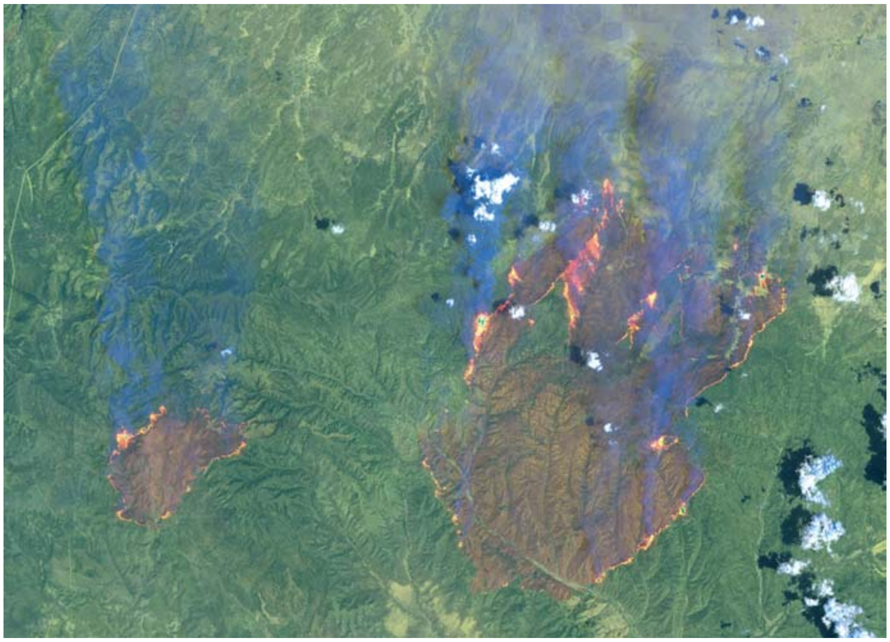
ERI — Issues in Forest Restoration

Forestlands health and carbon sequestration —

Strengthening the case for Western forest restoration



Ecological Restoration Institute

The Ecological Restoration Institute

The Ecological Restoration Institute at Northern Arizona University is a pioneer in researching, implementing, and monitoring ecological restoration of southwestern ponderosa pine forests. These forests have been significantly altered over the last century, with decreased ecological and recreational values, near-elimination of natural low-intensity fire regimes, and greatly increased risk of large-scale fires. The ERI is working with public agencies and other partners to restore these forests to a more ecologically healthy condition and trajectory—in the process helping to significantly reduce the threat of catastrophic wildfire and its effects on human, animal, and plant communities.

Cover photo: Large fires, such as the 2002 Rodeo-Chediski—here in its early stages—quickly release huge quantities of stored carbon into the atmosphere. Ecologically-guided thinning lowers the incidence, size, and intensity of such fires.

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Forest-lands health and carbon sequestration — Strengthening the case for Western forest restoration

There is general and widespread agreement that human actions are causing changes in global climate through increased emissions of greenhouse gases. There are a number of strategies to tackle the problem. Forests have the potential to help reduce emissions and slow changes if they are protected, expanded, or returned to healthier condition. In the western United States, forest restoration—a ecologically-guided thinning process—could be a way to increase carbon sequestration. By preventing unnatural catastrophic wildfire and creating healthier ecosystem conditions, restoration can store biomass carbon.

Introduction

Carbon is stored in vegetation, soils, oceans, the atmosphere, and fossilized remains of carbon-based organisms (forming fossil fuels). Over the last century the carbon cycle—a flow between release and absorption—has gradually become unbalanced, with an accelerated release of carbon dioxide and other gases beyond what natural processes can re-absorb or recycle (EPA 1998). The increase in these "greenhouse gases" has altered the chemistry of the atmosphere. Because they trap heat, it is well-accepted that accumulation of these gases is raising global temperatures.

Carbon dioxide (CO_2) is the most abundant of these greenhouse gases. Most CO_2 is produced by the combustion of fossil fuels, with lesser but still-significant amounts from human-caused fires, deforestation, and natural processes. When fossil fuels such as coal, petroleum, or natural gas are burned, the carbon they contain is released into the atmosphere, principally as carbon dioxide. Smaller amounts of fossil materials such as limestone are used in such industrial processes as cement manufacture, also giving off CO_2 to the atmosphere.

While scientists can detect increasing levels of atmospheric carbon coinciding with the rise and development of the Industrial Revolution, the principal concern is with the accelerating rise in CO_2 over the last few decades (Malhi, Baldocchi, and Jarvis 1999). As more fossil fuel, the currently most favored energy source, is consumed, more greenhouse gases are produced. The potential effects of global warming associated with a build-up of greenhouse gases are not yet well understood. However, there is sufficient evidence that changes may be large-scale, transforming global and regional weather and vegetation patterns.

There are strategies that may reduce the total amount of atmospheric CO_2. Some strategies, such as a reduction in fossil fuel use—or, best, its replacement with renewable energy—are long-term. Other strategies buy time by locking-up existing terrestrial carbon as long as possible or by removing carbon from the atmosphere and delaying its re-release.

Carbon offset strategies

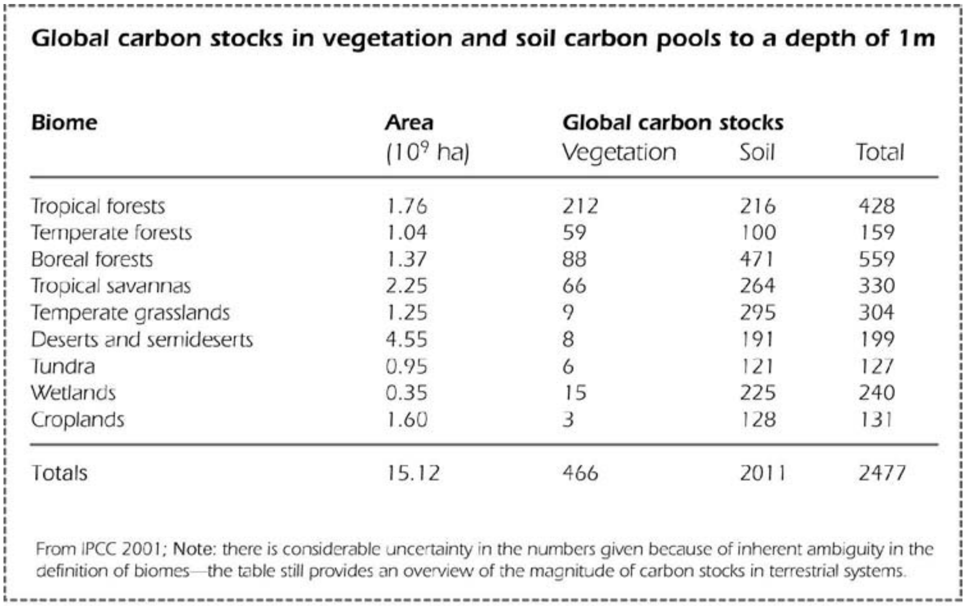
There are a number of basic strategies to either reduce the amount of carbon dioxide released into the atmosphere or to increase the amount stored:

- reduce the total amount of energy used;
- in place of primary fossil fuels, substitute alternative or renewable forms of energy that generate fewer greenhouse gases;
- clean (scrub or decarbonize) emissions from existing fossil energy generation;
- recycle and reuse products and materials;
- develop new or additional capacity to capture and store greenhouse gases;
- protect existing stores of terrestrial carbon, avoiding release of CO_2.

A great deal has been written about each of these strategies; only the last will be discussed here primarily in the context of forest restoration in the western United States. The primary interest here is forest ecosystem health and the carbon-release role of wildfire.

Forests, forest management, and forest products

Forests, operating both to capture additional carbon and as carbon reservoirs, have long been identified as major contributors to stabilizing levels of atmospheric carbon dioxide (IPCC 2000) (Figure one). A significant percentage of the earth's carbon is stored in forests, particularly rainforests and old-growth or frontier forests. A forest's net carbon budget is a delicate balance between carbon acquisition (soil carbon accumulation, photosynthesis, tree growth, forest aging) and carbon release (respiration of living biomass, tree mortality, microbial decomposition of litter, oxidation of soil carbon, degradation, and disturbance) (Malhi, Baldocchi, and Jarvis 1999). Simply put, as trees grow they take in carbon; as they die and decay they release it. This is typically a long-term cyclical process, but deterioration of forests through fire, disease, or pest infestations can accelerate carbon release. Protecting forests maintains their ability to take in and store carbon.



Global carbon stocks in vegetation and soil carbon pools to a depth of 1m

Biome	**Area**	**Global carbon stocks**		
	(10^9 ha)	Vegetation	Soil	Total
Tropical forests	1.76	212	216	428
Temperate forests	1.04	59	100	159
Boreal forests	1.37	88	471	559
Tropical savannas	2.25	66	264	330
Temperate grasslands	1.25	9	295	304
Deserts and semideserts	4.55	8	191	199
Tundra	0.95	6	121	127
Wetlands	0.35	15	225	240
Croplands	1.60	3	128	131
Totals	15.12	466	2011	2477

From IPCC 2001; **Note:** there is considerable uncertainty in the numbers given because of inherent ambiguity in the definition of biomes—the table still provides an overview of the magnitude of carbon stocks in terrestrial systems.

figure one

Increasing the amount of carbon forest-lands can absorb or sequester can be done by:

- protecting existing forest biomass resources;
- reducing deforestation;
- increasing total forest area through afforestation or reforestation;
- improving silviculture and management so that existing forests are more efficient at carbon uptake and storage;
- storing more carbon in forest-derived wood products; or,
- restoring forests to a healthier condition.

Protecting existing biomass would be the most efficient way to protect the large amount of carbon contained in forests. This is not a simple proposition for reasons touched on below. It is difficult enough to address protection and deforestation; increasing forest-land area in the face of increasing human demands is an equally daunting task. Forest management techniques are an important and evolving component of carbon storage. Products or energy derived from forest biomass can hold some carbon in suspension, but this is not a long-term solution. However, there are more and more opportunities emerging to increase the significance of this strategy. Forest restoration involves ecologically guided activities that attempt to return a forest ecosystem to a more healthy state, which can improve carbon dioxide storage. Perhaps more important, forest restoration that reduces extreme fire events can check or forestall CO_2 release. Evolving forest restoration strategies in the western United States present opportunities to improve forest health, reduce extreme fire danger to ecosystems, life, and property, and contribute in some measure to carbon sequestration.

Protecting forests

Protecting forests and the carbon stock they contain is—at least at first appearance or in theory—the most logical way to keep forest carbon in long-term, slow-release storage. In a naturally functioning system, terrestrial and atmospheric carbon are kept in a rough fluctuating balance. Humans have affected this balance and continue to do so at an accelerating pace. Human demands on forest resources and forest land, unless some sustainable balance can be found (so far there is no evidence this is occurring), means a steady decline in carbon storage ability. This is particularly relevant in the face of population growth. In addition to human demands and consequences, natural occurrences destroy and degrade forests. For instance, a tremendous amount of carbon can be released during wildfires. Complete suppression of these fires could swing the balance back toward more equilibrium—but 100-percent suppression is of course impossible, and undesirable for forests that depend on fire for renewal. Even should this be achievable, at some point carbon would be re-apportioned to the overall balance, either a monumental human-guided effort or natural actions would accomplish the task.

The principal challenge is to maintain some balance between the forest carbon storage that accompanies fuel build-up and the probability of this store being destroyed by fire. However, any action takes place within the reality of high human demands on forests. Certainly forests and their carbon should be protected as possible within some range of natural variability. Careful consideration and planning in land-use can decrease or avoid vegetation and soil damage and CO_2 release, and protection can be furthered through thoughtful forest management.

Deforestation

Deforestation for agricultural, industrial, residential, or other purposes is the second leading human source of atmospheric CO_2 after fossil fuel use. Clearing is usually carried out by cutting and burning, emitting large quantities of carbon; clearing can also accelerate the decay of dead wood, litter, and below-ground organic carbon, hastening CO_2 release. Logging typically has less impact than agricultural clearing, as logged areas are often left to recover (Malhi, Baldocchi, and Jarvis 1999). Deforestation rates (and fuelwood use) are increasing globally (Ferguson, Sandberg, and Ottmar 1998); if this trend can be slowed, altered, or stopped in some way or in some areas, then the amount of carbon freed to the atmosphere is lessened.

Afforestation

Afforestation is defined by the Intergovernmental Panel on Climate Change[1] (IPCC 2001) as "...the establishment of forest on land that has been without forest for a period of time (e.g., 20–50 years or more) and was previously under a different land use." Since forests are efficient storehouses of carbon, converting lands under other use can usually increase carbon storage.

The establishment of commodity plantations that grow timber for lumber or other wood uses, or for foodstuffs, has been increasing world-wide and such plantations are believed to offset some of the effects of deforestation (IPCC 2001). Crops specifically developed for renewable bioenergy generation are being researched, as well as "carbon plantations" cultivated specifically for carbon storage ability. Urban areas can contribute through forestry activities that build "green infrastructure."

Reforestation

Reforestation is another strategy that can help in reestablishing a more stable carbon cycle. Replanting areas that have been harvested, deforested, or denuded, or are in some way unproductive, can establish new absorption and storage capacity. The restoration of damaged landscapes can "reinstate" or re-invigorate their ability to store and absorb carbon (IPCC 2001). The rehabilitation of fire-damaged sites, the restoration of wetlands or badly eroded landscapes, and the reestablishment of healthy native understory and habitats all contribute to better carbon balance. This value is in addition to benefits to biodiversity, soil protection, and other important ecological processes.

Included in reforestation activities are post-fire replanting, rehabilitation, or facilitation of natural regeneration. Comprehensive rehabilitation after a large and hot fire is essential, as once a destructive fire occurs carbon release continues and may accelerate. Since extreme fires can have such extensive consequences (including soil sterilization), soil carbon losses must be minimized and vegetation stabilized or reestablished to renew carbon uptake and storage. Quick action can help shield soil carbon from release by slowing or stopping erosion, and can help establish good vegetation conditions and facilitate new growth. The benefits of intervention do have to be weighed against the damage that can occur with increased human activity on fragile post-fire landscapes.

Forest management

Improved forest management can make a difference in carbon efficiencies and capacity. Activities that either limit disturbance of and damage to forest soils or vegetation, or improve soil or vegetation condition, create better carbon responses. Selective harvesting and purpose-designed low-impact machinery and light-on-the-land techniques are becoming more common, and the need for them greater. Limiting vehicle incursions into forested areas, for instance, will reduce soil damage and carbon release; fertilization can increase sequestration rates. Careful planning and execution of logging and other forestry activities can minimize releases and maintain or improve favorable ecosystem conditions. Lengthening stand rotations, controlling stand density, enhancing nutrient or water availability, careful salvage harvest, erosion control, and similar practices can improve forest health and storage ability.

Optimum forestry practices can shape forest structure, influence forest growth rates (and tree diameters and mass), determine stocking levels, and increase carbon up-take and storage efficiencies. Proper land management can limit insect and disease damage to stands and attendant loss of vigor, and limits erosion and soil losses. Comprehensive and sustainable forest management, becoming more common and sophisticated, can help address carbon imbalance and other ecosystem problems. As with any best-practices forest management, it is critical to manage for more than short-range objectives and to take into account non-market and external benefits and costs such as watershed and habitat protection, biodiversity, and carbon mitigation. Farsighted forest management, combined with restoration, can play a large part in improving future forests.

> *Large wildfires produce large quantities of carbon dioxide, burning of thinning debris produces much smaller amounts, and utilization produces the smallest amount. Carbon storage benefits can be maximized if utilization, where appropriate, is combined with forest ecosystem restoration.*

Forest wood products and bioenergy

One way to boost the amount of carbon stored or postpone its release is to increase the total mass of products made from wood. Forest restoration in the Western states—addressed below—typically entails removing debris and some downed material and cutting large numbers of the small trees on a site. When conducting restoration thinning a great deal of cut material is generated. In most cases this material is either burned on-site or left to decompose. However, these actions release carbon to the atmosphere—very quickly in the first case. Burning and decomposition can add nutrients to the soil, but burning carries its own set of risks and, while it is important to leave some decaying material for proper ecosystem function, excessive decomposing material can encourage insect outbreaks and has other negative consequences (Flanagan and Parks 2002).

The volume of wood from thinning projects can be quite high, but it currently costs more to remove than it is worth. If this material had higher value, its carbon content could be transferred to durable products with minimal loss to the atmosphere. “Utilization”—the commodity use of the smaller material and debris from thinning—can, in addition to other benefits, provide additional carbon storage.

Thinned material has a wide range of uses including lumber, logs, engineered composites, pulp and fiber, crafts, energy feedstocks, and more (e.g., Lynch and Mackes 2002). Products made from harvested wood can keep carbon in suspension for a considerable time in the form of housing structures, furniture, or other durable items. Ecologically sensitive harvesting can significantly decrease site damage and increase wood take, while newer and more efficient mills can use virtually the entire tree. Sawmill conversion efficiencies—the percent of a log that becomes lumber—can be over 70 percent (Eco-Link 2003) and sawdust and other wastes can be used for composite products and energy. Wood and wood residues in landfills will last almost indefinitely, and carbon can also be temporarily confined in paper and wood fiber products (Skog and Nicholson 2000). Forest slash from thinning can be reincorporated, via composting or gentle tillage, into site soils to help return carbon to the system (Sanchez, Carter, and Edwards 2001). This can be particularly effective on already disturbed soils (if used at the outset, no-till agriculture, for example, avoids much of the CO_2 release of soil disturbance). While there is some fossil fuel use associated with utilization harvesting and transportation, the net effect is positive.

Ecological restoration is an intentional activity that initiates or accelerates the recovery of an ecosystem with respect to its health, integrity, and sustainability. Frequently, the ecosystem that requires restoration has been degraded, damaged, transformed, or entirely destroyed as the direct or indirect result of human activities. In some cases, these impacts to ecosystems have been caused or aggravated by natural agencies such as wildfire, floods, storms, or volcanic eruption, to the point at which the ecosystem cannot recover its predisturbance state or its historic developmental trajectory. – Society for Ecological Restoration, Primer

* * *

Minimizing carbon release during forest restoration—

- *disturb sites as little as possible (particularly soil)*
- *minimize fossil fuel use*
- *minimize fire use, smoke generation, and decay*
- *maximize material conversion into durable products*

Energy generation, replacing some portion of fossil fuel use, is enjoying renewed interest with the potential for so much material from national forests. While not very efficient, and subject to location and supply constraints, bioenergy could absorb a large quantity of low-value material. Collected biomass can also be used to create industrial chemicals, liquid or gas fuels, and other products. The lure of bioproducts includes not only a renewable material source, but also the fact that conversion takes less energy than current conventional sources or processes (predominantly fossil-fueled). Essentially, “whatever products we can make from fossil fuels, we can make using biomass” (NREL

2003). And, essentially, anything that can be made from large trees can be made from small ones—the critical difference is the per-unit cost to harvest and process smaller trees (Duncan 1998; Horsfield 1982).

If thinned material is used in the manufacture of products or in energy creation, society derives direct benefits, jobs may be created or retained, and additional carbon can be temporarily held in place. While the situation is changing, utilization is currently not competitive except in particular cases because of the cost to harvest, haul, and process thinning material. There is certainly no shortage of material, and the more this wood is incorporated into durable products, the more carbon is stored. While there is debate about the effectiveness of storing carbon in wood products, there is no question that less CO_2 will be released as fossil fuel use is replaced by less carbon-intensive fuels or materials. A relatively recent calculation of the amount of carbon emission reduction for residential construction with wood indicates up to a 50 percent improvement over using steel and concrete (Goverse et al. 2001).

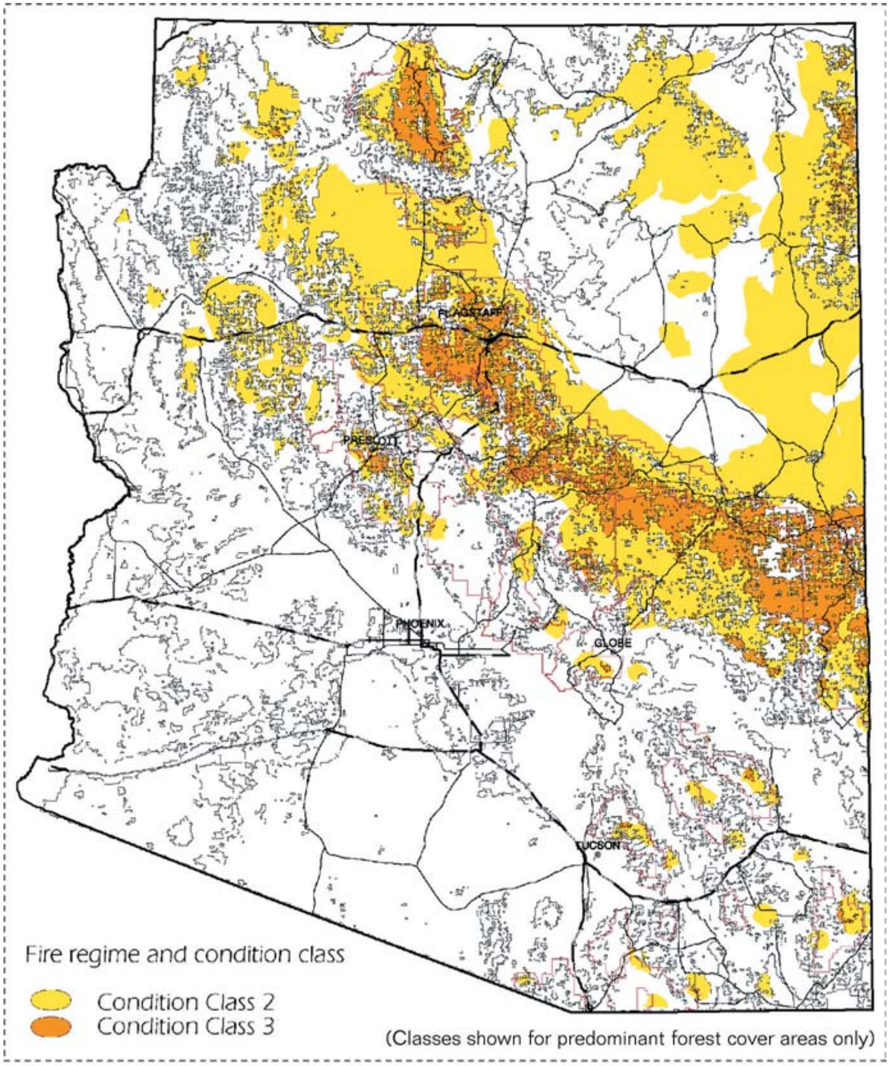


figure two

Forest restoration

There is wide consensus that many forests in the western United States are not healthy. This situation is largely the result of a century-long policy of fire exclusion and aggressive suppression (Arno and Allison-Bunnell 2003), and to a lesser degree, extensive livestock grazing (Belsky and Blumenthal 1997; Weaver 1964) and logging practices (Noss, LaRoe, and Scott 1997). Conditions have been aggravated in recent years by continued drought over much of the West. Forests, especially ponderosa pine forests, that once would have been thinned naturally by relatively frequent, low-intensity surface fires, are growing in much higher densities, with trees competing for limited resources. Not only are these forests overcrowded with small nutrient-starved trees, but the conditions are such that forests are much more prone to severe wildfire (Figure two, Arizona example; Condition Class 3 is high-risk areas and 2 medium-risk). Densely packed trees quickly carry fire up into the canopy and to the tops of larger trees, and the resulting crown fires spread quickly and destructively (Covington and Moore 1994; Mast et al. 1994).

As fire danger rises and as the number of small-diameter trees increases, forest health declines. This poor health is characterized by growth-suppressed trees less resistant to disease and insects, diminished understory growth, fewer species diversity, and other symptoms. And the more severe nature, on average, of today's fires means that forests suffer more complete burns, leading to tree mortality, reduced biodiversity, soil sterilization, erosion, and other consequences, including CO_2 release. In some cases recovery may take centuries, and a burned site's future capacity to sequester carbon may be severely diminished. Because future biomass production can be compromised, the negative consequences can in effect be doubled (Sampson, Smith, and Gann 2001). Large wildfires release large quantities of carbon dioxide into the atmosphere. Recent "extreme behavior" fires release enormous amounts of carbon very quickly. The 2002 Hayman and Missionary Ridge fires in Colorado "...released 5 million tons of CO_2 into the atmosphere," an amount "...equal to all the CO_2 released by cars and trucks in Colorado during the entire year" (The Forestry Source 2003). Even after a wildfire is extinguished, accelerated carbon emissions continue due to higher heat and moisture, elevated decomposition levels and soil erosion, and the probability of re-burns (IPCC 2001).

The most logical way to tackle the problems of forest health, large fires, and the accompanying release of carbon dioxide is through comprehensive forest restoration[2]. Restoration thinning, a process of ecologically guided thinning (often accompanied by low-intensity burning) to reach some desired landscape condition, specifically addresses degraded ecological conditions by focusing on altering forest function and not just structure[3] (Covington and Moore 1994). While prescriptions vary, restoration thinning typically involves removal (determined by ecosystem characteristics and treatment criteria) of many or even most of the overstock trees. Restoration emphasizes retaining and protecting old-growth trees while reserving sufficient younger trees to place forests back on a healthier and more natural trajectory. Increasing forest vitality through restoration should raise the capacity of forest biomass to absorb and store carbon. But the most effective way forest restoration can contribute to a better balance of atmospheric to terrestrial carbon is in a reduction in extreme wildfires.

Evaluating carbon levels

Understanding the potential effects of restoration activities on carbon balance is a very complex undertaking, particularly in determining, quantifying, and valuing levels for market credits. Discerning connections between the many variables, possible scenarios, geography, objectives, and changes in carbon balance, would involve baseline data, quantifying change in carbon volume in treatments, avoidance of release, and probabilities related to wildfire occurrence, extent, and severity. A first attempt at some of the points to explore or steps that might be undertaken would include knowledge of:

- **Pre-treatment carbon volume** (per some unit). There must be some sufficient period of time between initial treatment and current state, and we need some measure of vegetation and tree and woody biomass volume or diameter through this period.
- **Amount of carbon removed during treatment** in the form of woody biomass (either removed, burned, or other). Estimate of losses to soil and site disturbance.
- **Carbon expended through fossil fuel use during mechanized treatment** (plus estimates for hauling if material is removed).
- **Carbon-release rates from decay**, as applicable, for slash, crushed debris, other.
- **Amount of carbon consumed (in vegetation, or released from soil) through periodic low-intensity prescribed or natural surface burns.**
- **Increase in carbon in larger tree mass over time**; increased volume. Need percent carbon by species and volume carbon by diameter. Increase in understory vegetation mass.
- **Any increase in carbon storage ability of a healthier forest ecosystem** (including soils) over time. Redistribution of storage among vegetative types.
- **Some probability of intense wildfire and carbon loss in such an event** (vaporization, sterilization, consumed, erosion, etc.). Need some estimate of mortality, percent vegetation consumed, pattern, extent, severity, season, etc.

Depending on the situation and circumstances, some of these points may not be applicable, and there undoubtedly are—or will be—others to take into account.

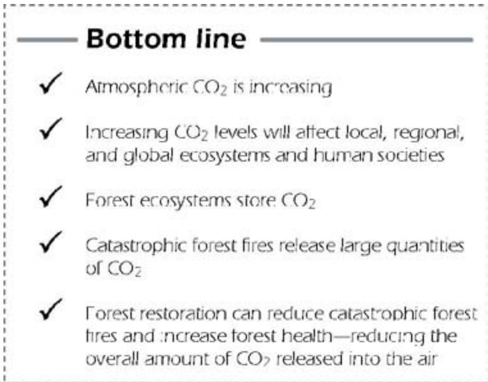
Discussion

Once a restoration thinning treatment is completed the chances of a catastrophic fire are reduced (Carey and Schumann 2003; Fiedler et al. 2002; Omi and Martinson 2002; Fulé et al. 2001). Tree damage and mortality will be much less as wildfire intensities drop, thus maintaining more of the carbon store, and doing so in larger trees, as forest health improves. The chances of, and severity, of insect and disease impacts are also lowered with forest restoration activities. In addition, soils, which hold the bulk of carbon (Figure one), will be much less affected. Careful restoration limits much of the damage, and subsequent carbon release, that can occur in soils (Minard 2003). Moreover, because the volume of wood and carbon in larger trees is so much greater than that in smaller-diameter ones, increases in tree size may have an effect on carbon retention[4]. Restoration is intended to place a forest ecosystem on a path to improved health, and healthier trees may better absorb and retain carbon.

> *Our assessment of historical and likely future changes in climate, atmospheric chemistry, and disturbance processes in the Inland West leads us to the conclusion that the risk of inaction seems far greater than that associated with taking reasoned remedial actions.*
> *– Covington et al. 1994*

While healthier forests are better able to store carbon, the *avoidance* of release is the best way that forest restoration can help reduce atmospheric carbon dioxide. Akin to slowing or halting deforestation, the avoidance of unnatural large and severe wildfires can sustain carbon storage capacity. If, as is intended, aggregate fuel loads begin changing and fire severity begins to drop, more CO_2 will be taken in and held in healthier forests.

With the extensive ponderosa pine forests in the West already stressed by overstocking, drought, and insect infestation, the strain on forest health and the additional fire danger is very high. Forest ecosystem restoration can create “open, vigorous forests [that] are more likely to be able to absorb these impacts without catastrophic readjustment” (Covington et al. 1994, 47). Based on the variety of reasons for and the benefits of pursuing forest restoration, including CO_2 storage, it is difficult not to conclude that restoration activities should be vigorously pursued across the West.



Bottom line

✓ Atmospheric CO_2 is increasing

✓ Increasing CO_2 levels will affect local, regional, and global ecosystems and human societies

✓ Forest ecosystems store CO_2

✓ Catastrophic forest fires release large quantities of CO_2

✓ Forest restoration can reduce catastrophic forest fires and increase forest health—reducing the overall amount of CO_2 released into the air

Endnotes

1. “The Intergovernmental Panel on Climate Change (IPCC) was established in 1988 by the World Meteorological Organization (WMO) and the United Nations Environment Program. It is charged with assessing the most up-to-date scientific, technical, and socio-economic research in climate change.” National Institute of Water & Atmospheric Research, New Zealand, www.niwa.co.nz/ncc/faq/ipcc.

2. Complete suppression of wildfires, maintaining forests intact and undamaged, would be a way to lock-up carbon. But full suppression is not possible. Since fires are getting larger and more severe and intense, this is not an option.

3. For more information on restoration concepts see www.ser.org/content/ecological_restoration_primer.asp; for more on southwestern forest restoration see Covington et al. 1997.

4. As volume is a function of the square of diameter, large trees have many times the mass of smaller stems. Despite the disparity in tree size numbers—many, many more smaller ones—the majority of the volume is in larger trees. In one study Vissage (2003) found, for the western United States, that smaller trees made up 86 percent of the number of trees and only 28 percent of the biomass, while trees larger than 10 inches diameter at breast height (dbh) were 14 percent of total trees and 72 percent of available biomass. And since timber is valued by volume, this is the principal hurdle to increased use of small-diameter material. For example, a 10-inch dbh log requires roughly the same amount of time to process as a 4-inch dbh log but yields about three times the amount of wood (Duncan 1998), so a much larger number of smaller diameter trees are needed to produce sufficient volume to make processing profitable (Horsfield 1982).

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