

In a Crowded Stand, Halving the Number of Trees Takes Less Than a Tenth off the Whole

— halving takes no more than a tenth off only when there were more than **800.000000** trees before, and from **500** to **250** the whole falls to **0.857143** — the separator is whether one asks about the stand as a whole or about the size of each tree — [Paper 867]

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Abstract

It is easy to assume that cutting half the trees cuts the stand's amount in proportion. This paper counts, with the reciprocal yield equation, that in a crowded stand what falls is the number of trees, not the amount in the whole stand. No new theorem or law is claimed. First, each tree shrinks as the stand gets crowded: taking the size of each tree as $1/(1 + 0.01N)$, it is **0.090909** at 1000 trees and **0.047619** at 2000 (Section 2). Second, and this is the core. Halving the number of trees barely changes the whole: going from 2000 trees to 1000 leaves the whole at **0.954545**, while each tree becomes **1.909091** times larger (Section 3). Third, the whole has a ceiling: however many trees are planted the whole does not exceed 100.000000; at 4000 trees it is **97.560976** (Section 2). Fourth, in a stand that is not crowded the story changes: from 500 trees to 250 the whole falls to **0.857143**. The number of trees at which a tenth is the border is **800.000000**, where bisection and the closed form agree within 10^{-6} (Section 3). Fifth, without competition the whole is proportional to the number of trees: setting the coefficient to 0, the whole matched the number of trees within 10^{-9} . That halving takes less than a tenth off is the work of crowding (Section 2). Sixth, the separator is whether one asks about the stand as a whole or about the size of each tree: halving a crowded stand barely moves the whole, while each tree approaches 2 times its size (Section 4). **Keywords:** thinning, law of constant final yield, density effect, stand yield, individual tree size, model.

Scope of this paper (scope note): No new theorem or law is claimed: that denser stands have smaller trees and a whole that approaches a constant (the density effect, the law of constant final yield), and writing this as the reciprocal yield equation, are known. No real values are claimed: the coefficient 0.01 and the ceiling 100 are model values matching no species and no stand. Time is not included: halving is counted as comparing stands with different numbers of trees grown fully under the same conditions. The amount right after cutting, the path of regrowth, mortality and self-thinning are not included. Timber is not discussed: wood quality and price by diameter are not treated. Thinning is not recommended: whether to cut, or to how many trees, is not answered. Relation to earlier papers: Paper 581 showed that the age at which a forest takes up carbon fastest is not the age at which it holds the most, and stated in its scope note that soil carbon, mortality, thinning and disturbance are not included. This paper takes that seat (no one has taken it before), counting not carbon but the stand as a whole and the size of each tree. What is added is laying out each tree and the whole by number of trees, measuring that going from 2000 trees to 1000 leaves the whole at 0.954545, obtaining the border of 800.000000 trees two ways and checking both sides of it, and placing the separator on the stand as a whole versus the size of each tree.

1. Notation and the Question

Setting: N trees are planted on the same area and grown fully under the same conditions; the size of each tree w and the amount in the whole stand Y are given by the reciprocal yield equation.

$$w(N) = \frac{w_{\max}}{1 + aN}, \quad Y(N) = Nw(N) = \frac{w_{\max}N}{1 + aN}, \quad \frac{Y(N/2)}{Y(N)} = \frac{1 + aN}{2 + aN}$$

We set $w_{\max} = 1$ and $a = 0.01$. Halving the number of trees is counted as comparing a stand of N trees with a stand of $N/2$.

Question: if the number of trees is halved, is the amount in the whole stand halved too?

2. Number of Trees and Amount

Computation 2.1: the size of each tree and the whole were computed for each number of trees.

trees	each tree	whole stand
250	0.285714	71.428571
500	0.166667	83.333333
1000	0.090909	90.909091
2000	0.047619	95.238095
4000	0.024390	97.560976

Observation 2.2

the whole approaches a ceiling. Raising the number of trees 16-fold from 250 to 4000 raises the whole only from 71.428571 to 97.560976, never exceeding 100.000000, because each tree shrinks as trees are added. With α set to 0, the whole matched the number of trees within 10^{-9} and the ceiling disappears.

3. Halving the Number of Trees

Computation 3.1: for each number before halving, the factors on the whole and on each tree were computed.

trees	whole stand	each tree
4000 to 2000	0.976190	1.952381
2000 to 1000	0.954545	1.909091
1000 to 500	0.916667	1.833333
500 to 250	0.857143	1.714286

Observation 3.2

this is the core. In a crowded stand, halving the number of trees barely changes the whole. Going from 2000 trees to 1000 leaves the whole at 0.954545, while each tree becomes 1.909091 times larger: the amount removed is almost made up by the remaining trees each growing larger.

Observation 3.3

in a stand that is not crowded, halving takes more than a tenth off. From 500 trees to 250 the whole falls to 0.857143: the number of trees at which $(1 + aN)/(2 + aN)$ equals 0.9 is 800.000000; bisection and the closed form $8/a$ agreed within 10^{-6} . From 1000 trees the factor is above 0.9, from 500 below.

4. The Separator

Observation 4.1

the separator is whether one asks about the stand as a whole or about the size of each tree. Asked about the whole, thinning a crowded stand changes almost nothing: asked about each tree, the same thinning makes it 1.909091 times larger. Which one moves more is decided by the degree of crowding aN .

Observation 4.2

taking the seat of Paper 581.581 showed that the age of fastest carbon uptake differs from the age of largest storage, and stated in its scope note that thinning is not included. This paper takes that seat, counting not carbon but the whole stand and the size of each tree. As 581 said that the answer changes with what is maximised, here too the effect of thinning looks opposite depending on the quantity asked.

Observation 4.3

what is not said. Real species and stands, the amount right after cutting, the path of regrowth, mortality, wood quality and price are not treated, and whether to thin is not answered. What is shown is that when a crowded stand is halved, what falls is the number of trees, not the amount in the whole stand.

5. Census and Closing

1. each tree is $1/(1 + aN)$ (Section 1): the reciprocal yield equation.
2. each tree 0.047619 at 2000 (Computation 2.1): shrinks with crowding.
3. ceiling 100.000000 on the whole (Observation 2.2): 97.560976 at 4000.

4. **2000 to 1000: whole 0.954545** (Computation 3.1): **the core.**
5. **each tree 1.909091** (Computation 3.1): **makes up the cut.**
6. **4000 to 2000: 0.976190** (Computation 3.1): **the more crowded, the less it moves.**
7. **500 to 250: 0.857143** (Computation 3.1): **more than a tenth off.**
8. **border at 800.000000 trees** (Observation 3.3): **bisection and closed form.**
9. **proportional when the coefficient is 0** (Observation 2.2): **the work of crowding.**
10. **the whole, or each tree** (Observation 4.1): **the separator; the seat of Paper 581.**

Closing: In a crowded stand, halving the number of trees takes less than a tenth off the whole. If each tree shrinks as $1/(1 + 0.01N)$, going from 2000 trees to 1000 leaves the whole at 0.954545 while each tree becomes 1.909091 times larger, because the remaining trees, each growing larger, almost make up the amount removed. But halving takes no more than a tenth off only when there were more than 800.000000 trees before; from 500 to 250 the whole falls to 0.857143: the same thinning looks opposite depending on whether one asks about the whole or about each tree. Placed among the earlier papers: we took the thinning seat left open in Paper 581's scope note, counting not carbon but the whole stand and the size of each tree. To be honest: the coefficient and ceiling are model values, and regrowth after cutting, mortality, wood quality and price are not included.

References

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