

ESTIMATION OF CARBON OFFSET BY TREES

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ECCM

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Estimation of Carbon Offset by Trees

Emissions from the combustion of fossil fuels are one-off, one-way processes. However, the process of carbon sequestration by trees (the storing of atmospheric carbon dioxide or CO₂) is complex and dynamic. There are flows of carbon into, and out of the tree and rates of flow change over time, affected by variables such as environmental conditions and tree maturity. Some of the factors that affect the rate of CO₂ uptake are discussed below. One method of estimating carbon sequestered by trees is to use empirical data incorporating actual tree measurements over time as is employed by the ECCM model, outlined below.

The incorporation of CO₂ into plants during photosynthesis

Photosynthesis enables plants to grow by converting light energy into chemical energy in organic molecules. Atmospheric CO₂ enters the leaf via stomata (openings) and diffuses into the chloroplasts where it is reduced and ultimately incorporated into carbohydrates. Oxygen (O) diffuses in the opposite direction, from the plant to the outside air. There are several factors that limit the rate of photosynthesis.

Atmospheric CO₂ concentration

The concentration of CO₂ in the atmosphere affects the rate at which CO₂ enters a leaf by diffusion. When levels are low, photosynthesis rates may be limited but will rise with increase in CO₂ concentration. Research indicates that as levels of atmospheric CO₂ increase, so photosynthetic rates increase. However, once a threshold is reached, there is no further increase in rates since the plant cannot produce the enzymes and other products required for the assimilation process, at the required pace.

Light

Light is required to stimulate the chlorophyll to enable the reductants (NADPH) and ATP to be produced, they are used to convert CO₂ to carbohydrate. Not all wavelengths of light intercepted by leaves induce photosynthesis (only 'photosynthetically active radiation' or PAR). Photosynthesis is therefore limited not only by daylight hours but also by light quality. Different species, and even different leaves on the same tree, respond differently to varying light levels. In a forest ecosystem, the annual uptake of carbon declines as trees mature, as competition for light and nutrients increases.

Water

During transpiration, water is lost from a plant through the same stomata as those through which CO₂ and O exchange occurs between the plant and the atmosphere. When temperature is high and air humidity low, plants lose water rapidly and the plant closes its stomata in order to conserve water. Hence, in such conditions there is a trade-off between the amount of CO₂ that can be photosynthesized without inducing wilting of the plant. During drought periods, a plant's stomata may close around midday. After stomatal closure, the remaining CO₂ trapped inside the leaf may continue to diffuse into the cells unless water stress has been prolonged, in which case the plant will suffer damage.

Temperature

At higher temperatures, enzyme activity and therefore the rate of photosynthesis increases. However, above a threshold temperature, the photosynthetic system breaks down.

Nutrients

Nutrient availability affects photosynthesis at several stages in the process. For example, photosynthetic capacity increases with increase in nitrogen presence in leaves.

Leaves

Leaves continue to increase in their ability to photosynthesize as they grow but after they are fully expanded, this ability starts to decrease. Since many of the native tree species of the UK are deciduous, photosynthesis only occurs in the growing season.

Losses of CO₂ from the plant to the environment

As discussed above, atmospheric CO₂ is incorporated into plants during photosynthesis and the carbon compounds are then transported throughout the plant to the various plant components. Following its absorption, there are several ways in which this carbon is lost from the plant. During photorespiration for example, CO₂ is generated and is ultimately released into the atmosphere. Carbon is lost through decomposition of roots, wood and leaves. This carbon may be held within the soil, assimilated by soil fauna, carried away in water or the cycle may be completed by the gas being released back into the atmosphere.

Calculating the carbon sequestered by trees

The amount of carbon sequestered by a tree increases substantially over time as the greater the leaf area of the tree, the greater the photosynthetic capacity. As the process is dynamic, a commonly used approach is to estimate carbon 'pools' stored within a tree over time using empirical data available for various tree components.

The ECCM model of CO₂ sequestration

The model divides the carbon sequestered by an area of woodland into the carbon pools contained in tree biomass:

- on-site biomass (including stemwood, crownwood, foliage and large roots)
- off-site biomass (including thinnings and timber products)

The gains in carbon for each of the carbon pools through time are estimated separately for each species. Standing and thinned timber volumes, taken from Forestry Commission yield tables are used to predict per hectare carbon storage at five year intervals. Data on wood density are used to calculate the quantity of carbon stored in woody material. The volume of branches is determined from the standing timber volume. The volume of branch wood left in the forest after thinning and the volume of timber used in forest products is determined from the thinning volume. The carbon content of foliage is calculated using published parameters.

Relating carbon sequestered by trees to greenhouse gas emissions

The IPCC currently refers to the impact of greenhouse gasses in terms of Global Warming Potential (GWP). If CO₂ is withdrawn from the atmosphere for a specified period, for example by a forestry project over one hundred years, the resulting cooling effect (or negative GWP) can be approximated by the area under the total carbon storage curve measured in units of tC.years (a multiplier unit analogous to the energy unit, kWh). However, to relate this offset figure to an equivalent amount of C emitted in the first year, a conversion factor needs to be applied. The ECCM model calculates the cooling effect of one hectare of a forest type and employs the conversion factor to obtain the end result in tC. An equation can then be used to convert tC to tCO₂, based on molecular weights (10 tC is equivalent to 36.67 tCO₂).

The amount of carbon offset by one hectare of mature oak woodland (of yield class 4, planted at an initial spacing of 1.2 m, stocking density of 4,200 plants per ha, intermediate thinning, excluding soil) is estimated by the ECCM model, to offset 75 tC over a 100 year period. This corresponds to 275 tCO₂.

A mixed species planting of lowland native woodland type, containing approximately 50% oak, or other main tree species, (of average yield class 4, planted at variable spacing, stocking density of 1,500 plants per ha, minimal thin, excluding soil) is estimated by ECCM to offset between 30-60tC per ha (110-220 tCO₂). This estimate assumes that open space is not included and that woody shrubs account for 10% or less of the planting mix. The actual number of trees that will be planted by the planting partner varies with site. Taking the total number of trees that will be typically planted per hectare (1,500) and dividing by 60 (if 60 tC are offset in that hectare) gives 25 trees planted per tC at the start of the rotation. However, assuming that the minimum number of trees that will be planted is 1,100/ha (in accordance with the minimum required by the Forestry Commission Woodland Grant Scheme) the minimum that would be planted is 18 trees per tC. This approach gives a range of trees being planted between 18 and 25 trees per tC.