ERI—Issues in Forest Restoration

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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: A view of a restored section of ponderosa pine on the Apache-Sitgreaves National Forests in eastern Arizona. In this ERI white paper, the authors discuss how the Forest Service or other federal land management agencies might, in the near future, be able to receive monies from the sale of carbon credits for restoring forests like this one.

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Table of Contents

Abstract

Paying for large-scale ecological restoration of dry forests on federally managed lands throughout the western United States is urgently needed, but also quite expensive. Most experts agree that federal dollars will not be enough to do the job. While one of the obvious ways to help pay for restoration of overstocked forests is from timber sale proceeds, there may be another option—the sale of carbon credits in the newly emerging carbon marketplace. In this white paper, we discuss the basic issues involved in carbon trading, especially as it applies to forests and forest restoration in the American West. While the current carbon market situation is unlikely to provide much economic advantage, emerging federal cap-and-trade legislation and continuing interest in "green" economics may soon support a market-based scenario where healthy, restored forests are valued for their prodigious ecosystem services.

Keywords:

carbon markets, carbon trading, additionality, permanence, ponderosa pine

Introduction

Global climate change is the environmental issue of the twenty-first century. Its impacts are already being felt and more are expected to occur during the coming decades (Karl et al. 2009). However, international, national, corporate, and individual efforts are underway to soften the blow of climate change and eventually decrease its influence. These actions include changes in land use; developing better, carbon-neutral technologies; and conservation/recycling efforts. In forestry circles, people now recognize the ability of forests and forest products to sequester carbon. They are also implementing ways that use woody biomass to generate energy that would otherwise have been produced by petroleum-based fuels. In this white paper, we discuss how restoring ponderosa pine forests, especially on public lands, can provide a way to positively sequester carbon and aid in dampening the expected effects of climate change. In addition, we examine how the various carbon market structures and/or federal cap-and-trade legislation may provide a way to pay for restoration treatments through the sale of carbon credits.

The changing global climate is projected to increase by about 0.4°F (0.2°C) per decade for the next two decades with longer-term projections suggesting a 3.3°F (1.8°C) to 7.2°F (4°C) temperature rise by the year 2100 (Solomon et al. 2007)—a rapid and profound change that requires our immediate attention in order to maintain essential ecosystem and social services for future generations. Some significant changes are already underway, especially in the polar regions where scientists and local residents have observed ice sheets and glaciers melting at an alarming rate due to increasing temperatures.

The causes of climate change—the intensified emissions of greenhouse gases (GHG) due to a century or more of increased burning of carbon-based fuels (petroleum, coal), logging of forests, and other disruptive land uses—are well documented (Karl et al. 2009, IPCC 2007). Expected environmental responses from global climate change include: increased sea levels, more regional hot spots, loss of ecosystem services, longer droughts, more severe storms—all of which are likely to cause changes to and/or stress existing ecosystems as well as human-made infrastructure and social systems. Scientists who study forested ecosystems predict that these systems will experience an increase in diseases and insect-caused defoliation, and they expect that some tree species may migrate northward or upward in elevation as temperatures increase (Rehfeldt et al. 2006). In addition, work by van Mantgem and Stephens (2007) and van Mantgem et al. (2009) suggests that frequent-fire, old-growth stands may suffer increased mortality due to droughty conditions caused by increasing temperatures. Reports like these suggest that the ecosystem services provided by forested landscapes (e.g., carbon storage, clean air, fresh water supply, wildlife habitat, recreational opportunities) may be seriously compromised unless actions are taken to avoid significant losses of these vital services.

Given a growing global economy, stabilizing GHG and neutralizing the effects of warmer temperatures will demand major public and private efforts in terms of improving energy efficiency, finding non- or low-emitting GHG sources of energy, and making changes to business-political sectors. Formative steps are now being taken to address these and other needed changes. One area of interest to researchers, policymakers, business managers, environmentalists, and others is finding ways to store carbon as a means of mitigating current and future GHG emissions and, hopefully, to provide a “bridge” between the current situation and a more carbon-neutral, lower GHG future.

Since vegetation and soils are primary means of sequestering carbon in terrestrial ecosystems, forested ecosystems have a major role to play in addressing the climate change problem. For example, the deciduous forest of the northeastern United States, following extensive cutting and agricultural use during the eighteenth and nineteenth centuries, has re-established itself and become a significant carbon sink (Birdsey 1996, Foster and Aber 2004). Unfortunately, storing carbon in fire-prone, overstocked ponderosa pine forests, as they presently exist on public lands throughout much of the western United States, is a short-term solution that will eventually be lost in large wildfires resulting in significant carbon losses to the atmosphere and a long-term loss in terrestrial carbon storage (Western Forestry Leadership Coalition 2009, Dore et al. 2008, Hurteau et al. 2008, Selmants et al. 2008).

Carbon, the Carbon Cycle and Climate Change: The Basics

Carbon is one of the most plentiful chemical elements in the universe. It is found in all known life forms, and occurs in myriad chemical combinations (nearly ten million organic compounds have been described to date). Greenhouse gases, for example, include numerous carbon compounds—carbon monoxide (CO), carbon dioxide (CO_2), methane (CH_4), chlorofluorocarbons (CFC), hydrochlorofluorocarbons (HCFC), hydrofluorocarbons (HFC), and perchlorofluorcarbons (PFC). The presence of carbon in organic deposits of peat, coal, and petroleum has helped fuel cultures for millennia. In fact, the word, carbon, comes from the Latin, carbo, which means coal or charcoal.

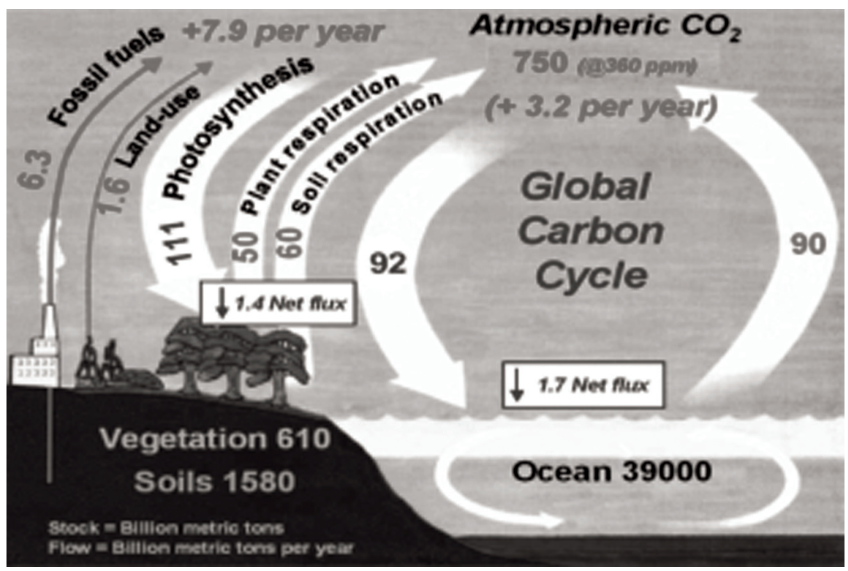


Figure 1. Global Carbon Cycle

Carbon flows through the atmosphere, terrestrial biosphere, oceans, and lithosphere in what is called the carbon cycle (Figure 1). Like other biogeochemical cycles, the carbon cycle is composed of various processes (in this case, photosynthesis, respiration, decomposition, and air-sea exchange) and various reservoirs that accumulate, store, and release carbon. The global carbon budget is the balance of inputs and outputs between the carbon reservoirs or between one specific segment (e.g., ocean and the atmosphere) of the carbon cycle. Scientists can measure whether a reservoir is a source (a place that emits carbon to the atmosphere) or a sink (a place that removes carbon from the atmosphere) for carbon. The carbon sink of forested ecosystems includes organic carbon in the soil and living and dead vegetation. Wood products also serve as an important carbon sink. Transfers of carbon to the atmosphere occur when forests burn (rapid transfer) or as leaves, trees, and other detritus decay (slow transfer).

Methods for Sequestering Carbon

Sequestering carbon from the atmosphere is vital to slowing or reversing global climate change. There are four basic methods for sequestering carbon: 1) storage in geologic formations, 2) injection into oceans, 3) mineralization, and 4) storage in terrestrial ecosystems.

Sequestration in geologic formation requires injecting CO_2 and other greenhouse gases into oil- and gas-bearing formations, saline formations, basalts, deep coal seams, and oil- or gas-rich shales. The injected gases replace water in the porous spaces of the formation. After considerable research, geologic sequestration is now viewed as having significant potential as a means of sequestering carbon (U.S. Department of Energy 2009). Ocean sequestration, meanwhile, involves capturing and separating CO_2 from the flue gas of fossil fuel-burning power plants and then converting the gas into a liquid state so that it can transported by a submerged pipeline for injection into the deep ocean. Oceans offer enormous potential as carbon storage sinks, but the current level of scientific understanding to support ocean sequestration as a major CO_2 storage option remains uncertain. Mineralizing CO_2 entails combining CO_2 with another element (e.g., sodium, calcium) to produce solid compounds (e.g., cyclic carbonates, calcium carbonate, sodium bicarbonate). This process produces products with many practical applications and will very likely prove a useful means of reducing and recycling CO_2.

Terrestrial ecosystems naturally sequester carbon in vegetation and soils (Heath et al. 2003) because vegetation absorbs CO_2 during photosynthesis. The total amount of carbon stored in soils and vegetation throughout the world is estimated to be roughly 2,000 billion tons (U.S. Department of Energy 2003). However, terrestrial carbon sequestration can be enhanced in a variety of ways, including 1) creating more carbon-neutral land-use patterns; 2) reducing the decomposition of organic matter; 3) increasing the photosynthetic carbon fixation of trees and other vegetation; 4) substituting wood for fossil fuel-intensive products (e.g., steel, concrete, brick, vinyl); 5) creating energy by using biomass instead of fossil fuels; 6) thinning forests to shift wildfire behavior from catastrophic to low-severity; and 7) storing carbon in long-lived wood products such as lumber, oriented strand board, and plywood.

Policymakers in the United States have looked at terrestrial ecosystems as an obvious means of sequestering carbon because of the vast agricultural and forest resources in the country. Industry, especially the energy-producing sector, has undertaken numerous tree-planting projects in order to mitigate emissions from power plants and factories. Little has been done, however, to assign values to existing or restored forest systems, especially in developed countries. Moreover, there are drawbacks to terrestrial sequestration because it can be difficult to estimate GHG removals and emissions resulting from these activities. In addition, GHG may be unintentionally released into the atmosphere if a forested sink is damaged or destroyed due to a fire or plant disease outbreak (Galik and Jackson 2009).

Markets and Registries for Buying and Selling Carbon Credits

After decades of top-down regulation, governments now rely on free-market incentive systems to solve environmental problems caused by identifiable polluters and/or industries. Today, governments at all scales (international, national, regional, state) seek to regulate GHG emissions and sequester carbon through market transactions, using market structures and financial instruments that are adapted from those developed by well-known stock market exchanges and commodity markets.

At this time, carbon markets in the United States are voluntary, although there are regional registries--the Regional Greenhouse Gas Initiative in the Northeast and Middle Atlantic States, and eventually the Western Climate Initiative (Arizona, California, New Mexico, Oregon, Utah, Washington, British Columbia, Manitoba, Ontario, and Quebec)—that employ a mandatory, market-based system for their member states. Existing voluntary markets are further divided into two main segments: 1) the voluntary, but legally binding, cap-and-trade system (the Chicago Climate Exchange or CCX), and 2) the non-binding, over-the-counter (OTC) offset market. These voluntary markets offer the greatest potential for innovation because they are not constrained by the vagaries of international agreements or the regulatory nature of regional mandatory registries. They also enable more entities to voluntarily participate in a carbon market and gain experience in such transactions. The State of the Voluntary Carbon Market report (2009) pegs the international voluntary carbon market's 2008 value at US$705 million, more than double the 2007 value. While the CCX generated more tons of carbon credits than the OTC markets (69 million tons vs. 54 million tons), the OTC traded more carbon credits in terms of dollar value because the OTC markets have a better reputation for quality carbon sequestration projects and, thus, demand a higher price for the credits they sell. The SVCM report also confirms that the United States is both the largest provider and buyer of voluntary offsets in the world.

Market transactions aimed at reducing GHG emissions can be classified as either allowance-based or project-based (Capoor and Amborsi 2007). Both types of transactions are measured and traded in standard units representing a quantity of CO_2 equivalent (metric tons of CO_2 equivalent = MTCO2). **Allowance-based carbon transactions** (or emission allowances) are created by a regulatory or other cap-and-trade body and are initially allocated or auctioned to the user. Emission allowance transactions are based on the buyer's direct emissions. Entities that emit pollutants, such as power plants and factories, are typical buyers of carbon credits in allowance-based carbon transactions. **Project-based carbon transactions** (or emission reduction credits) are created for projects that can credibly demonstrate reduction in GHG emissions compared to what would have happened without the project. The results of such project must be verified using methodologies/rules approved by the organization issuing the transactions. Forestry offset projects, conservation tillage, and alternative energy projects are types of activities that can provide emission reduction credits. The amount of verified MTCO2 from a project is then purchased by a market and then purchased by a carbon-positive party (e.g., a polluting industry, a person who flys frequently and wants to lower their personal carbon footprint) to mitigate or offset carbon emissions.

The Chicago Climate Exchange

The CCX is "the world's first and North America's only voluntary, legally-binding, rules-based greenhouse gas emission reduction and trading system" (Chicago Climate Exchange 2008). The CCX trades six different types of GHGs converted into one common unit of CO_2e (or carbon dioxide equivalent). The CCX's unit of trade is the Carbon Financial Instrument (CFI), which represents 100 tCO_2e (or the impact of 100 tonnes of carbon dioxide equivalent). The CCX CFIs can be either *allowance-based credits* (an allowance-based carbon transaction) issued by emitting members in accordance with their emission baselines and the exchange's reduction goals, or offset credits (project-based carbon transaction) generated from qualifying emissions reduction projects, such as

forest offset projects. However, *offset-based credits* can only be used to mitigate 4.5% of members' total emissions, so the majority of credits traded on the CCX are allowance-based (Hamilton et al 2008, pp. 17-18).
In other words, if an industry with 300,000 CFIs is looking to mitigate its pollution, only 13,500 CFIs from a forest offset project could be sold to provide the offset, the remainder would have to found elsewhere or be part of an emission-reduction effort by the polluting industry.

Hamilton and her colleagues (2008, p. 9) note that the CCX forestry offset program:

- Includes afforestation, reforestation, and forest enrichment projects initiated on or after January 1, 1990 on unforested or degraded forest land;
- Makes forest conservation projects eligible to earn CFI offsets if they are done in conjunction with forestation on a contiguous site;
- Requires demonstration that entity-wide forest holdings are sustainably managed;
- Requires demonstration of long-term commitment to maintain carbon stocks in forestry;
- Requires use of approved methods to quantify carbon stocks; and
- Requires independent third-party verification of carbon stocks (where required).

There are three levels of CCX membership: 1) full members or the buyers of emission mitigation credits; 2) associate members who work on their own to offset emissions; and 3) participant members are basically those who sell, aggregate, and/or develop projects that reduce GHG emissions. If the U.S. Forest Service or other government agencies became involved in this market exchange, it would likely be as a participant member—possibly a project developer, offset provider, or offset aggregator. The agency might also decide not to be a member but to sell its projects that sequester carbon to a CCX offset aggregator.

As mentioned earlier, prices for carbon sold through the CCX are generally lower than those sold on the OTC, and standards for projects are considered lower.

Over-the-Counter Market (OTC)

In addition to the CCX, the OTC market offers a range of voluntary transactions that are not linked to any GHG emissions cap or to any formalized exchange. Typically these transactions are for project-based carbon offsets. This market operates in a more laissez-faire manner than the regulated markets. Buyers in this carbon market may have an interest in "green" philanthropy and/or public relations, they may need to prepare for anticipated regulation, or they may simply want to buy carbon credit in order to resell them for a profit. Meanwhile, sellers might include conservation organizations seeking to advance their cause through the sale of carbon credits, developers of potential projects in developing countries (Clean Development Mechanism or CDM, Joint Implementation or JI), other project developers, and aggregators. Transaction in the voluntary offsets market can be as simple as a final buyer purchasing credits from a project developer or as complex as a project developer selling credits to an aggregator who then sells them to a retailer who, in turn, sells them to the final buyer.

The OTC market does, however, have third-party standards that define the rules of its transactions and the quality of the carbon projects. The 2009 State of Voluntary Carbon Market report (Hamilton et al. 2009) identifies four of these standards as the mainstays of the market: 1) the Voluntary Carbon Standard, 2) the

Gold Standard, 3) the Climate Action Reserve, and 4) the American Carbon Registry. Each of these programs provides measures to ensure credibility and sustainability in terms of voluntary carbon reduction and sustainable development projects, especially through the use of third-party verification of project quality.

Carbon Registries

In addition to carbon markets, there are a number of voluntary, non-market-based carbon registries. These are either government run (i.e., California Climate Action Registry, Georgia Carbon Sequestration Registry, Department of Energy 1605(b) Guidelines) or a non-profit organization effort (i.e., The Climate Registry, American Carbon Registry, The Climate Trust). Some of these registries simply provide the means and standards by which landowners can record the amount of carbon sequestered in a particular project. Others help landowners navigate the voluntary carbon markets, but they are not traders or brokers themselves.

Transaction Costs

As in any financial situation, there are costs for doing business. In carbon trading, these transaction costs are the financial liabilities imposed by a carbon market on a carbon credit seller or carbon buyer, or on both parties. These fees may cover such items as market maintenance costs, broker fees, and costs for baseline measurement, monitoring, and verification. Many of these costs depend on the scale of the exchange with the cost of the transaction declining as more transactions take place (USEPA 2005, pp. 6-12). Since the various carbon markets within the United States have differing standards for eligibility, this leads to additional transaction costs, and may limit participation and investment in carbon offset projects (Ruddell et al. 2006, 2007).

Forest Carbon Credits Accounting Problems

In any type of terrestrial carbon sequestration project there are problems accounting for the actual carbon sequestered and/or the side effects of a given project. Researchers have terms for each of these situations: 1) additionality, 2) leakage, 3) permanence, 4) saturation, and 5) equivalence. Each carbon market and registry has a slightly different take on these terms (see Call and Hayes 2007, Sampson 2005 or http://www.carbonfarmers.com/toolbox/primer/7.html)--differences that are important when considering the advantages and disadvantages of a particular market or registry.

Additionality

The term additionality refers to the net additional carbon sequestered by a carbon project. To realize this number, a carbon baseline must be established in order to measure the net change in carbon stocks once a project is underway or completed. The reduction in carbon emissions must be greater than what would have occurred without the project or in a "business-as-usual" scenario. Carbon credit registries in the United States employ a base-year metric (an actual measurement of carbon emissions from the project site in the year prior to the treatment or the average of several years prior to treatment). In terms of forest-related carbon projects, typical forest biometrics (i.e., direct and modeled measurements) can be used to quantify baselines. Verification is required by some registries.

Leakage

Leakage refers to a situation where a carbon sequestration activity, such as reforestation, on one piece of land unintentionally causes an activity elsewhere (e.g., tree cutting) that, in whole or in part, counteracts the effects of initial project's effort to sequester carbon. Leakage often occurs when a carbon sequestration project dramatically reduces the supply of a good or resource that remains in demand, thereby causing scarcity and shifting similar resource extraction activities elsewhere. Discounting or lowering the number of carbon offset credits for a project can help account for leakage in situations where it is likely or expected to occur. All carbon registries in the United States require reports of leakage within project boundaries (i.e., internal leakage).

Permanence

The term "permanence" suggests the possibility that sequestered carbon will be released into the atmosphere at some point in the future. This is a particular problem for sequestration projects in terrestrial ecosystems because they can be destroyed by wildfire, disease, or human development. Moreover, some ecosystems, such as overstocked, frequent-fire forests, are more susceptible to disturbances that result in dramatic losses of carbon. Carbon registries in the United States use various tools to insure permanence, especially deed restrictions, conservation easements and other legal instruments on private lands, and reserve pools of credit for both public and private lands.

Saturation

Terrestrial carbon sinks can only sequester a finite amount of carbon. When a sink has reached a point where carbon inputs equal carbon outputs it is in a carbon-saturated state. While saturation levels and CO2 uptake depend on species, site quality, temperature, management practices and water availability, new plantings or early vegetative stages tend to be carbon positive in terms of inputs compared to outputs. For example, ponderosa pine trees reach their maximum level of carbon input (3 tons/acre/year) at roughly 70 years (Richards et al. 1993). Research by Birdsey (1996) suggests that afforestation and reforestation projects typically require 90-120 years before they reach saturation. This is not to suggest, however, that old-growth forests are carbon sources; they remain sinks for many decades, if not, centuries (Luysssaert et al. 2008, Schlesinger 2007).

Equivalence

In voluntary markets, those selling forest carbon-offset credits must assure buyers that their credits are equal to clean technology projects (e.g., solar and wind power, biomass and biofuels, hydropower) in terms of climate mitigation. This is a problem for forest carbon offset projects because while clean technology emissions can be accurately measured, forest carbon offset projects are more difficult to measure with a similar level of accuracy. Malmsheimer and his colleagues (2008, p. 162) suggest 1) discounting only the growth portion of forest credits to provide conservative estimates for carbon dioxide and, thereby, strengthen the additionality and permanence of the project or 2) employing insurance instruments or reserve pools to even the playing field between the clean technology projects and forest carbon offset projects.

Forest Management Options and Carbon Sequestration

In the United States, about 33 percent of the land base is forested (303 million ha/749 million acres) (Smith et al. 2004), and those lands sequester about 200 million metric tons of carbon each year (Heath and Smith 2004). While these numbers are impressive, more sequestered carbon is needed to offset 1,600 million metric tons of CO2 emitted every year in the United States (Schlesinger 2007). There are several ways to increase the amount of carbon sequestered in forested landscapes: 1) afforestation, 2) reforestation, and 3) forest land management, including ecological restoration.

Afforestation

Afforestation is an activity that converts previously unforested land into forested acreage. The Intergovernmental Panel on Climate Change defines afforestation as *"direct human conversion of land that has not been forested for a period of at least 50 years to forested land through planting, seeding, and/or the human-induced promotion of natural seed sources"* (IPPC 2007). While afforestation has tremendous potential to sequester carbon and revegetate degraded lands, global afforestation projects represented only 1% of the traded volumes in 2006 (Capoor and Ambosi 2007).

Afforestation projects tend to experience significant leakage, although this varies according to regional market conditions. On the other hand, establishing a baseline and monitoring results is typically straightforward. Additionality can be a problem, however, and the risk of the land use reverting to some non-forested activity is relatively high unless restrictions are in place (USEPA 2005). Furthermore, afforestation projects often include fast-growing, non-native species that, while good at sequestering carbon, can introduce totally new species into an area and possibly damage existing ecosystems.

Reforestation

Reforestation is the return of a formerly forested site to a forested condition. The IPCC defines reforestation as *"direct human-induced conversion of non-forested land to forested land through planting, seeding, and/or the human-induced promotion of natural seed sources on land that was previously forested but converted to non-forested land. For the first commitment period of the Kyoto Protocol, reforestation activities will be limited to reforestation occurring on those lands that did not contain forest on 31 December 1989"* (IPCC 2007). Like afforestation projects, reforestation is an excellent way to sequester carbon, and it has the same advantages and disadvantages in terms of additionality, leakage, creating a baseline, and monitoring results.

Forest Management Practices

While the Kyoto Protocol remains the global regulatory mechanism for addressing the related issues of controlling/limiting GHGs and thwarting the effects of global climate change, according to Ruddell and colleagues, it "authorizes only afforestation and reforestation activities, excluding soil carbon storage, sustainable forest management, and avoided deforestation. It appears that forestry emission reduction projects will continue to be restricted from participating in offsetting GHG emissions associated with Kyoto Protocol compliance targets through 2012" (Ruddell et al. 2006, p. 5). Thus, forest restoration or fuel reduction projects, which would fall under the definition of avoided deforestation, would not be considered under any of the current Kyoto guidelines for trading carbon credits.

There are, however, several definitions that are used to describe forest management within the realm of climate change. The IPCC broadly defines forest management as: *"the application of biological, physical, quantitative, managerial, social, and policy principles to the regeneration, tending, utilization, and conversion of forests to meet specified goals and objectives while maintaining forest productivity. Management intensity spans the range from wilderness set-asides to short-rotation woody cropping systems. Forest management encompasses the full cycle of regeneration, tending, protection, harvest, utilization and access"* (IPCC Special Report on LULUCF 2003).

In a report to the IPCC, Brown and her colleagues (1996) were more specific, defining forest management practices as: *"(i) Management for carbon conservation; (ii) management for carbon sequestration and storage; and (iii) management for carbon substitution. Conservation practices include options such as controlling deforestation, protecting forests in reserves, changing harvesting regimes, and controlling other anthropogenic disturbances, such as fire and pest outbreaks. Sequestration and storage practices include expanding forest ecosystems by increasing the area and/or biomass and soil carbon density of natural and plantation forests, and increasing storage in durable wood products. Substitution practices aim at increasing the transfer of forest biomass carbon into products rather than using fossil fuel-based energy and products, cement-based products, and other non-wood building materials."*

Ecological Restoration

While the IPCC aims much of their work at forestry issues in developing countries, both of the definitions above have enough latitude to describe forestry practices in the United States, including the ecological restoration of forests.

Ecological restoration of the dry, frequent-fire forests in the Intermountain West entails moving these systems into their historic or natural range of variation in terms of trees per acre, basal area, tree size class composition, and spatial pattern. Mechanical thinning followed by the reintroduction of frequent, surface fires is the typical means of restoration. This results in cuttings of mainly small-diameter trees that can be used to make various wood products and for biomass—products that can be substituted for products made from fossil fuel. It also reduces the catastrophic fire potential within these forests and in that sense can be thought of as avoided deforestation. Finally, these projects do sequester carbon within the forested ecosystem.

While forest-oriented ecological restoration projects face all the accounting problems presented earlier, they are especially good at addressing issues of permanence because they tend to stabilize the ecosystem and reduce carbon loss due to wildfire and insect damage (Hurteau et al. 2009); this is especially true for projects on federal or state lands where land use changes are relatively stable. Moreover, when such projects are done on public lands, they effectively address the accounting issues of leakage because small-diameter trees are being actively removed thus creating local markets for wood and biomass, and not creating logging outside the project area and/or region. However, developing carbon baselines for restoration projects can be time consuming and expensive. In addition, the changes in fire risk following restoration treatments need to be quantified, typically through the use of established research or knowledge of how similar silvilcultural treatments reduce fire risk in comparable forest types (Spalding et al. in review) and/or through modeling. Despite their transaction costs, such efforts are clearly needed to ascertain whether projects have actually sequestered carbon as promised and, therefore, are eligible to receive carbon credits

Establishing a Baseline for Ecological Restoration Treatments

The IPCC (2007) defines a baseline as: *"The reference for measurable quantities from which an alternative outcome can be measured."* In other words, the carbon baseline represents the point from which the net change in carbon is measured. In relation to additionality, a project must sequester more carbon than the baseline, or it is not additional.

For forestry projects of all types, standard forestry biometric methods, including direct and statistically designed and modeled measurement techniques, can be used. For an ecologically based forest restoration project this might include an evaluation of the following features of the project site:

- aboveground biomass (i.e., all the living biomass above the soil including stems, stumps, branches, bark, seeds, foliage, and live understory)
- belowground biomass (all coarse living roots greater than 2 mm diameter
- all dead wood lying on the ground
- all litter on the ground
- soil organic carbon, including all organic material in the soil to a depth of 1 meter, excluding the coarse roots (IPCC 2003).

These measurements would be followed by determining the project site's potential future carbon stores using growth and yield models along with data about the amount of potentially harvestable material. Two software programs that may be useful when establishing a baseline are CVal and the Forest Carbon Calculation Tool 2007. CVal is a non-proprietary carbon valuation tool that can be used to easily evaluate the net present value (NPV) of a potential managed forest carbon contract. It was designed for use with CCX Exchange Forestry Offset (XFO) contracts, but can easily be calibrated for use with other protocols. The Forest Carbon Calculation Tool 2007 is a software program that provides information about carbon stocks on forest land at a statewide level using FIA data (Smith et al. 2007).

Information about GHG emissions due to implementing treatments (e.g., tree removal, trucking, prescribed burning, brush pile burning) along with data about carbon sequestered in long-lived wood products are also required.

Quantifying GHG Emissions from Ecological Restoration Treatments

Restoring the overstocked dry forests of the Intermountain West generally involves mechanical thinning followed by prescribed burning in order to create a tree density that will a) allow the remaining trees to grow larger due to reduced competition for limited resources, and b) decrease significantly the potential of catastrophic crown fire and/or expansive insect infestations. While these activities relatively quickly produce a forest that is a carbon sink, they produce a number of GHG emissions that must be taken into account when assessing the overall GHG budget.

Unfortunately, at this point, studies of this type of restoration scenario and its effects on carbon stocks are limited. There are, however, at least two studies—Finkral and Evans (2008) and Spalding and her colleagues (Spalding et al. in review)—that provide some direction on this topic. The Finkral and Evans study, which was conducted on a 90-ha site in Northern Arizona University's Centennial Forest near Flagstaff, involved the mechanical and handing thinning of small-diameter ponderosa pine from 579 trees/ha to 163 trees/ha. Existing Gambel oaks were not thinned. Measurements indicated that 42,500 kg C/ha in aboveground biomass existed before treatment, with 30,200 kg C/ha left after treatment. Finkral and Evans found that 12,504 kg C/ha was released from the thinning operation, including 4,140 kg C/ha from slash burning and 8,240 kg C/ha from burning of logs that were distributed to homeowners. Using the thinnings as firewood produced a net carbon release of 3,114 kg C/ha. They concluded that if the thinnings had been used for pallets and construction material, the thinning operation would have actually stored 3,351 kg C/ha. Finkral and Evans also noted that the thinning "reduced the risk of stand-replacing wildfire on the site and the consequential release of carbon by 2,410 kg C/ha" (p. 2747). The study by Spalding and her colleagues is discussed in detail later, but they were also able to determine the GHG emissions from restoration treatments.

Quantifying GHG Emissions from Wildfires, Prescribed Burns, and Wildland Fire Use Fires

In the United States, the annual average amount of CO_2 emitted from fires—wildfires, prescribed burns, Wildland Fire Use fires, and biomass burning—is about 5 percent of all the CO_2 released due to human causes (Wiedenmyer and Neff 2007). While this is a relatively small amount when measured at the continental scale, in regions where large fires have become an annual occurrence, like the western United States, annual wildfire-caused emissions of CO_2 can, at the statewide-scale, exceed CO_2 emissions due to the use of fossil fuel (Wiedenmyer and Neff 2007). Moreover, as research by Dore et al. (2008) indicates, carbon losses following a stand-replacing wildfire in a ponderosa pine forest tend to persist for decades, turning what was once a carbon sink into a long-term carbon source.

No carbon registry or carbon exchange requires quantifying GHG emissions from any type of fire, although the new draft of the Forest Sector Protocol from the California Climate Action Registry, includes wildfire as one of its risk types. Nevertheless, in order to obtain a full accounting of GHG emissions, some measure of carbon loss due to fires of all types is preferable. The problem is that there are few reliable metrics to do the job.

Two of the better methods for measuring GHG emissions from fires are discussed by Wiedinmyer and her colleagues (2006) and Campbell and his colleagues (2007). The paper by Wiedinmyer's group discusses the use of various satellite modules, including the MODIS Thermal Anomalies Product, the Global Land Cover Characteristics 2000 dataset and the MODIS Vegetation Continuous Fields Product, in conjunction with data from other scientific literature, to determine fire location and timing, fuel loadings, and emission factors. Meanwhile, the group led by Campbell used a ground-based approach that measured the effects of the Biscuit Fire on every level of biomass. To do so, they used a back-calculation method where combustion factors were calculated solely from post-burn measurements of charring and perceived loss of foliage and branches, and a before-and-after method where combustion factors were calculated as the difference between pre-burn and post-burn mass.

Another potential method for quantifying GHG emissions is CONSUME 3.0, a free software program that can import data directly from the Fuel Characteristic Classification System (FCCS). While this tool is typically used to feed other models and provide usable outputs for burn plan preparation and smoke management requirements, there is a function that will assess carbon emissions.

Quantifying Carbon Sequestered in Long-lived Wood Products

Harvesting timber and processing it into wood products transfers already sequestered carbon from a tree into another identifiable carbon-storage entity (e.g., paper, a desktop, a 2 x 4, firewood). Once in this new state, carbon is emitted at varying rates depending on the type of timber, the type of product created, the use of the product, and various environment conditions. For example, if timber is harvested to produce energy, carbon is released immediately upon combustion as in the study by Finkral and Evans (although the use of woody biomass for energy does help offset the production of fossil fuel-derived energy, and emits fewer GHG than fossil fuels). Conversely, if timber becomes lumber for a house, it may be many decades or even centuries before the lumber decays and the carbon is released to the atmosphere. And, carbon may be stored even longer or indefinitely when wood products are disposed in a landfill. Current estimates suggest that the annual sequestration of carbon by forest products ranges from 26 to 139 million tons, which is enough to offset all or most of the annual GHG emissions due to forest products manufacturing (Miner 2003).

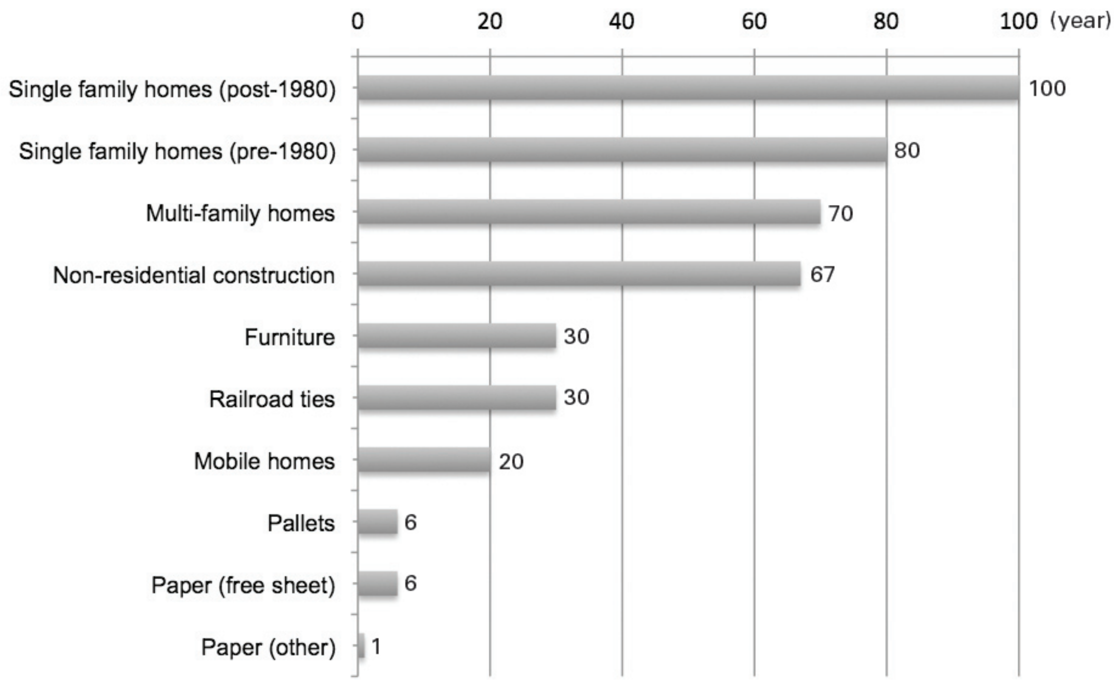


Figure 2. Examples of half-lives of wood products in end-uses. Source: Skog and Nicholson 2000, p. 82.

There are three types of methods for estimating changes in carbon stocks from wood products at the national scale: 1) inflow-outflow methods, 2) stock data methods, and 3) emission accounting methods. Inflow-outflow methods (see Gjesdal et al. 1998, Winjum et al. 1998, Ford-Robertson 2003) estimate the changes in wood product carbon by obtaining information about the inflow of wood products created and then calculating the assumed lifetimes and decay factors of these products. Stock-data methods (see Gjesdal et al. 1996, Alexander 1997, Flugsrud et al. 2001, Pingoud et al. 2001) estimate the changes in carbon stocks of wood products by calculating the difference between the total stock at the beginning and at the end of a given period. This method is often limited to long-lived wood products such as those used for building houses. Emission accounting methods measure the decomposition and/or combustion of wood products in situations such as bioenergy, waste incineration, landfill gas, fires in buildings, and natural decay of wood-based materials in buildings. Typically this method underestimates emissions because it fails to include some emission sources (United Nations Framework Convention on Climate Change 2003, http://unfccc.int/resource/docs/tp/tp0307.pdf).

Miner (2003, 2006) presents a method to account for carbon sequestration in forest wood products that is better suited to the corporate or land management agency sector. This method involves four basic steps and seeks to determine the amount of carbon in the current year's production that is expected to remain in use when measured against a 100-year time period. The four steps are:

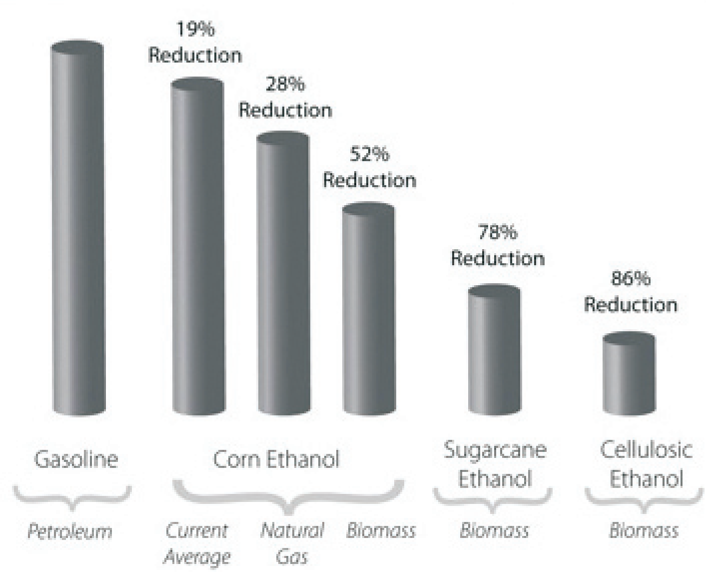
1. Identify the types of products-in-use that are made from current production
2. Determine the carbon contained in those products
3. For each product-in-use, obtain a decay curve or other information that describes or quantifies the amounts of carbon expected to be in use in the future
4. Use the decay curves to estimate the amount of carbon remaining in use for at least 100 years.

Completing these four steps will produce an amount that represents the carbon sequestered in the wood products examined.

Quantifying the Potential for Woody Biomass Utilization

Using woody (cellulosic) biomass to generate heat or energy is an attractive end-use for many reasons (Richter et al. 2009, Figure 3 below). First, burning woody biomass tends to produce lower GHG than fossil fuels such as coal, oil, and natural gas, and at costs comparable to the cheapest of these fuels—coal—and with similar levels of energy efficiency (Roj 2005, Energy Information Administration 2008). Second, its use supports domestic economic development, especially in rural areas that were once dependent largely on lumbering. Third, it helps decrease the nation's dependence on imported sources of energy. Fourth, thinning helps decrease the potential for catastrophic wildfires near populated areas as well as in wilderness areas. Fifth, adding biomass sales to existing high-value timber sales may be one of the best ways for timber concerns to survive and grow new markets. Nicholls and his colleagues (2008) provide an excellent overview of the potential for biomass utilization in the western United States.

Figure 3. Greenhouse gas emissions by transportation fuel and type of energy used in processing. Source: Wang et al. 2007.



While carbon markets and registries typically don't require making estimates of the potential of using thinnings for woody biomass utilization, such estimates are very useful in terms of understanding the economics of a project and how the project might support local and regional communities and infrastructure. The exception is the CCX, which has established credits for burning carbon-neutral fuels, such as woody biomass, in place of fossil fuels. Since woody biomass prices are roughly comparable with the price of coal, a power plant or other industrial facility may find it economical to use woody biomass and make up any negative price differential between woody biomass and coal by obtaining credits from the CCX for burning woody biomass. They may also be able to earn credits and transfer the cost savings or revenue from the credits to forest landowners by paying a higher price for the raw feedstock.

There are several tools available to estimate how revenues from biomass thinning can offset treatment costs at a landscape scale. FIA BioSum is one such tool and it derives its simulations from FIA inventory data. It "presents policy makers with the opportunity to display various policy options and discuss them in terms of costs, volume produced, and effectiveness in fire hazard reduction" (Fried et al. 2004).

Quantifying Any Climatic or Other Effects Due to Ecological Restoration Treatments

Restoration treatment thinning as well as prescribed burning may, when done at a regional scale, affect climate. For instance, thinning small-diameter trees may increase the region's albedo level (i.e., the fraction of solar radiation reflected by a surface or object, including the Earth). This, in turn, may cause a cooling effect in the area because instead of absorbing heat in the coniferous vegetation, for example, the light energy is reflected back into the atmosphere (Liu et al. 2005, Hurteau et al. 2008). Research is underway to measure the extent to which this is the case (Hurteau, pers. comm.).

Prescribed burning, an important part of the restoration treatment methodology, is the application of high-frequency, but low-severity fire to a treatment area or landscape. Such activity produces both GHG (although significantly less than a high-severity wildfire or Wildland Fire Use fires) and aerosols. Aerosols, which are suspended or liquid particles, are produced by a variety of natural and human sources, including burning. Unlike GHG, we know relatively little about the effects aerosols have on regional or global climate change, although many researchers think it is more regional than global, especially in the case of small events of which prescribed burns would be one. The National Atmospheric and Space Administration recently released a report that cited the need for more research about aerosols in order to improve climate change predictions (http://www.climatescience.gov/Library/sap/sap2-3/default.php).

One of the goals of restoration treatments in ponderosa pine ecosystems and other dry, frequent-fire ecosystems of the western United States, is the recovery of grassy openings and meadows—areas that are, in many cases, now dominated by small-diameter trees. The restoration of these areas, including burning them occasionally, will likely result in the sequestration of carbon in the soil and perennial root systems of grass plants rather than in any aboveground structure of trees. These openings and meadows are largely resistant to loss by fire, although they will likely lose any carbon sequestration ability if overgrazed (Ojima et al. 1993) or tilled (Follett et al. 2001). While research into grasslands in other regions has shown their ability to sequester carbon (Owensby 1998, White et al. 2000, Kucharik et al. 2006) and suggests that similar sequestration could happen in southwestern forest meadows and openings, more research is also needed in this area. It should be noted that estimating changes in soil carbon over time is generally more challenging due to the high degree of variability of soil organic matter and because changes in soil carbon may be small compared to the total amount of soil carbon.

Paying for Forest Restoration with Carbon Credits

The ability of terrestrial ecosystems to store carbon is an important, if newly recognized, ecosystem service. Like many ecosystem services (e.g., clean air, fresh water), our society has, until recently, paid little attention to how important these services are to human welfare and how quickly our industrial society can damage or destroy them. Because we have overlooked the services ecosystems provide us, we have failed to account for them in our economic analyses and planning. That is starting to change and selling credits for activities that sequester carbon, such as forest management projects, is one facet of that change. This movement marries our market-driven economy with efforts aimed at environmental and social sustainability. In terms of restoring the health of over-stocked, fire-prone forests in the West, this is a welcome possibility because paying for forest restoration remains one of the key roadblocks to implementing large-scale projects on federal lands.

Because carbon is presently selling at slightly less than $2 per metric ton on the CCX, there is little incentive now to try to obtain carbon credits for forest restoration projects—the income would not offset the costs. However, as Spalding and her colleagues report "Most participants expect this depressed price is a temporary phenomenon which will reverse itself when a federal mandatory market is put in place" (Spalding et al. in review). In fact, there is much anticipation within these markets that Congress will pass cap-and-trade legislation sometime in 2009 or 2010, and it will be signed by President Obama (Kharouf 2009). This could mean that within a few years the United States could be the largest carbon market in the world with as much as $1 trillion traded annually (Kharouf 2009).

Following up on Finkral and Evan's study, Spalding and her colleagues (Spalding et al. in review) examined the break-even point between ponderosa pine forest restoration treatment costs and the price of carbon credits ($/mt CO_2). To do so, she made four assumptions: 1) the removed biomass would be sold for $40/ton and converted into pallets or building material, 2) there were no additional project development costs (i.e., transaction costs) beyond what would normally be incurred for an avoided deforestation project without thinning, 3) the carbon stored in the wood products is accounted for immediately upon harvest, and 4) the net carbon storage from the reduction in wildfire potential (i.e., the difference between the potential carbon release due to fire in the pre- and post-treatment stand) is accounted for the year of harvest. Like the study by Finkral and Evans, they included all costs of harvesting (e.g., road construction, fuel costs) as well as estimates of carbon releases from logging, slash burning, trucking, and production processes. Taking it all into account, Spalding and her colleagues found that the break-even point for carbon was roughly $5 mt CO_2 (actual: $4.81 mt CO_2)—a number that, according to industry analysts, compares favorably with typical "hurdle rates" for development projects. While the carbon market did surpass that $5 level during 2007, it is now below that level, but could return as the recession eases and as federal energy and GHG legislation becomes increasingly likely.

A study in Oregon (Dushku et al. 2007, pp. 67-72) examined whether cuttings transformed into biomass for energy facilities was potentially profitable. They found that 1.2 million ha of ponderosa pine and dry mixed conifer forest would be available for treatment when they applied a set of criteria including 1) cutting on slopes less than 40 percent, 2) maximum yarding distance of 0.25 miles from existing roads, 3) maximum haul distance of 50 miles to existing power plants, and 4) treatment block of at least 80-100 acres. Knowing that not all the biomass would be removed from the 1.2 million hectares due to the variability among stands in terms of pre-treatment conditions and desired future conditions, the researchers devised two possible biomass removal scenarios. In the first scenario, about 12 bone dry tons (BDT) of biomass would be available to the energy facilities, while in the second scenario, about 23 BDT would be available. Assuming treatment costs from $34-$48/BDT (costs based on research by US Forest Service and the Western Forest Leadership Coalition in 2003), the treatment costs of scenario 1 ranged from $397 million to $560 million. Scenario 2 costs ranged from $794 million to $1.1 billion. With the value of this biomass pegged at $36/BDT (Fried et al. 2003), the treatment costs at the extreme lower end of both scenarios would produce net revenues, but once the treatment costs passed $36/BDT, the projects, regardless of the scenario, would require significant subsidies. The researchers then asked: Could dollars from the sale of carbon credits help pay the difference? They determined that, depending on the price of carbon, the quantity of carbon emissions that would need to be reduced ranged from 3.2 t C/ha to 26.5 t C/ha—and that obtaining this level of carbon (CO_2 and C) emission reduction depended on how well the thinning reduced high-intensity or medium-intensity fires to low-intensity fires (i.e., how far it moved the emission level from the business-as-usual baseline, see table below). Citing a study by Brown and Kadyszewski (2005) of carbon emission from medium- and low-intensity fires in all forest types in Oregon, they believe this is possible.

Subsidy	$2.4/t CO_2		$10/t CO_2	
	t CO_2/ha	t C/ha	t CO_2/ha	t C/ha
$117/ha	48.8	13.3	11.7	3.2
$233/ha	97.1	26.5	23.3	6.4

Table 1. Quantity of CO_2 emissions reductions (t CO_2/ha and t C/ha) that would need to be produced by Hazardous Fuel Reduction activities in order to cover estimated per-hectare subsidies needed for Cut-Skid-Chip-Haul Treatment. Source: Dushku et al. 2007

Being Ready for the Future

Federal agencies, such as the Forest Service, are now publicly declaring their interest in managing public lands, including forests, to reduce GHG and mitigate global climate, while maintaining the ecosystem and other services provided by these lands (US Forest Service 2008). While now may not be the time to sell carbon credits from federal lands, planning to do so could be undertaken in order to be prepared for the time when prices rise, as most experts suggest they will.

Federally managed forest restoration projects, in particular, have several advantages that make them unique in a carbon market. They:

- Provide environmental and social co-benefits that many buyers and trading markets desire;
- Contribute to biodiversity conservation;
- Demonstrate an ability to reduce GHG emission levels beyond what would have occurred had nothing been done (i.e., they address the problem of additionality);
- Provide a relatively high degree of permanence by reducing risk from wildfire and/or insect outbreak and, because they are federal lands, from deforestation due to land use changes;
- Are being offered by a known, reputable entity with sizable land holdings and a staff that includes people familiar with carbon markets and forestry issues;
- Are based in the United States and, thus, carbon buyers cannot be criticized for "carbon colonialism" (Eraker 2000) or funding carbon projects in developing countries in order to maintain unsustainable activities in developed countries.

In general, preparing for the carbon market will likely involve new accounting tasks to ensure that the problems of carbon trading are handled properly. However, these tasks do not appear insurmountable and the benefits of increased monies for restoration treatments will make the frequent-fire forests of the western United States healthy, resistant to catastrophic disturbances, and a sink for carbon.

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Ecological restoration is a practice that seeks to heal degraded ecosystems by reestablishing native species, structural characteristics, and ecological processes. The Society for Ecological Restoration International defines ecological restoration as "an intentional activity that initiates or accelerates the recovery of an ecosystem with respect to its health, integrity and sustainability….Restoration attempts to return an ecosystem to its historic trajectory" (Society for Ecological Restoration International Science & Policy Working Group 2004).

In the southwestern United States, most ponderosa pine forests have been degraded during the last 150 years. Many ponderosa pine areas are now dominated by dense thickets of small trees, and lack their once diverse understory of grasses, sedges, and forbs. Forests in this condition are highly susceptible to damaging, stand-replacing fires and increased insect and disease epidemics. Restoration of these forests centers on reintroducing frequent, low-intensity surface fires—often after thinning dense stands—and reestablishing productive understory plant communities.

The Ecological Restoration Institute at Northern Arizona University is a pioneer in researching, implementing, and monitoring ecological restoration of southwestern ponderosa pine forests. By allowing natural processes, such as fire, to resume self-sustaining patterns, we hope to reestablish healthy forests that provide ecosystem services, wildlife habitat, and recreational opportunities.

The ERI White Papers series provides overviews and policy recommendations derived from research and observations by the ERI and its partner organizations. While the ERI staff recognizes that every forest restoration is site specific, we feel that the information provided in the ERI White Papers may help decisionmakers elsewhere. This publication would not have been possible without funding from the USDA Forest Service. The views and conclusions contained in this document are those of the authors and should not be interpreted as representing the opinions or policies of the United States Government. Mention of trade names or commercial products does not constitute their endorsement by the United States Government or the ERI.

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