dies ist fast dreimal so viel wie bei Bäumen derselben Art mit einem Durchmesser von 50 cm und entspricht der Masse eines völlig neuen Baumes mit einem Durchmesser von 10–20 cm, der jedes Jahr dem Wald hinzugefügt wird...