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Carbon Sequestration Strategies in the Forest Sector

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SUMMARY

The U.S. forest sector (forest management and wood products manufacturing) sequesters enough carbon each year to offset 10% of the nation's carbon dioxide (CO_2) emissions. Managing forests to uptake and store more atmospheric carbon adds another dimension to the enduring question, when should trees be cut? One strategy is harvesting at an old age or not at all. Although young forests uptake carbon faster, old forests store more carbon. Very old forests reach a point where carbon flux becomes negative as CO_2 expired during respiration and decomposition exceeds CO_2 uptake. A second strategy is periodic timber harvesting to manufacture wood products that substitute for concrete and steel building materials, thereby displacing fossil fuel energy use and emissions. This strategy will sequester more carbon than the no harvest choice in high productivity forests. The no harvest choice sequesters more carbon in low productivity forests or when energy displacement is inefficient. A third high payoff strategy is reducing the extent of wildfires because they emit carbon equivalent to 4% of the nation's human-caused CO_2 emissions and more fine particulate matter (soot) pollution than regulated sources.

Despite increased attention to carbon sequestration, forest management issues are unsettled because other environmental, social and economic considerations remain important. Furthermore, forest scientists do not speak with one voice. Two testified before Congress during 2007: 1) Professor Schlesinger said replacing old forests that no longer provide carbon sequestration with young forests is a mistake because old forests retain large stores of carbon; 2) Professor Helms said a sequence of sustainable harvests for wood products manufacturing in the long run sequesters more carbon than an unmanaged forest.

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1. Introduction

Forests affect climate and climate affects forests; carbon links the two.[1]* Forests contain three-fourths of the earth's plant biomass, about half of which is carbon. The forest sector—including forest management and the manufacture and use of wood products—therefore plays a key role in the global carbon cycle by storing carbon.[2] Although forests can fulfill many different objectives, this issue brief addresses only forest sector carbon management strategies with the potential to store more carbon and/or reduce carbon dioxide (CO_2) emissions.

In section **2** forest sector carbon stock pools and flows ("fluxes") are discussed Three strategies are analyzed in Section **3**: [1] increasing forest carbon on-site; [2] off-site manufacture of wood products that substitute for energy-intensive concrete and steel building materials, thereby dis-placing emissions from fossil fuel use; and [3] reducing emissions from wildfires. Implications for Idaho forest managers and policymakers at all levels are discussed in section **4**, then in section **5** conclusions are drawn. As the **Acknowledgments** (page 16) state, this brief responds to an Idaho legislator's question about carbon sequestration (see section **3.4**, page 10).

2. Carbon Stocks and Flows

Trees take up CO_2 from the atmosphere during photosynthesis, emitting oxygen while using the carbon to build woody stems, branches, roots, and leaves. Trees give off CO_2 during respiration, and when they die CO_2 is released slowly through decomposition or rapidly during combustion as biomass burns. Sequestration occurs when carbon uptake exceeds respiration and other carbon losses and is added to carbon stock pools. Young forests assimilate carbon faster than old forests (**Figure 1**, page 2) because CO_2 uptake greatly exceeds respiration, whereas in very old forests respiration may exceed uptake. Old forests store more carbon than young ones.

From 1990 through 2005, the forest sector in the conterminous U.S. sequestered an annual average of 162 million metric tonnes† of carbon, offsetting about 10% of the nation's CO_2 emissions.[3] Increased use of wood products and wood energy represent part of the solution to concerns about reduction of greenhouse gases.[4] When trees are harvested, carbon is extracted from the forest but not necessarily returned directly to the atmosphere. If trees are used to make wood products, a portion of the sequestered carbon will remain stored in solid form for several decades in the wood products carbon pool or even longer in the landfill carbon pool. If wood is used to produce energy, carbon released through combustion offsets or displaces carbon that otherwise would have been released through the burning of fossil fuels.[5]

A comparison of the relative magnitudes of storage (stocks) of various forest sector carbon pools shows that in 2005, 48% was in forest soils and 35% in trees, with much smaller proportions in other pools (**Table 1**, page 2). Changes in pools ("flux") during 2005 show that 49% of the additional carbon sequestered that year in the forest sector was in live and dead trees, 27% was in wood products in landfills, with the remainder in other pools (**Table 1**).

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* Footnotes are keyed to numbered **References** listed on pages 14-16.

† Hereafter "tonne" will be used to indicate a metric tonne (1,000 kilograms or 2,205 pounds).

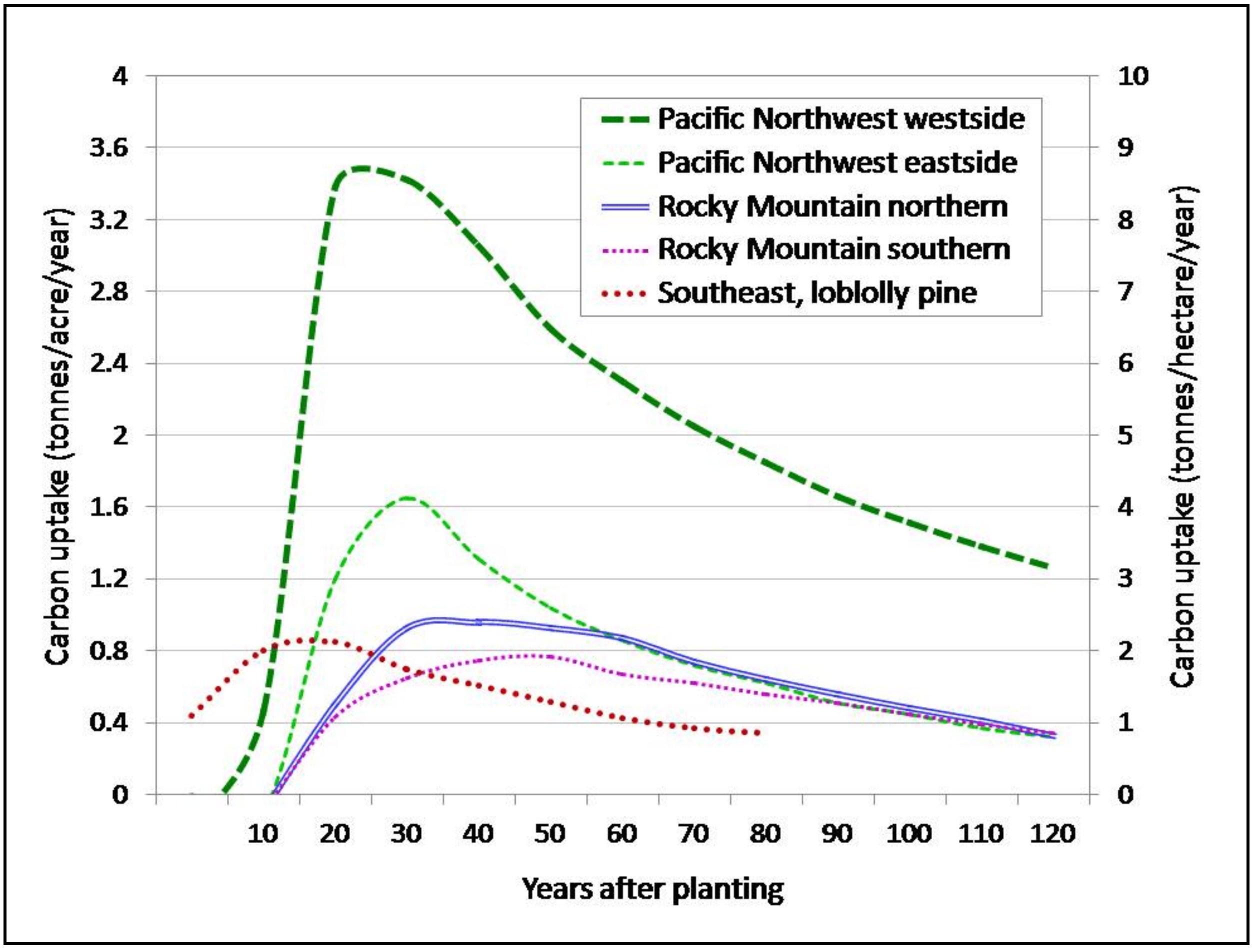

Figure 1. Carbon sequestration (uptake) rates for newly planted Douglas-fir forests on average sites in four western regions, compared with an average loblolly pine site in the Southeast region.[6, 7] (data sources)

Table 1. Comparison of stocks and fluxes for each forest sector carbon pool in 2005.[3]

Pool	Stock	Flux or net change
	– % of total –	
Trees	35	49
Down dead wood	3	11
Understory	1	0
Forest floor	8	1
Forest soils	48	2
Wood products	2	10
Landfilled wood	3	27

In the near future U.S. forests are expected to sequester carbon at rates similar to recent years, in which forests, urban trees, and wood products were responsible for 65-91% of this carbon sink.[3] In total, 95% of forest sector carbon stocks are on-site and 5% off-site, whereas 37% of the net increase in carbon storage in 2005 occurred off-site (**Table 1**).

Off-site pools (wood products and landfilled wood) play key roles in carbon sequestration strategies, even though their stocks are much lower than the on-site carbon pools (**Table 1**). The total amount or stock of carbon in a pool can be increased if carbon flows into the pool are increased and/or if carbon flows out of the pool are decreased. This can be done on-site through either the expansion or conservation of stocks, and off-site with emissions reductions through activities that include substituting wood products for concrete or steel building materials,[8] and use of woody biomass for energy that substitutes for or displaces fossil fuel energy.[5] This combination of on-site forest management actions with off-site wood products utilization has five positive impacts for carbon management (see box below).

Positive Impacts of Forest Sector Carbon Sequestration [9, 10, 11, 12]

- ✓ Trees remove carbon from the air and store it as wood.
- ✓ Trees and wood products have long lives.
- ✓ Wood can generate energy in biomass or cogeneration facilities; indeed, most of the energy used to manufacture wood-based products is from woody biomass.
- ✓ Wood products can substitute for some concrete and steel building materials (e.g., above-grade walls in residential construction), thereby avoiding and displacing emissions associated with these energy-intensive products.
- ✓ Forests can be regenerated, so while much of the carbon from a harvested forest remains sequestered in wood products, growing new trees takes more carbon out of the air.

3. Forest Sector Strategies

Activities in the forest sector can help reduce atmospheric CO_2 relative to that which would otherwise occur.[2] The biological storage of carbon in forests is one of a portfolio of current technologies to meet the world's energy needs over the next 50 years and limit atmospheric CO_2 to a trajectory that avoids a doubling of the preindustrial concentration.[13] Such activities can be grouped into three general categories:

[1] increasing on-site carbon density (tonnes of carbon stored per acre or hectare);

[2] increasing off-site use of forest-derived materials to substitute for competing materials and thereby displace fossil fuel energy use and emissions, and/or increasing the use of forest biomass-derived energy to substitute for fossil fuel use and emissions; and

[3] increasing or maintaining the forest area by avoiding deforestation and reducing the extent of wildfires.[2]

3.1. Strategy [1] – Increasing forest carbon on-site. Storing more carbon in forests can be accomplished by establishing new forests or modifying management of existing forests. Reforestation involves planting forests in areas that were previously forested but trees were removed by disturbances such as timber harvesting or wildfire. Afforestation involves encouraging successful forest growth in areas where trees did not previously grow. Silvicultural techniques that accelerate forest growth can increase on-site carbon sequestration rates. Longer harvest rotation ages and protection against fire and insects also increase on-site storage.[2]

3.1.1. Timber Growth = Carbon Sequestration. The amount of carbon a new forest will sequester corresponds to an S-shaped growth curve, with accrual rates highest at a young age, after an initial lag phase, and then declining towards zero as the timber growing stock approaches a maximum.[14] **Figure 2(a)** depicts timber growth over time for new Douglas-fir forests on average sites in each of four western regions, with an average loblolly pine site in the Southeastern region for comparison. At 85 years loblolly pine growth is leveling off towards a maximum, whereas Douglas-fir will continue to grow well beyond 125 years, but at a decreasing rate. The productivity of these average sites—measured in cubic feet per acre per year (ft^3/ac/yr) during the decade of most rapid volume accumulation—ranges from 205 for Pacific Northwest (PNW) westside sites to 40 for sites in the Rocky Mountain south region. Rocky Mountain north and Southeastern loblolly pine site averages are 65 and 67 ft^3/ac/yr, respectively; PNW eastside sites average 100 ft^3/ac/yr. Average Douglas-fir sites in the PNW region clearly are more productive than in the Rocky Mountain region (**Figure 2(a)**).

Figure 2(b) depicts carbon storage in the forest pool, which is directly related to timber growth. This graph also includes the other forest carbon pools: standing and down dead trees, understory vegetation, and litter on the forest floor. Similar data for average spruce-fir sites in the Interior West region (PNW eastside and Rocky Mountain regions) show they are slightly less productive than Douglas-fir sites. However, average lodgepole and ponderosa pine sites in the Interior West are 30-45% less productive than Douglas-fir sites.[6, 7]

3.1.2. What is an "average" site? The average sites depicted in **Figure 2** could be considered as a dividing line between high and low productivity sites. Analysis in the next section is based on a PNW westside "reference site" that at age 125 stores 360 tonnes of carbon per hectare. On **Figure 2(b)** this "reference site" lies between the average PNW westside and eastside sites. Where would an average site in Idaho lie?

Appendix Table A (page 17) provides forest land productivity data by U.S. regions. In the South-central region 85 ft^3/ac/yr is considered high productivity forest land.[7] Applying this benchmark to Idaho, there are 7.6 million acres (mm-ac) of high sites and 9.2 mm-ac of low sites. Montana has 2.6 and 16.6 mm-ac of high and low sites, respectively. In Idaho and Montana the ratio of high sites to low is 0.83 and 0.16, respectively, so Idaho is well above the Rocky Mountain north line on **Figure 2(b)**. The PNW eastside region has 5.1 and 13.6 mm-ac of high and low sites, respectively, for a ratio of 0.37, so the average Idaho site would be well above the average PNW eastside site and likely close to the indicated "reference site" in **Figure 2(b)**.

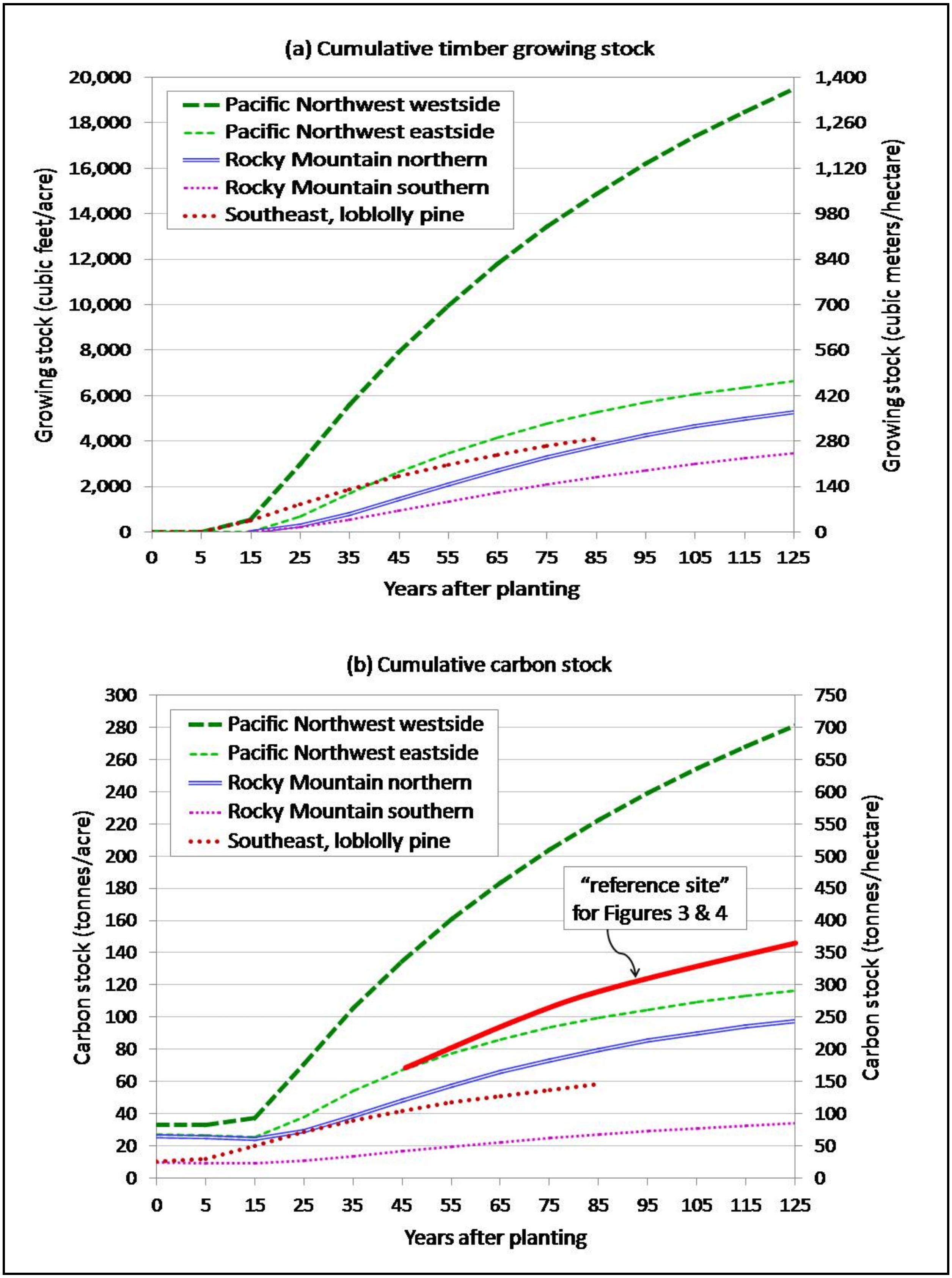

Figure 2. Cumulative **(a)** timber volume and **(b)** carbon stock for new Douglas-fir forests on average sites in four western regions, compared with loblolly pine in the Southeast region,[6, 7 (data sources)] and the "reference site" used in subsequent analysis (see **Figures 3 & 4**).

3.1.3. Sequence of Harvests vs. No Harvest. When carbon becomes a forest management objective several factors and trade-offs need to be considered.[2] Foremost is the trade-off between the rate of carbon uptake and the amount of carbon stored; i.e., the relative contributions of younger and older forests to carbon sequestration.

Figure 3 depicts the cumulative change in carbon stocks over 160 years after a new Douglas-fir forest has been established on a moderately productive PNW westside site.[10, 11] This is the "reference site" depicted in **Figure 2(b)**. In **Figure 3** the no harvest scenario for the reference site is compared with 3 different rotation age scenarios of 45, 80, and 120 years. The 80 and 120-year harvest rotation sequences also include two and three thinnings, respectively, at various times between forest establishment and final harvest. The no harvest scenario results in more on-site carbon storage than the sequence-of-harvest scenarios, regardless of rotation age (**Figure 3**). However, the fate of harvested carbon needs to be accounted for.[10, 11] Off-site factors considered in **3.2. Strategy [2]** are the transfer of harvested timber into the wood products pool and substitution of wood products for energy-intensive alternative products.

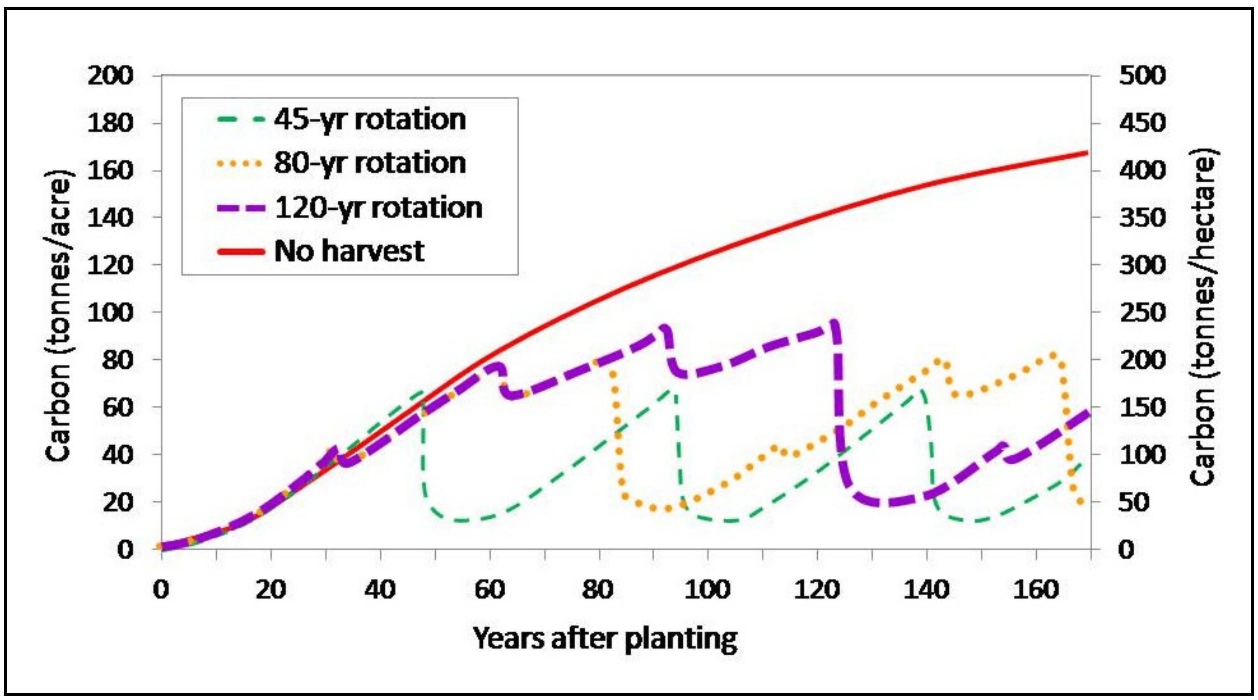

Figure 3. Carbon storage in the forest pool for 45-, 80-, 120-year rotations or harvest cycles and no harvest option that should be considered a potential maximum for carbon storage in the forest pool.[4, 10, 11 (redrawn)]

3.1.4. Timber Management and Other Objectives. Forest managers have expanded their focus over the last two decades to include recreation, endangered species habitat, and fire management objectives along with timber production. Increasing on-site carbon storage is compatible with objectives that require maintenance of forest cover, such as conserving old-growth forests and endangered species that depend on these ecosystems. Other management objectives that restrict timber harvest, such as buffers along streams to improve fisheries or along highways to enhance scenery for tourists, also lead to greater on-site carbon stores. Prevention of large-scale wildfire events that would release large quantities of carbon into the atmosphere maintains such storage.[2]

3.2. Strategy [2] – Increasing off-site use of forest-derived materials as substitutes for energy-intensive building materials.

Forests managed with a sequence of harvests for timber production sequester carbon on-site while trees are growing (as in **Figure 3**), and also generate a flow of carbon into the off-site wood products pool of manufactured products at all stages of use as well as manufacturing residue.[2] The wood products carbon pool more than offsets harvesting and manufacturing emissions.[10] Carbon stored in wood products is gradually released as CO_2 when the wood eventually decays or combusts. If wood products end up in landfills, the carbon contained in the wood may be stored for a long time, sometimes permanently.[3]

Furthermore, if wood products substitute for more energy-intensive products, then carbon emissions from other manufacturing sectors are avoided.[2] For example, in residential construction an above-grade wall framed with concrete blocks requires 250% more energy than using kiln-dried lumber for the same purpose.[12] Substituting lumber for fossil-fuel intensive cement and steel building products generates substantial benefits from energy displacement and avoided emissions. These benefits may continue almost indefinitely into the future.[4, 9, 10, 11, 12, 14]

The scenario in **Figure 4(a)** builds upon **Figure 3**. A forest stand is harvested in the 45th year to produce lumber, which captures about 50% of the wood in timber.[10, 11] In this example lumber substitutes for above-grade concrete block walls in residential construction. **Figure 4(b)** concludes the analysis by illustrating that when wood products carbon pools and avoided emissions from displacing fossil fuel energy use are considered, the 45-year timber harvest rotation is a better carbon management choice than the no harvesting alternative. The area above the no harvest curve represents a carbon management benefit attributable to avoided emissions due to fossil fuel energy displacement resulting from the substitution of wood products for concrete products. The 45-year rotation is also superior to longer rotation options.[9, 10]

When wood products substitute efficiently for fossil fuel energy-intensive products, such as concrete, a sequence of sustainable harvests produces greater net carbon benefits than does protection of standing forests. This benefit increases rapidly with increasing productivity. Carbon storage is very sensitive to the forest growth rate and to the efficiency with which wood products substitute for alternative products or fuels. When wood products are not used efficiently as susbstitutes, the greater carbon benefit is achieved through reforestation and protection of standing forests, and efforts to increase the rate of stand growth yield little gain.[15]

Using woody biomass as fuel may also be part of a carbon sequestration strategy and is dependant on site-specific parameters and the technical factors of energy substitution to help determine whether harvesting woody biomass for fossil fuel substitution should be preferred to on-site carbon sequestration strategies.[15] A good reason to harvest woody biomass for energy or other uses is to reduce wildfire intensity and extent.

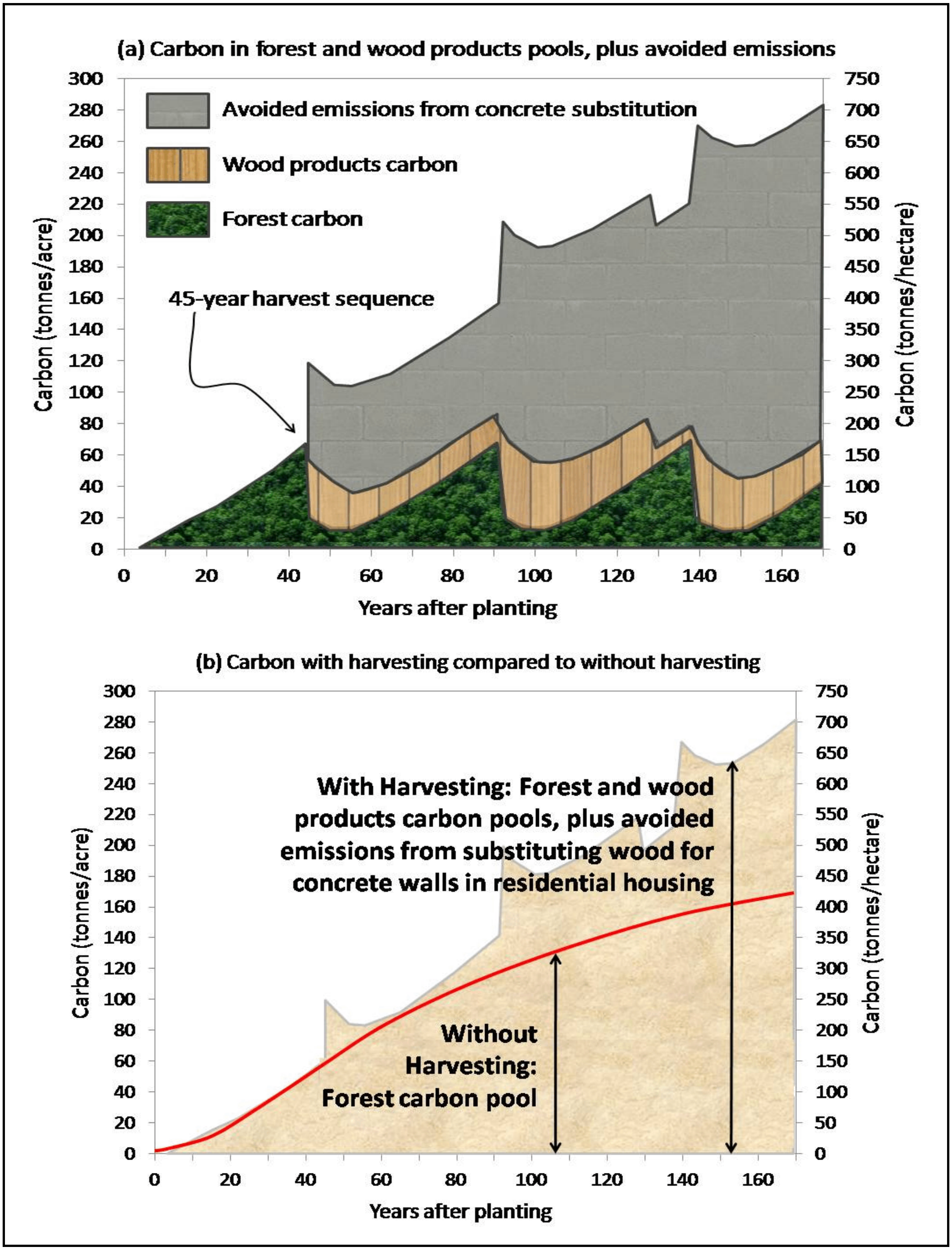

Figure 4. Carbon in forest and wood product pools over time for the 45-year harvest cycle scenario, plus avoided emissions from using lumber instead of concrete blocks to frame walls in residential construction: **(a)** total carbon stocks with harvesting, and **(b)** total carbon stocks with harvesting compared to the no harvest scenario.[4, 10, 11 (redrawn)]

3.3. Strategy [3] – Increasing or maintaining forest area by avoiding deforestation and reducing wildfires. Much of the international focus on forest carbon stocks has been on preventing practices that result in deforestation. Although some forest land is lost to urban development in the U.S., deforestation is low compared to many other countries, so attention to other concerns may be more important for reducing U.S. forest carbon losses.[8] Disturbance events such as fire, windthrow, insect outbreak, or timber harvest can be thought of as deforestation events because they transfer some of the carbon out of the forest ecosystem.[2]

Recall that each year forests in the conterminous U.S. sequester approximately 162 million tonnes of carbon.[3] Wildfires emitted an annual average of 59 million tonnes of carbon in 2002-2006 as CO_2,[18] and another 2 million tonnes per year as particulate matter.[19] Wildfire transfers carbon out of the forest storage pool into the atmosphere, whereas timber harvesting transfers a substantial amount of carbon into the wood products pool.[2] A 10% reduction in wildfires would avoid emissions of 6 million tonnes of carbon per year, equivalent to CO_2 emissions from about 4 million "average" automobiles, each emitting 6 tons of CO_2 per year (www.terrapass.com).*

Needleleaf forests in the southern and western states are the dominant source of CO_2 emissions from wildfires. Emissions are typically highest in drought years, and climatic variability is a major factor in year-to-year and spatial variations in fire emissions.[18] Fuel accumulation is also a factor,[20] as there is more to burn. The amount of CO_2 emitted from U.S. wildfires is equivalent to 4-6% of human-caused emissions at the continental scale. At the state-level, CO_2 emissions from wildfires can sometimes exceed annual emissions of CO_2 from fossil fuel usage. Idaho is one such state.[18]

The short-term release of carbon by wildland fires is largely offset over longer time scales (decades) by the uptake of atmospheric carbon from forest regrowth. From this standpoint, fires and fossil fuel emissions have different effects on atmospheric CO_2 levels. In the absence of changes in wildland fire frequency or intensity, emissions would be balanced over a period of many decades by forest regrowth and carbon assimilation.[3] However, the recent trend is a dramatic increase in wildfire extent and intensity (**Figure 5**). From 1970 to 1999, an annual average of 3 million acres per year burned. In 2000-2004, the annual average doubled to 6 million, and in 2005-2007, increased to 9 million acres per year; meanwhile the number of fires stayed approximately the same. The smoke and carbon emission implications of this trend lend some urgency to reconsideration of wildland fire management policy.[21]

In summary, the CO_2 released from fires, overall, is a small fraction of the estimated average annual forest productivity and, unlike fossil fuel CO_2 emissions, the pulsed emissions of CO_2 during fires are partially counterbalanced by uptake of CO_2 by regrowing vegetation in the decades following fire. Changes in fire severity and frequency can, however, lead to net changes in atmospheric CO_2 and the short-term implications of wildfire emissions for monitoring, modeling, and carbon management policy are substantial.[18] The dramatic upward trend in wildfire intensity and extent since 1999 (**Figure 5**) needs to be considered in carbon management strategies.

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* A factor of 3.67 converts tonnes of carbon to CO_2 equivalents.

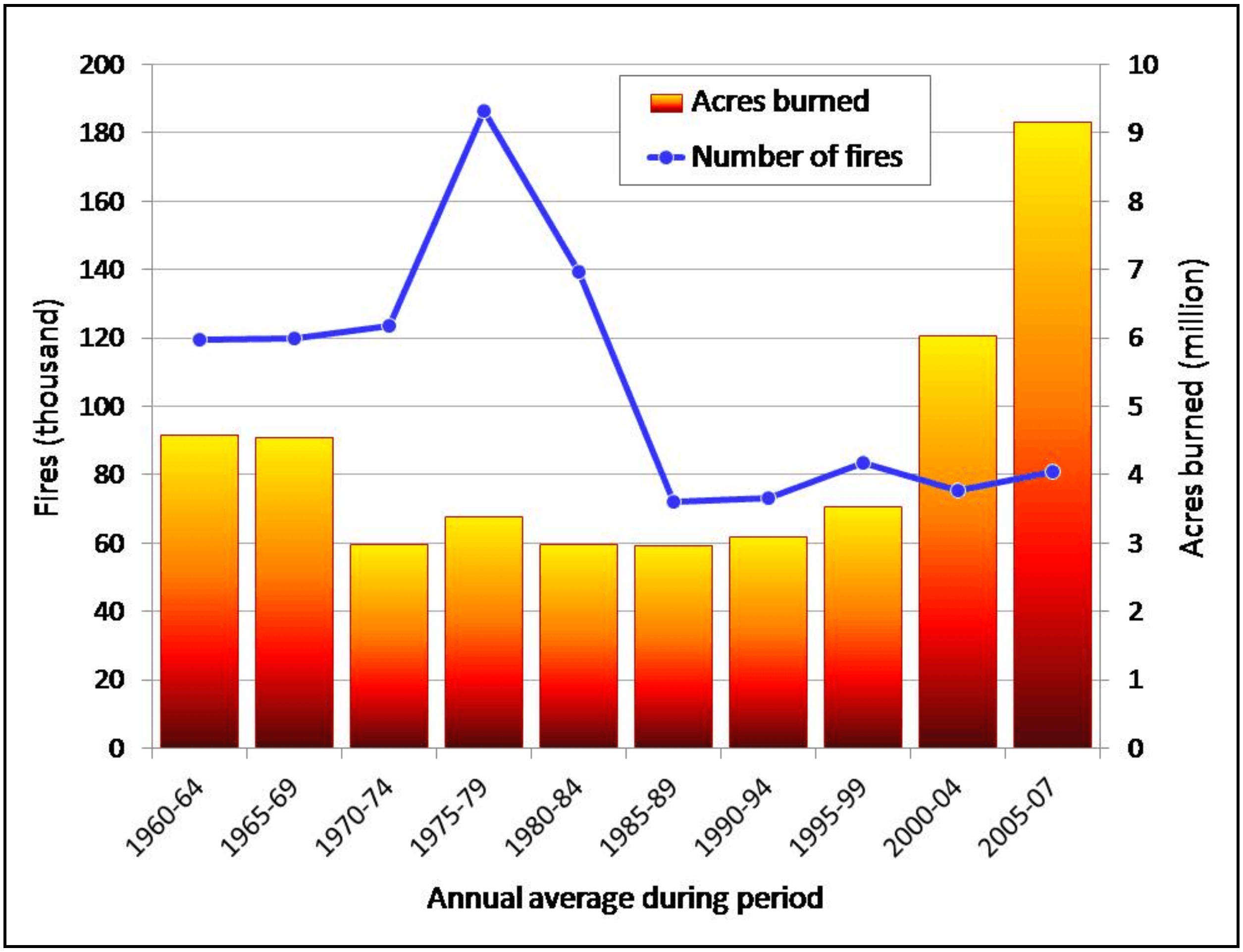


Figure 5. Wildfires in U.S., acres burned and number of fires, 1960-2007.[22 (data source)]

3.4. Summary – When should trees be cut? Does a forest harvested periodically for wood products sequester more carbon than an old-growth forest? Yes and no. The answer depends on three factors: [1] considering only the on-site biological growth of trees, not harvesting will always sequester more carbon, regardless of the harvesting rotation age **(Figure 3)**; [2] not harvesting remains the better choice even after adding off-site conversion of harvested timber into long-lived wood products; but [3] harvesting is the better choice if wood products substitute for concrete or steel building materials and thereby avoid emissions by displacing fossil fuel use (**Figure 4**), but only in high productivity forests and only if the product substitution is efficient.[15]

Research also shows that when wood products and fossil fuel-intensive product substitution are considered, the shorter the forest rotation age, the more favorable the carbon balance becomes over time.[9, 10, 11]

To sum up, for high productivity forests the reply is yes, harvested forests do sequester more carbon than unharvested forests, but only if accompanied by efficient use of wood products, with efficient use defined as wood products substituting for fossil fuel-intensive products in applications such as lumber instead of concrete block walls in residential housing construction, and/or using wood products manufacturing residues to displace fossil fuel energy use.[4, 10, 11] For low productivity forests and/or inefficient use of wood products to displace fossil fuels, the reply is no.

4. Implications

The preceding analysis has implications for managing forests that are specific to Idaho due to the fire-prone nature of forests and accumulations of fuels, especially on National Forest System lands in the state administered by the U.S. Forest Service. In addition there are implications that apply more generally to forest and carbon management policies at the national level.

4.1. Implications for Idaho. In the lower-elevation pine forests of the Interior West, a century of fire suppression has created fuel conditions that lead to very large, intense, and destructive wildfires.[8] Such fires occur over a one or two month period but can release as much carbon as the annual emissions from the entire transportation or energy sector of an individual state.[18] Idaho is one such state.

4.1.1. Wildfires and Carbon Emissions. In some western states, such as Alaska and Idaho, the annual emission of CO_2 from wildfires in some years equals or exceeds the emissions from fossil fuel combustion. For example, CO_2 emissions from wildfires in Idaho during 2006 were 1.6 times greater than annual fossil fuel-burning emissions. Montana and Washington also experienced CO_2 emissions from fires in 2006 that were equivalent to approximately 47% and 42% of the total annual state-level fossil fuel-burning CO_2 emissions, respectively.[18]

4.1.2. What to do? Reducing fuels can reduce wildfire emissions. In a study on the Boise National Forest, an aggressive forest fuel treatment program featuring the physical removal of excess fuels and the widespread use of prescribed fire would result in a 30-50% reduction in the average annual wildfire area; a 14-35% reduction in average annual fire-related carbon emissions; and a 10-31% reduction in particulate emissions.[23]

4.2. Policy Implications. Consideration of how forest management decisions affect carbon pools has implications for wildland fire and smoke management policies. In addition, roadless area conservation and old-growth protection policies are affected. The “leakage” issue in carbon accounting has implications for establishing forest reserves for carbon management purposes.

4.2.1. Wildland Fire and Smoke Management. Active forest management techniques used to maintain healthy forests and sequester carbon also offer another carbon management benefit by reducing the threat of high-intensity wildfires that release large quantities of carbon into the air,[24] both as greenhouse gases and as particulate matter (soot) that reduces air quality and causes significant human health problems.[21]

Fuel reduction treatments that involve prescribed burning reduce carbon stores temporarily. The objective of hazardous fuel treatment is to reduce the burning intensity of future fires, which in the long term will maintain higher carbon stores in forest landscapes.[2] Air quality would also be improved due to the overall reduction of pollutants in smoke emissions, including fine particulate matter and carbon monoxide. Atmospheric scientists examining these issues concluded,

> Fire is one of the largest potential risks to loss of stored terrestrial carbon. At regional and national levels, terrestrial sinks driven by historic land use change, such as reforestation efforts, can be sizeable and may represent an attractive target in future carbon mitigation negotiations. Similarly, fire mitigation programs such as forest thinning may reduce the severity or extent of fires, but may also have uncertain impacts on sequestered carbon (depending on the fate of carbon removed from forests). From this standpoint, the potential for carbon losses from fire represents a risk to carbon sequestration potential and a factor that needs to be considered in discussions regarding appropriate credit for terrestrial sinks in atmospheric carbon mitigation.[18]

Decisions to maintain large unroaded areas may also be influenced by consideration of carbon emissions from wildfires, as such areas cannot be accessed by ground-based firefighting equipment.[2] This also has implications for the creation or maintenance of old-growth forest reserves.

4.2.2. Old-Growth Forest Conservation. When carbon becomes a forest management objective, the fact that old forests store more carbon than young forests is sometimes used to support arguments for preserving old-growth forests. For example, Professor Schlesinger, former dean of the forestry program at Duke University, told Congress,

> It is tempting to suggest that we should cut down such old, mature forests that no longer provide carbon sequestration and replace them with young forests that do so. This would be a mistake. When an old forest is cut, much of the carbon that it contains is released back to the atmosphere as CO_2. ... Old growth forests retain large stores of carbon, and we should make every effort to retain them.[25]

Considering only on-site carbon storage, the longer the rotation, the more carbon will be stored, regardless of any other on-site considerations. But forests are not a “carbon graveyard.”[17] Old forests eventually die and release the carbon the trees once stored as they decompose or burn. When off-site wood products and landfill carbon pools are considered, harvesting will sequester more carbon in high productivity forests when wood products efficiently substitute for energy-intensive competing products.[15]

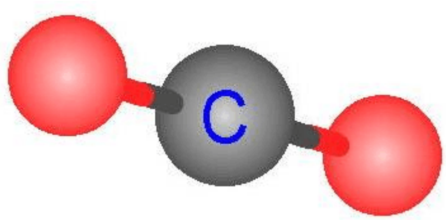
4.2.3. The “Leakage” Issue. The impact of forest management activities on carbon stores lasts for many decades and changes over time. For example, conservation measures that prohibit logging offer immediate on-site benefits from prevented emissions.[2] However, the off-site “leakage” issue in carbon offset accounting also needs to be considered.[26] Leakage occurs when a forest management decision reduces the local supply of timber and thereby displaces timber production and associated carbon management issues to another location.[27]

A textbook example is the carbon impact of reducing timber harvesting on federal lands in the Pacific Northwest to protect the northern spotted owl. For every tonne of emissions avoided by federal timber harvest reductions, 0.88 tonnes of emissions occurred from increases in harvesting somewhere else. If the federal government had attempted to claim carbon credits for the spotted owl-driven timber harvest reductions as a greenhouse gas offset project, due to leakage only 12 percent of the net greenhouse benefit could be claimed as carbon credits. This 88% leakage estimate is calculated from supply and demand elasticities and is an extreme case, but similar forest offset projects often have leakage in excess of 50%.[25]

4.2.4. What to do? As a first step in increasing carbon sequestration in the forest sector, the government should examine how it can modify management practices on its extensive land holdings to emphasize carbon sequestration in a manner that is consistent with other land management objectives such as habitat protection, erosion control, and timber production. The most promising avenue involves reducing the risk of catastrophic loss of forests to wildfires.[8]

The management of national and global carbon pools should take into account a policy of reducing wildfires.[16] The cost of substantial additional wildland fire management activities may be justified by carbon benefits alone.[16] Removing excess debris and thinning overstocked forests can reduce the "fuel ladders" that provide pathways that can carry flames from what would otherwise be small, non-lethal ground fires into the forest canopy, resulting in intense, stand-replacing crown fires.[8] Methods are available to compare the benefits from reducing wildfires compared to the additional costs imposed. Such information could be used to help guide wildland fire management policy decisions. Using a wildfire reduction scenario, the benefits of increasing timber market welfare and reduced climate change damages can be compared with cost estimates.[16, 17]

Other steps that could encourage additional carbon sequestration in the forest sector would be the inclusion of wood products in "green" building certification programs,[4, 9] and in carbon credit offset projects under emissions cap-and-trade or comparable programs designed to reduce CO_2 emissions.[28, 29]



5. Conclusion

Figure 6 provides a subjective view summarizing the relative contribution that different management strategies in the forest sector make to carbon management. Although increasing the growth rates or carbon storage of existing forests, the use of wood products, and tree planting provide carbon benefits, larger benefits may come from avoiding deforestation and reducing wildfires.

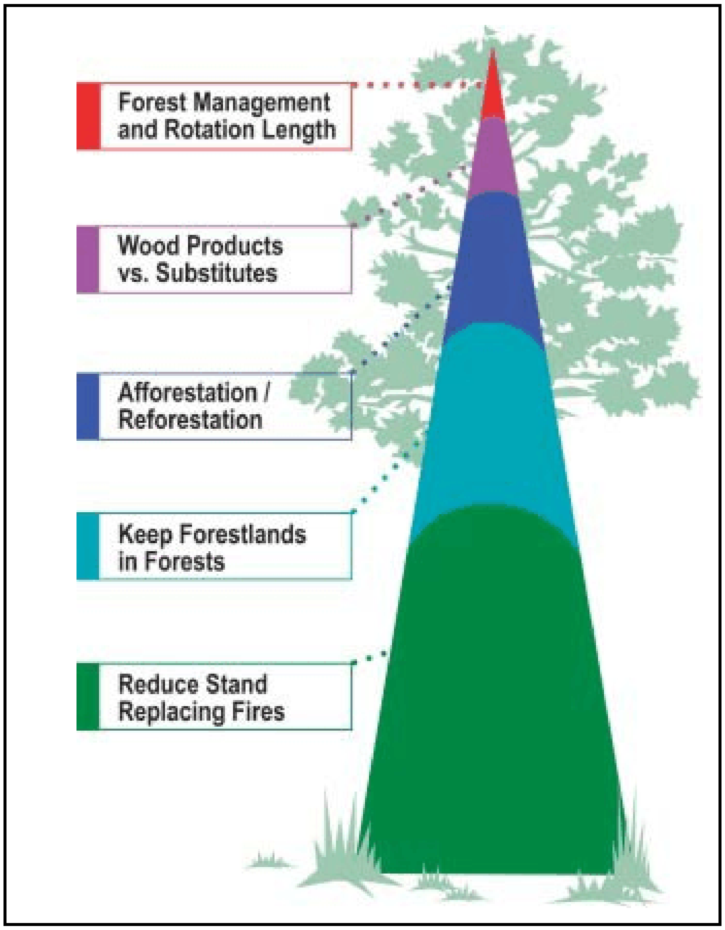


Figure 6. Relative contributions of various forest sector activities with regard to carbon management.[30]

Forest management cannot fully solve the problem of carbon accumulation in the atmosphere, but neither can any other individual sector. Forest management activities can contribute significantly to the solution. Over the course of the next 50 years, reforestation, afforestation and reduced deforestation globally could provide a cumulative sequestration of 25 billion tonnes of carbon. This is similar to the effect of doubling the current global nuclear power generation capacity or doubling the fuel economy of cars.[12]

Increased carbon storage, in combination with a host of emission reduction measures, can help reduce and even end the ongoing rise of carbon concentration in the atmosphere.[2] Consider, however, that although existing forests annually sequester enough carbon to offset 10% of the nation's annual CO_2 emissions, attempting to attain a similar amount of offset by afforestation would require new forest plantations covering an area the size of the state of Texas.[25]

The payoff in forest sector carbon sequestration will come from a combination of actions. Professor Helms, former department head of forestry at the University of California – Berkeley and president of the Society of American Foresters, told Congress that the nation's highest priorities are to reduce wildfire, stabilize the forest land base, and limit forest conversion, development, and parcelization. He championed the use of wood products and woody biomass energy.[31] Pertinent to the relative contributions of young and old forests, he concluded,

> This much is certain: rapidly growing trees sequester carbon more quickly and efficiently than old ones. That fact should stay front and center in policy discussions. If we want to maximize carbon sequestration and storage, we need forest management that results in healthy forests of all ages on the landscape. That means sustainable forestry and plenty of young forests.[24]

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Appendix Table A. Forest land area in the U.S. by productivity class and region, 2002.

Region	Total	Productivity Class (cubic feet/acre/year)					Reserved Forest Land
		120+	85-119	50-84	20-49	0-19	
	– thousand acres –						
North	169,685	8,093	25,680	54,521	70,420	3,054	7,916
South	214,603	33,788	57,945	83,917	27,023	7,427	4,503
Rocky Mtn.	144,344	3,231	8,332	21,615	37,449	54,766	18,950
(Idaho)	(21,646)	(2,648)	(4,977)	(5,394)	(3,805)	(1,115)	(3,708)
(Montana)	(23,293)	(453)	(2,133)	(7,093)	(9,505)	(426)	(3,682)
Pacific Coast	220,291	28,195	12,467	14,220	16,642	103,085	45,682
(PNW westside)	(27,761)	(13,393)	(4,692)	(4,020)	(794)	(2,735)	(1,587)
(PNW eastside)	(25,230)	(1,458)	(3,610)	(10,397)	(3,229)	(5,060)	(1,476)
Total U.S.	748,922	73,308	104,424	174,274	151,535	168,331	77,501

Source data from U.S. Dept. of Agriculture – Forest Service,[32] except PNW westside and eastside.[33]

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