



Maximizing Forest Contributions to Carbon Mitigation

The science of life cycle analysis – a summary of CORRIM's research findings

*Some suggest storing carbon in the forest as the best mitigation against increasing carbon emissions. Others note that storing carbon in manufactured products extends the carbon stored in the forest to buildings. Wood products also substitute for fossil-intensive products and fuels displacing their carbon emissions. **Growing trees takes carbon out of the atmosphere storing it first in the forest, which when harvested moves this carbon to storage in products while at the same time displacing fossil intensive***

products like steel and concrete. At the end of a wood products life it can be recycled for a second life, burned as a fuel displacing fossil intensive fuels, or land filled, extending the storage for decades until decomposed. When wood products or biofuels displace fossil intensive products or fuels, a permanent reduction in fossil carbon emissions occurs, equally as important to mitigating climate change as storing carbon from the atmosphere in the forest.

The Consortium for Research on Renewable Industrial Materials (CORRIM), a 15-research institution consortium, has for the last decade developed ISO consistent research protocols for Life Cycle Inventory (LCI) measuring all inputs and outputs for every stage of processing from forest regeneration, harvesting, transportation, wood processing, building construction, maintenance and use; and ultimate demolition with recycling or disposal. This database makes it possible to track carbon from the forest to post harvest uses, following the carbon from one pool to the next, measuring the interactions between them. Carbon tracking charts display the impacts on all carbon pools making it possible to understand the impact of management and policies on the total carbon across all pools. Such tracking charts were developed by CORRIM for the major supply regions in the US (Lippke et al 2004, Perez Garcia et al 2005).

Forest carbon: As trees grow, they remove carbon from the atmosphere. As trees reach maturity, growth slows and ultimately stops as mortality catches up to growth as shown in Figure 1 for the average of Federal forest plots in Western Washington, a region where we have an adequate sample of forest stands in all ages (USFS FIA inventory data).

Alternatively the rate of removal of atmospheric carbon can be sustained by harvesting trees before growth slows moving the carbon into products.

Figure 2 shows the carbon remaining in the forest for a Pacific Northwest commercial 45-year rotation, including the dead wood (crown, litter, roots) left behind to decompose (Perez-Garcia et al 2005). With a financial incentive much like the subsidy received for corn ethanol production, many of these forest residuals could be economically collected and processed into biofuels like cellulosic

Figure 1: Carbon in USFS Western Washington Standing Inventory by Age

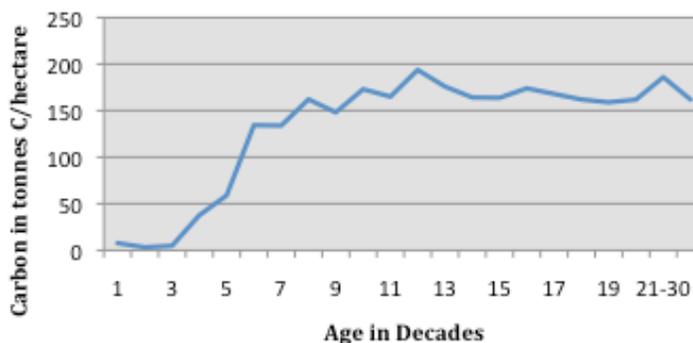
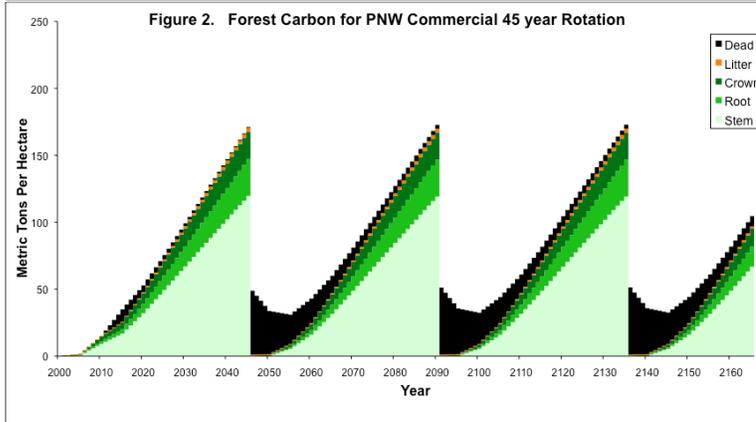


Figure 2. Forest Carbon for PNW Commercial 45 year Rotation



ethanol, displacing gasoline and reducing oil imports. While the store of carbon in the forest under a short rotation is reduced below the potential of an older forest, it is instead being used as a pump to move the forest carbon to other carbon storage pools at the maximum rate that it can be sustainably grown.

Products carbon and substitution:

Figure 3 shows the carbon impact of manufacturing the most common wood products (Puettmann and Wilson 2005) and the comparable impact of substituting a concrete slab floor for a residential wood floor of the same area. The emissions from the energy needed to process the wood products (shown as negative in red) is roughly $\frac{1}{4}$ that of the emissions from a comparable floor area made of concrete without considering the carbon stored in the wood. With the net carbon stored in the wood products (carbon stored net of energy emissions, a positive shown in blue) they store enough carbon to offset the emissions from many other fossil intensive products used in construction. The wood products store about as much net carbon over their useful-life as initially emitted from producing the concrete floor. At the end of their useful product life, if the wood products are recycled to produce energy, the carbon stored becomes permanent such as displacing coal emissions with wood as their heating values are comparable. If the recycled wood is used as the resource for other wood products such as fiberboards, the useful life is extended while retaining the opportunity to recollect the material after its second life. If the used products are land-filled, they decompose slowly, extending the carbon over a much longer period although ultimately decaying.

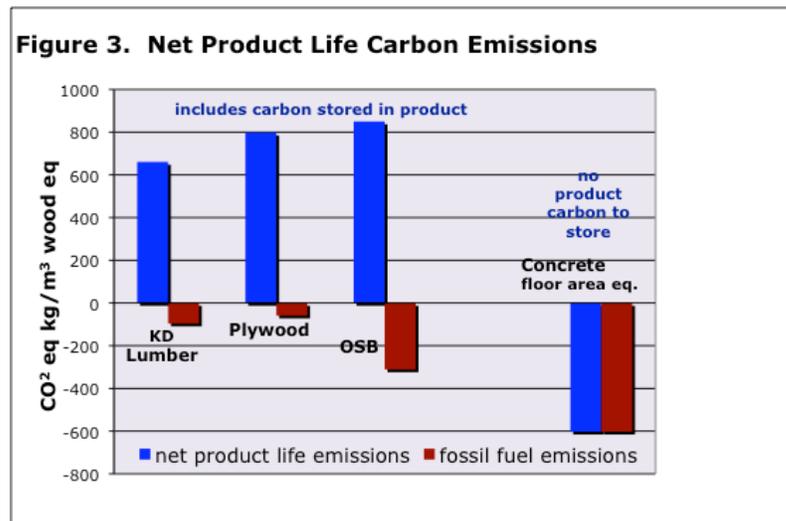
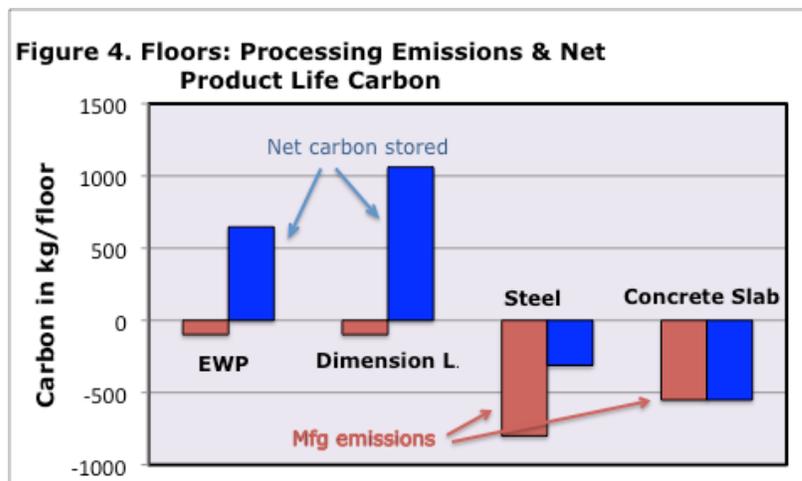
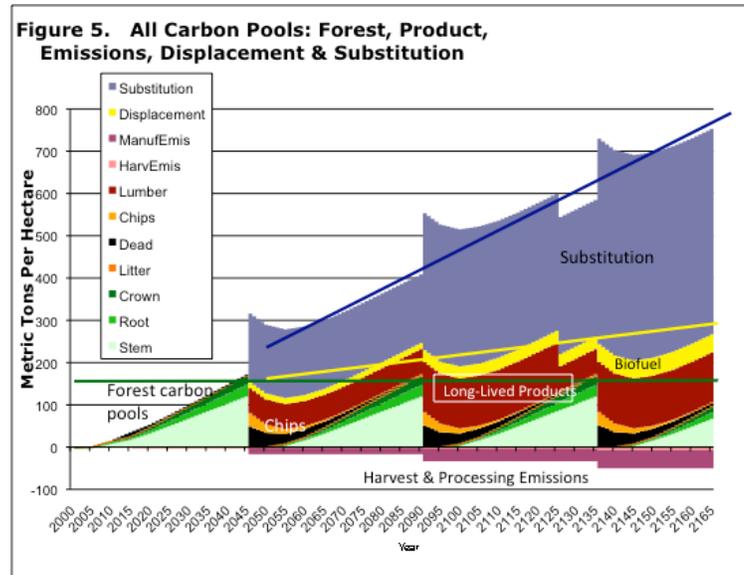


Figure 4 provides the carbon emission comparison for floor designs (768 sq. ft.) using Engineered Wood Products (EWP: I-joists), dimension lumber joists, steel joists (with wood covering), or a concrete slab. Since there is more mass and carbon in the wood dimension joists it shows the greatest carbon sink over the other floor designs, more than offsetting the emissions from processing energy. The EWP uses less fiber and therefore stores less carbon, however with greater material use efficiency the extra fiber provides increased supply that could substitute for other fossil emitting materials (not shown). The steel floor shows high processing emissions in floor applications where heavier gauge steel is needed to avoid bending and bounce but its wood sheathing surface offsets part of the emissions with the net carbon emissions lower than the concrete slab. These are just a few of many opportunities that exist to reduce carbon emissions by design and product selection using more wood and biofuels to substitute for, steel, concrete, brick, aluminum and plastics (Lippke and Edmonds 2006).



Life-cycle carbon in all pools: The carbon stored in all pools is illustrated in Figure 5 under sustainable 45-year rotations. The emissions from the total energy used for harvest and processing are shown as negative pools (Puettmann and Wilson 2005). The unused forest residuals decompose rapidly as will the chips used to make short-lived paper products. The carbon in long-lived lumber products will last at least as long as the 80 year average life observed for houses built in the 1920's (Winistorfer et al 2005).

These products are shown as burned for the tutorial value of noting that it occurs just before the third harvest even though carbon mitigation could be enhanced by recycling, land-filling, or collecting and processing the waste into biofuels. At the mill, biofuel from residuals used for heat and power is shown as a positive displacement (in yellow) offsetting much of the manufacturing and harvest energy. Lastly the substitution for fossil intensive products is shown for the most common form of substitution, a house with the frame of a cement block & stucco wall replaced by a lumber frame with vinyl siding. For this substitution of a wood framed house for a concrete wall framed house, 2.5 tons of carbon emissions are displaced for every 1 ton of carbon used in wood products. A recent analysis of all available substitution studies (Sathre and O'Connor 2008) found the most frequent displacement ratio to be 2:1 just slightly less than the concrete house example shown here. Their ratio includes medium-to-long-lived fiberboard products used in non-structural interior applications including furniture, which would increase the benefits from substitution beyond that shown above.



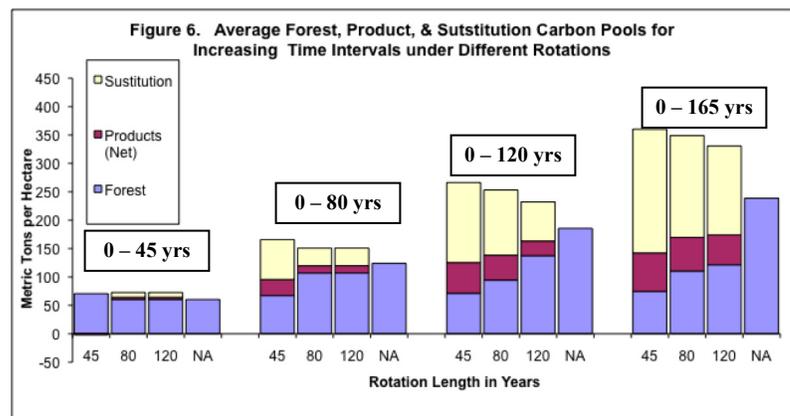
Note that in figure 5 when all carbon pools are tracked *the forest carbon pool is sustained across periodic rotations, while there is an increasing trend in the forest plus products carbon including the use of mill residuals for processing energy.* The carbon produced by the forest and products continues to grow in spite of the long-lived products being burned in the 80th year and is therefore better than permanent storage, which is often considered a requirement. With the addition of the substitution pool, the trend in carbon growth is as high as the maximum growth rate that was possible in the forest. *As carbon prices increase, collecting forest residuals and previously used wood for biofuels; and seeking out building materials with a lower carbon footprint, will increase substantially the trend in total carbon stores and emission offsets.*

Life Cycle Lessons for Carbon Mitigation: One cannot look at any single pool and understand the role forests play in mitigating emissions. Considering only the forest, suggests not harvesting as the forest carbon pool will continue to grow for a few decades beyond a commercial rotation before growth slows down. However, while this strategy may suggest permanence in the forest pool, it would be counterproductive to carbon mitigation by increasing substitution of fossil-intensive products.

Focusing only on the forest and products pool under commercial rotations, it takes a very long time for the increasing carbon stored in products to offset the decomposition of forest residuals left behind at harvest. However, the sum of carbon across all pools including substitution for fossil intensive building materials greatly exceeds the carbon that can be stored in the forest and is maximized by harvesting before the forest growth slows down.

Continuously pumping the growing forest carbon into other wood uses provides the greatest mitigation of carbon emissions.

Figure 6 compares the forest, product and substitution pools averaged across increasing time intervals, for rotations of 45, 80, and 120 years as well as for no harvest or disturbance (Perez-Garcia et al



2005). While it does not matter what rotation is chosen over the first 45 years, for any interval beyond the first harvest, the maximum carbon is stored from the shortest rotation even though it has the least forest carbon, and this advantage is magnified with time. The most storage comes from intensive short rotations harvesting before the forest growth begins to slow, storing carbon in products and substituting as early as possible for fossil intensive products. While managing strictly for carbon benefits suggests intensive short rotations harvesting before the forest growth begins to slow in order to sustain the carbon in other pools, ***some environmental values will require longer rotations and thinnings and will also need consideration.***

Some older (primarily inland) forests have become high fire risk as density has increased from a century of fire suppression, and are now being further stressed by climate change. The expected high rate of future fires over many acres will eliminate the opportunity to store carbon in product pools unless the fire risk is reduced which requires thinning dense forest stands to remove ladder fuels while also storing some carbon in products and displacement pools (Lippke et al 2008, Mason et al 2006).

Maximum carbon stores and offsets by the 110th year ranges from 550 metric tons per hectare (mt/h) in the Pacific Northwest to 350 in the dryer Inland West on private lands, with a low of 80 for Federal Lands at high fire risk and without thinning, to 200 mt/h with thinning and retention of overstory trees that restore more natural forest structures and habitat.

Carbon Incentives: Productive or Counterproductive? (Lippke and Perez-Garcia 2008):

- Current carbon exchanges that pay forest owners to defer or avoid harvesting for the increased forest carbon they store *is counterproductive*. Reducing wood uses results in increased use of fossil intensive products and emissions.
- Incentives to grow the forest faster through more intensive management and harvesting *will maximize the carbon across all pools*.
- Incentives to remove forest residuals to increase biofuels *can be productive*; but not if the incentive diverts wood from higher valued uses like fiberboards that substitute for fossil intensive products.
- Incentives that recognize the losses in carbon from fires and the costs of fighting fires would encourage below cost thinnings, which will almost certainly reduce carbon emissions from fires.
- Incentives that encourage builders to use life-cycle assessment in design and product selection, will mitigate carbon directly through their choices and bid the savings back through the resource supply chain motivating increased investments that will reduce emissions. *Given the high leverage from substitution, builders have the greatest opportunity to reduce emissions.*

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