

Where does a tree get most of its dry mass?

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A tree can gain a substantial trunk without removing a trunk-sized quantity of soil from beneath it. The apparent puzzle comes from watching the roots while overlooking the leaves. Roots supply water and dissolved nutrients, but leaves take in a gas whose carbon becomes part of wood. For an ordinary photosynthetic tree, atmospheric carbon dioxide supplies the carbon framework of its growing organic material. That answer is sound only if we distinguish carbon from the whole mass of the tree.

Dry wood is not pure carbon. It contains oxygen, hydrogen and other elements as well. Its construction depends on both carbon dioxide and water, together with mineral nutrients. Saying that a tree is made from air can correct the soil misconception while creating another: neither all dry matter nor all its atoms should be assigned to carbon dioxide without further accounting.

1. Decide what the balance is weighing

Fresh mass includes water present in cells and spaces within the tissue. Dry mass is what remains after a specified drying procedure removes that water. Drying does not remove the hydrogen and oxygen chemically bound into cellulose, proteins and other compounds. A dry sample still contains atoms that entered through water-related processes during growth.

OpenStax's plant-nutrition chapter gives an illustrative dry composition of about 45 percent carbon, 45 percent oxygen and 6 percent hydrogen. These are teaching-scale averages, not a certified composition for every trunk, leaf or root. The same source describes uptake of water and dissolved nutrients through roots. [1] The important empirical premise is that carbon, oxygen and hydrogen dominate plant organic material; mineral nutrition is essential without supplying most of that material's mass.

A measurement must also specify its boundary. Weighing a trunk excludes roots, leaves, shed litter and material transferred outside the plant. Comparing one tree at two dates measures a change in its retained inventory. It does not directly measure everything the tree fixed, respired or lost during that interval.

2. Follow the carbon instead of the slogan

Carbon dioxide enters leaves through stomatal openings. Carbon fixation incorporates its carbon into organic molecules; products of the Calvin cycle contribute to the synthesis of other plant compounds. [2] The pathway does not convert sunlight into carbon atoms. Light supplies energy for chemical transformations, while the atoms come from material inputs.

This difference is testable in principle with two separate measurements. A gas-exchange measurement asks whether carbon dioxide is entering or leaving a leaf or enclosed plant. An elemental analysis asks how much carbon remains in sampled biomass. Agreement requires accounting for the interval, the parts sampled and the fluxes crossing the chosen boundary. Neither instrument alone supplies the complete history.

Plants also respire, using organic compounds in metabolism and releasing carbon dioxide. Photosynthetic fixation and respiration therefore belong on opposite sides of a carbon budget. [2] A tree's increase in retained carbon is smaller than gross fixation whenever some newly fixed or previously stored carbon returns to the atmosphere or leaves the measured system in other forms.

3. A calculation that does not pretend wood is sugar

Consider a hypothetical 10 kilograms of newly retained dry matter containing 45 percent carbon. The retained carbon is 4.5 kilograms. Using rounded atomic masses of 12 for carbon and 16 for oxygen, carbon dioxide has a molecular mass of 44 and contains a carbon mass fraction of 12/44.

Supplying 4.5 kilograms of carbon therefore requires carbon from $4.5 \times 44/12 = 16.5$ kilograms of carbon dioxide. This is an equivalent quantity for the retained carbon, not a measured gross uptake by a real tree. Respiration and exported carbon could require additional fixation. The 16.5 kilograms also does not all remain in the 10 kilograms of dry matter: the oxygen and hydrogen budgets involve other inputs, products and exchanges.

The calculation makes the scale visible. A gas can supply substantial mass even though a person cannot see it entering the leaves. It also shows why the phrase “45 percent carbon” cannot be replaced by “45 percent carbon dioxide.” Carbon dioxide includes the oxygen accompanying that carbon; confusing the two changes the answer by a factor of 44/12.

4. Why a balanced equation is not an atom-by-atom film

The simplified photosynthetic balance often written with carbon dioxide, water, carbohydrate and oxygen is useful for checking the numbers of atoms. It does not by itself identify which particular oxygen atom ends in which product after the real reactions and exchanges. A net balance cancels intermediates. It deliberately suppresses some of the molecular history.

Cellulose offers another useful distinction. Its idealized repeating unit is $C_6H_{10}O_5$. With the same rounded atomic masses, carbon contributes 72 of the unit's 162 mass units, or about 44.4 percent. This is a chemical calculation for cellulose, not a claim that every tree tissue has that composition. Wood is a mixture, and mineral residues, proteins and other components change its elemental proportions.

A phrase such as “mostly carbon” can thus be misleading if it means carbon alone exceeds half the mass. What is largely constructed from fixed carbon is an assembly of carbon-containing molecules. Those molecules contain substantial mass from other elements. The distinction is small in wording and large in scientific meaning.

5. Essential does not mean abundant

A tree lacking a required nutrient may grow poorly even though that nutrient contributes little to its eventual mass. Controlled nutrient-solution cultivation allows investigators to vary mineral supply without treating bulk soil as the plant's principal food. OpenStax describes this use of hydroponics in nutrient-deficiency research. [1]

Imagine a construction project stopped by a missing fastener. Its small mass does not make it dispensable, and its indispensability does not make it the main substance of the building. The analogy concerns limiting requirements, not the detailed physiology of roots. In the same way, a material budget and an explanation of growth limitation answer different questions.

Water has several roles too. Some is retained temporarily, some participates in chemistry, and much can pass through the plant and leave again. The amount transported need not equal the amount retained. Counting only the water found in a final dried sample would miss these different functions and pathways.

6. What the answer establishes

For a photosynthetic tree, the carbon in newly built organic matter comes chiefly from atmospheric carbon dioxide. Most dry biomass is organic material assembled using that carbon together with hydrogen, oxygen and nutrients. It is not a mass of soil lifted upward, and it is not matter created from light. [1,2]

The uncertainty lies in the detailed budget for a specified tree and interval: tissue composition, respiration, allocation, losses and environmental constraints. Those details can change quantities without reversing the basic source of the carbon. A useful answer therefore names both the main input and the limits of the shorthand used to describe it.

Related reading

Article 026, “How can a seed remain alive without growing?”, separates stored material from the processes required to resume growth. The comparison is optional and reciprocal.

References

[1] OpenStax. Biology 2e, section 31.1: Nutritional Requirements of Plants.

<https://openstax.org/books/biology-2e/pages/31-1-nutritional-requirements-of-plants>

[2] OpenStax. Biology 2e, section 8.3: Using Light Energy to Make Organic Molecules.

<https://openstax.org/books/biology-2e/pages/8-3-using-light-energy-to-make-organic-molecules>