Hardwood trees or softwoods for carbon storage?

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Planting trees and caring for woods is increasingly popular and discussed. One aspect is the role woodlands and forests play in reducing climate heating. Individual trees do this by absorbing carbon dioxide gas from the atmosphere and transforming it, by photosynthesis, into the woody material of stems, roots and branches. Carbon dioxide is a major greenhouse gas – it traps the heat of sunlight within our atmosphere. As more wood is created by growth of trees the less of this gas there will be in the atmosphere. But which trees might be best for this? Volunteer tree planters concentrate on broad-leaf species, the hardwood trees. Foresters need to produce a harvestable crop of timber or lumber, and mostly plant needle-leaf conifers, all softwoods, although hardwood trees such as poplar, beech and oak are grown in plantations to provide wood for making furniture and veneers.

Some people argue that natural forests are best for taking in carbon dioxide and storing it. The more hardwood trees there are in the landscape then surely they will store more carbon? Hardwood is denser than softwood: a floating log of hardwood will be lower in the water than a softwood log. A wood, natural or planted with the intention of becoming as natural as possible, will lead to a varied structure where all the trees can contribute to carbon uptake and storage of it as wood. It may be claimed that such woodlands are better for mitigating the problem with carbon dioxide than are plantations of softwood conifer trees.

Most species of hardwood trees grow slowly – oaks and beeches are typical – taking about eighty years to grow to harvestable size in a plantation. Poplars and birches grow more rapidly, and birches in Scandinavia are a major components of large forests. Softwood trees grow at about twice the rate of hardwood trees. A plantation of beech trees will be ready to harvest in about eighty years; a plantation of spruce trees in about forty. Thus it is likely that growth patterns and dynamics of these various species are crucial to understanding their differences in uptake of carbon.

Carbon in woody tissue is mostly of three forms: hemicellulose, cellulose, and lignin. These are complex polymers with lignin being a very large and variable molecule. Lignin provides the toughness and durability of wood. This woody character develops as the water conducting vessels grow as arrays of elongated cells that join together then lose their end walls, so forming xylem tubes. These tubes need to resist much pressure from the suction forces of water being drawn up from roots into the canopy. However, many other materials in the tree that also contain carbon, from the glucose to proteinaceous enzymes within leaf cells, are not included in comparisons of carbon content of softwoods and hardwoods.

A cross section of stem wood of a tree, cut smoothly in a laboratory, shows many small holes. These are formed by the xylem cells. (See 'Leaves: when should they fall?') Woody tissue of the stem shows as a mass of yellow to brown material that is formed by the living cells of wood. There are distinct patterns seen in cross sections, formed by the xylem tubes. Hardwoods have in addition to the xylem tubes, many larger-bore tubes called vessel elements. These enable the tree better to control water transport than soft-wood trees can: specially important during springtime bud-break of leaves. The rest of the wood of a hardwood tree has narrower bore xylem tubes and the walls of these tubes are thicker with more wood than those of softwood trees. This is what makes hardwoods dense and hard.

Often a figure is used for carbon content of wood, soft or hard, as 50% on a weight for weight basis. This is a handy approximation for use in carbon trading and popular accounts about the problems with carbon dioxide. The question here demands a more detailed basis of facts. What are the proportions, as percentages, of the element carbon held within the vastly complex material that is wood?

To allow for these structural differences between soft and hard woods, researchers have used chemical analysis to estimate percentages of carbon in samples of wood from many species of tree. Samples are kiln dried to remove water, then ground to a fine powder before chemical analysis that can measure all the carbon, as that element. Such studies are complex to perform and seldom done, but one reported results from twenty-two species of hardwoods and twenty-one softwoods; all them native to the USA. The average carbon content of these hardwood species was 48.43%, and of the softwoods was 51.05%. This is a significant contribution to the question posed here, but chemical analysis is one perspective only of the ecological complexity that is a forest.

Estimates of carbon content are also made by counting and measuring the size of whole trees as they stand in forests. Such studies have the advantage of including both the standing live wood and deadwood as branches; deadwood as stumps left in the ground after harvesting; leaf litter on top of the soil, and rotting leaves within the soil to a researchable depth of 20 centimetres. A study of this type in old-growth (mature) forests of three states of north eastern USA separately for hardwood and softwood forests, revealed 216 tonnes of carbon per hectare for hardwoods and 267 tonnes per hectare for softwoods. The authors of this study concluded the difference was mostly because of the larger accumulation of leaf-litter on the floors of the softwood forests. All leaves are deciduous in the long run, and needle-leaves of conifers drop when no longer functional, not after one season's activity. They rain down continuously and their thick cuticle and resin content delays their decay.

Similar results have been found for softwoods, as plantations in Britain. In live standing trees there will be typically 40 to 80 tonnes of carbon per hectare. On the plantation floor there will be 15 to 25 tonnes per hectare of leaf and woody litter, and the largest store of carbon will be found within the soil as decomposing organic matter, at 70 to 90 tonnes per hectare. The total stock of carbon averages at 185 tonnes per hectare during the repeated cycles of planting, growth and harvesting (see 'Trees to store carbon.)

Old trees, those reproductively mature decades ago, continue accumulating carbon. A comparison of 403 species of trees from temperate and tropical regions of the world showed that increase in the total mass of a tree is continuous until some some limit on height, or weight of long branches, vulnerability to storm or attack by disease organisms and herbivores, is more than a tree can withstand. This study raises the question: is comparing hardwood forests with softwood forests typical of temperate climates and fertile soils relevant to the behaviour of trees in tropical forests on infertile soils?

A plantation of trees, softwood or hardwood, is poorly comparable to a forest of mixed species that regenerate naturally. The plantation needs much management: planting and repeated rounds of thinning, ground preparation, creation of access roads, control of herbivores and diseases . . . All this involves machinery, from chain-saws to semi-robotic harvester machines, burning fossil fuels into carbon dioxide. How might a full accounting of the carbon cycle of a plantation be compared to a natural forest? A comprehensive accounting comparison would seem to go against the managed plantation. That is, until comparison is made of area of fully natural forest against area of forests that are maintained by planting of seedlings or by the natural regeneration of felling coupes with seed-rain from surrounding trees.

Huge areas of northern temperate regions of North America, Europe and Eurasia have managed forests of many softwood species, also birch and other species that are managed for timber production. There is steadily increasing commercial demand for this natural product. This is where the greatest bulk of carbon uptake and storage by trees is being done. Measures to reduce carbon dioxide in our atmosphere need urgency. The hardwood species grown for timber or planted for amenity do contribute to this and it makes negligible difference if their carbon content is lower than that of the softwoods. Natural woods and those planted to grow naturally are for nature conservation, aesthetics and the simple pleasures of walking through them: better than a walk along a plantation track any day.

continued

References (in order of presentation above).

Lamlon, S.H. & Savidge, R.A., 2003. A reassessment of carbon content in wood: variation within and between 41 North American species. Biomass and Bioenergy, 25: 381-388.

Hoover, C.M., 2011. Assessing seven decades of carbon accumulation in two U.S. northern hardwood forests. Forests, 2: 730-740.

Hoover, C.M., Leak. W.B. & Keel, B.J., 2012. Benchmark carbon stocks from old-growth forests in northern New England, USA. Forest Ecology and Management, 266: 108-114.

Stephenson, N.L., et al., 2014. Rate of tree carbon accumulation increases continuously with tree size. Nature, 507, issue 7490, 90-93.

Dewar, R.C. & Cannell, M.G.R., 1992. Carbon sequestration in the trees, products and soils of forest plantations: an analysis using UK examples. Tree physiology, 11: 49-71.

Cannell, M.G.R., 1999. Growing trees to sequester carbon in the UK: answers to some common questions. Forestry, 72, 237-247.

Nunery, J.S. & Keeton,W.S., 2010. Forest carbon storage in the northeastern United States: Net effects of harvesting frequency, post-harvest retention, and wood products. Forest Ecology and Management, 259: 1363-1375.

England, J.R., et al., 2013. Cradle-to-gate inventory of wood production from Australian softwood plantations and native hardwood forests: carbon sequestration and greenhouse gas emissions. Forest Ecology and Management, 302: 295–307.