

# **Climate change and forest carbon** How much carbon is there in our woodlands?

James Morison and Robert Matthews



Forests are a key part of the global carbon cycle. As trees grow, carbon is removed from the atmosphere so there is much interest in tree planting and woodland expansion to help slow down the increase of atmospheric greenhouse gases that is causing rapid climate change. It is important to understand how much carbon trees and woodlands in the UK take up, and how much they store.

#### Trees and carbon

- Woody plants, because of their large size and longevity, can accumulate large amounts of carbon as they grow.
- While the carbon fraction of dry woody plant material varies little (48-52%), wood density (mass per unit volume) varies by a factor of two (approx. 0.35 0.70 t m<sup>-3</sup> at 12% moisture content). In general, hardwood species, such as oak and beech, are slower growing but denser than softwoods, such as pine and spruce, so that oak timber holds approximately 70% more carbon per unit volume than spruce timber.
- Typically, 50-65% of the mass and carbon is in the stem and 20-30% is in the woody roots, with the rest in branches, foliage and fine roots. Broadleaved species usually have a larger proportion of mass in the branches than conifers.

## Woodland carbon stocks

• Woodlands vary hugely in the tree species present, their numbers, age and size, so the amount of carbon held in the trees (C stock) varies from very little for a new woodland with young trees, up to 300 tC ha<sup>-1</sup> (tonnes carbon per hectare) for a dense stand of large trees of either conifer or broadleaved species.



Large oak tree felled in Oxfordshire for timber and carbon measurement. This 220-year-old tree was 24 m high, with a stem diameter of 90 cm and contained 4.9 tonnes of carbon in total.

• Litter (fallen leaves, twigs, etc.) and deadwood also contain carbon and contribute to the woodland C stock, but the largest component is often in the soil. This differs between soil types and locations: mineral soils (sands, brown earths, clays) typically contain 60-240 tC ha<sup>-1</sup>, while those with a high organic content, such as deep peat soils, can contain much more (up to 750 tC ha<sup>-1</sup> in the top 1 m of the soil).

- The National Forest Inventory estimates there are 3.1 million hectares of stocked woodlands (i.e. woods that are not felled, open ground or awaiting planting after harvesting) in the UK with a total C stock of 250 million tonnes (Mt C) in the trees and 1,095 Mt C in all woodland components.
- Across all types, locations and ages of UK woodland the calculated average tree C stock is 81 tC ha<sup>-1</sup>, and the total C stock is 356 tC ha<sup>-1</sup>. These averages reflect the large proportion of relatively young plantations on organic upland soils.

Carbon pool	Total Mt C	Average tC per ha
Trees (above ground)	184	60
Trees (below ground parts)	66	22
Total tree biomass	250	81
Deadwood	41	13
Litter	52	17
Soil	753	244
Total	1,095	356

C stock in UK woodlands (FC Statistics, 2022).

## Woodland carbon uptake rate

- The rate at which a woodland removes carbon from the atmosphere depends on the tree growth rate, which in turn will depend on species, age, climate, soil conditions, tree health and management.
- The carbon uptake of a tree stand varies over time, starting slowly but increasing as the tree canopy expands and more solar energy is absorbed for photosynthesis. As trees age respiration losses increase, so the *net* uptake rate declines in older stands.
- Carbon may also be lost from a woodland through decomposition of litter, deadwood and soil organic matter, being dissolved in

drainage water or being lost in fires or floods. Timber harvesting also removes carbon from the woodland, but the derived wood products may continue to store carbon for many years, depending on their lifespans.



Instruments above the tree canopy of the research forest at Alice Holt that measure directly the net uptake of this oak woodland.

- The *net* carbon uptake rate by woodlands therefore varies from near zero (for a newly planted woodland on a mineral soil) up to maxima near 10 tC ha<sup>-1</sup> y<sup>-1</sup> (equivalent to 37 tCO<sub>2</sub> ha<sup>-1</sup> y<sup>-1</sup>).
- The total *net* carbon uptake by all UK forests after allowing for timber harvest is estimated as 4.8 Mt C y<sup>-1</sup> in the national Greenhouse Gas Inventory, and the calculated average net rate across all woodland ages, locations and types is  $1.5 \text{ tC ha}^{-1} \text{ y}^{-1}$  (equivalent to 5.6 tCO<sub>2</sub> ha<sup>-1</sup> y<sup>-1</sup>).

### More information:

Further details of our work on forest carbon and climate-change mitigation are available on our website:

www.forestresearch.gov.uk/research/forestryand-climate-change-mitigation/

Find us on Twitter **@Forest\_Research** 

Contact: www.forestresearch.gov.uk/contact-us

#### © Crown Copyright 2023