



Experience with Fire and Fire Management in U.S. Forests and the Potential to Increase Carbon Stocks on Forest Land by Changing Practices¹

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Introduction

In the 4 centuries or so that we have documented our experience with fire and fire management in the U.S., it goes without saying that much has happened and much has changed. Instead of trying to chronicle that experience, which is a historical exercise that has been done exceptionally well by authors like Stephen Pyne (1982), we are more concerned with where that history has brought us. Today's forest conditions are a reflection of the manner in which people have affected them in the past and, in many areas, the most significant effect has been the management of fire. So, the combination of understanding current forest conditions and the history of fire management can lead to some insights as to what different kinds of management might do to forest conditions over the near future. Knowing that, we can make some inferences about many aspects of forest condition, including the amount of biomass and its change over time. That tells us what our potential for carbon sequestration (or emission reduction) is likely to be.

It is important to realize in this brief review that there are many different types of forests, and what is true of one forest type may be totally untrue elsewhere. The Forest Service recognizes dozens of different forest types, and every type has a variety of different conditions based on its age, ecological succession, and past treatment. Generalizations are seldom possible. We will try to be as clear as possible in talking about the potential in different forest types, but before trying to apply any of these concepts to a specific forest area, it is essential to ground the ideas in the physical reality of that forest area and type today.

Fire in U.S. Forests

First, we need to establish the fact that fire has been one of the primary ecological processes shaping forest ecosystems. Parenthetically, that holds true for grassland and brushland systems as well, but today we'll focus on forests. The extent of historical fire is one indicator. By applying what is known about the fire regimes associated with different ecosystems, and using the best available estimates of the extent and location of pre-settlement ecosystems, Leenhouts (1998) estimated that pre-settlement fire must have averaged something on the order of 100-150 million acres a year. Nothing less could have shaped the ecosystems that emerged. Obviously, that number would have varied considerably from year to year, and was no doubt affected by long-term climate swings, but as an average, it is still pretty impressive. By comparison, if we see 5 or 6 million acres of fire today, we call it a major fire year.

Human decisions were heavily involved in that situation. Indian people used fire as a management tool – the most powerful one at their disposal. By lighting fires when and where they were needed, they encouraged food and forage plants, concentrated game, controlled insects, reduced hiding cover for enemies, and lowered fuel levels that would support major fires that would threaten their villages (Cronin 1983). Indians were the original land management experts in the U.S., and fire was their most significant management tool.

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Settlement, of course, brought a different culture and a different type of management. Europeans wanted to reduce fire's impact on their more sedentary life style and more permanent settlements. Wooden buildings and fences don't tolerate fire, and the elimination of fire damage occupied a major place in the new land management approach. In addition, European settlement created a much larger demand for wood, and an emerging industrial technology used it in great quantity. So fire was seen as destroying wood that could otherwise be appropriated for use, and thus it was avoided wherever possible.

On the grasslands, fire burned forage and threatened humans, so range fires were extinguished wherever possible. Those grassland areas had often been intentionally burnt before, to create areas of new grass and concentrate grazers. So, where fires had once run from grassland bottoms up into forested hills and shaped those systems, it became largely absent.

Many forests were grazed by domestic livestock, which shifted the understory from herbaceous species to woody species. Without fire to periodically reduce that wood, it continued to grow and fill space. Species composition and stand structure were changed significantly. Forests where early settlers told of being able to drive a horse and wagon through the trees became tangled jungles of vegetation. Examples include the Oak-dominated forests of the East and the ponderosa pine forests of the West. The areas involved were enormous.

These forests, impacted by 3-4 centuries of change in the East and over a century of change in the West, are what we find today. It is from this condition that we need to ask whether or not changed fire management can affect carbon sequestration and greenhouse gas emissions.

Managing Fire

Fire management in this context has two equally important, and related, dimensions. The first is avoiding the type of fires we don't want to see, and the second is re-introducing fire and its ecological impact back into forests in an appropriate way. Both are difficult, since the first is often not physically possible, and the second raises very difficult issues. But both are critical to future forest health and to the role of these forests in helping us to manage greenhouse gases.

We must begin, then, with the concept of "good" fire versus "bad" fire, and that can be a difficult distinction to explain to people. It is not hard to explain the extremes. Some forest fires move through fine fuels on the ground, consuming a few tons of fuel per acre, and killing very few of the larger trees. The soil is scarcely warmed beneath the surface, and the main impact of the fire is to weed out some of the weaker or smaller trees and convert the unavailable nutrients in the vegetation into available forms that can once again be used by plants. Such fires were essential in shaping the oak and pine savannas that characterized much of the pre-settlement forest. They were also the easiest for people to extinguish, so they were most often eliminated, and many forests have not seen such fires for decades, if not centuries (Pyne 1993).

At the other extreme, fires that consume the entire forest, from soil to canopy, can burn up to 100 tons or more of fuel per acre. Think of the difference in energy release alone. Most, if not all, of the trees are killed, and the topsoil may be heated to several hundred degrees. Nutrients are often lost in the process, because they are not only oxidized, but carried off in the blast of superheated air and smoke. Soil organic matter is vaporized, and soil quality is compromised as a result. Severely impacted sites are not just blackened by a fire of this intensity; they can suffer serious reductions in site quality that affects forest re-growth or may, in extreme cases, even preclude it (Cromack et al. 2000). There's not much that is good about this kind of event.

What we find, in too many forests today, however, are fuel situations that are prime for the second type of fire event but where the first type cannot happen. The fuels are so heavy, and so structured throughout the stand, that any little fire that is not immediately extinguished is likely to climb into the crowns and grow into the second type of event. That will be particularly likely in dry periods when the fuels are highly flammable and the plants are stressed and prone to damage. In many areas of the West today, we are experiencing a dry cycle that makes matters worse. So, from a fire management standpoint, we have the worst of all possible worlds at this point.

In large areas therefore, it is not physically possible to begin to re-introduce fire until those fuels have been reduced. For most places, that will require some kind of mechanical removal, often involving quantities that range from 15 to 70 tons of material per acre. Some of that wood can be utilized in the standard wood products market, but much of it is too small or low quality, and must be utilized elsewhere. Sometimes it can be used for wood pulp, but where there is no pulp market, the options are things like landscaping mulch or hog fuel for energy production. We'll come back to that later.

The forest management goal, in all these situations, is to shape the fuel situation in the forest so that the landscape supports good fire, but is less prone to bad fire. Where that is the case, the managers can either ignite or let burn fires that are desired, and more readily extinguish or guide those that they don't want.

A completely different situation exists in the forest types where fire was fairly rare, but generally lethal.

These forests, often in wetter climates or higher elevations, burned in stand-replacing fire events and the tree species were adapted to re-forest the site after the fire. Lodgepole pine in the west and spruce in the east are examples. It might be 100 to several hundred years between fires in these areas, and there are great regions of the United States today that have not seen a “normal” wildfire since settlement. Fire management in those forests is dramatically different, because fuel reduction is often not feasible – or helpful. In those areas, harvesting or burning small areas on a regular basis creates a patchwork of ages that can help keep down the size of wildfires and make them more patchy, but it doesn’t alter the fact that most fires in these forests will, if they get started, be pretty lethal in the burned areas.

Carbon Implications

Assuming then, that we can find ways to be successful in changing the type of fire that affects managed forests, the implications for greenhouse gas emissions can be significant.

For every dry ton of forest biomass that burns in a fire, we can estimate that roughly 1.4 to 1.7 tons of carbon dioxide, 0.06 to 0.2 tons of carbon monoxide, and 0.003 to 0.01 tons of methane will be emitted in the combustion (Leenhouts 1998). That is not the end of the story, however, as there continue to be emissions for some time afterward. Dead vegetation decomposes, and blackened soils gain more heat and moisture since the dead trees are not taking it up. Thus, soil organic matter and surface debris continues to decompose and emit greenhouse gases until new growth again provides canopy shade, moisture cycling, and carbon sequestration. In some situations, recovery may happen in a year or two; in badly damaged systems, it may be several years.

One study on the Boise National Forest in ponderosa pine indicated that, in two major wildfires during 1994, the average emission across the fire area was about 75-80 tons of CO₂ equivalent per acre (Neuenschwander and Sampson 2000). With over 119,000 acres affected, those fires were responsible for an estimated 9.4 million tons of carbon dioxide emissions.

Based on measured plots within the same forest, and using locally adapted fire effects modeling, it was estimated that where fuels had been reduced to the point where prescribed fire could be safely used, the prescribed fires emitted an average of 18-20 tons of carbon dioxide per acre.

The study then looked at the amount of prescribed fire that it would take to work those forests back toward an ecologically-based fire regime. The numbers were pretty impressive. The managers would have to burn some 40,000 to 50,000 acres a year, and locate those fires strategically so that they effectively broke up the huge areas of fuel that would otherwise support a major wildfire. In the process of carrying out that much prescribed fire, the fire-related emissions would be about 750,000 to 1,000,000 tons of carbon dioxide a year. But that would represent a 35 percent reduction in the emissions they can otherwise expect from the average annual wildfires they are going to experience. In the process, they would avoid wildfire damage to an average of 46,000 acres a year, along with millions of dollars in firefighting costs, and produce a significant amount of wood, pulp, and energy products as part of the fuel reduction efforts. Reduced GHG emissions would total around 500,000 tons of carbon dioxide a year, just on that one forest.

In addition, instead of having large blackened areas that take years to recover and begin sequestering carbon through forest growth, the areas treated with prescribed fire would continue to grow and sequester carbon in the wood of the large trees. Thus, from an economic and environmental viewpoint, this management strategy has a huge potential set of benefits. That it is almost impossible to contemplate in today’s political climate is a forest health tragedy that has yet to present its full dimensions.

Turning Disaster into Opportunity

The obvious question that rises out of this situation is, what can be done? Are there ways to take advantage of the huge amount of biomass involved and use it in constructive ways that will contribute to emissions reduction while also improving forest health? Can these emissions reductions be turned into legitimate reduction credits that can be measured, verified, and capitalized? I believe that positive outcomes are possible, if we seriously seek them out. Here are some ideas.

The first idea involves the development of increased use of forest biomass for energy. The technologies exist, but many are not economically competitive in today’s fossil fuel economy. In addition, many of the available technologies may not be well adapted to the realities of biomass sourcing. Huge plants with long design lifetimes will need more fuel than many areas can produce. In general, biomass for energy probably needs to move 50 miles or less, in order to keep transportation costs manageable (Sampson et al. 2001). In addition, many of these forest types that need fuel reduction so badly today will not continue to produce fuel once management has successfully restored an ecological fire regime. They are essentially a one-time resource opportunity. One answer might be

transportable energy plants that can work in an area for 10-15 years, then move, or switch to other feedstocks. Another answer is to size the energy plant so that its annual fuel usage and design life is compatible with the area involved.

Neither of these is easy. The forests most in need of treatment are federal lands, mostly National Forests. Their legal requirements, not to mention the political issues involved, will not let them commit to long-term fuel supply contracts. Without such contracts, banks aren't interested in financing major investments. Breaking this political logjam would probably take ground-breaking legislation in Congress.

If those barriers could be overcome, however, measuring and verifying emission reduction impacts could be fairly straightforward. If the power plant can claim biomass energy credits, the record-keeping for biomass usage is standard business practice. If those credits can be entered into a market trading system, capitalizing them would be equally simple. This brings us back to public policy, of course, since market trading in credits is likely to require a new regulatory framework that has yet to fully emerge.

Additional emission reduction credits should be available through the reduction of emissions due to reduced wildfire damage in these forests. That becomes a bit more difficult to measure and verify, but as many of the energy companies know, it would be no different in concept than the emissions reduction programs you are testing in the protection of tropical forests from deforestation. It is a matter of establishing a credible baseline from which the reduced wildfire damage and emissions can be calculated. That takes a fairly sophisticated risk assessment, but there is a great deal of work underway to provide useful modeling tools for wildfire hazard and risk assessment in North American forests. What is available today is probably as credible as any of the baseline methods used to estimate development pressures on forests in developing countries. Again, however, these models would need to be used in some pilot projects and verified before they would achieve the credibility needed in the marketplace.

Summary

In summary, then, I believe there are opportunities to achieve multiple environmental and economic benefits by making dramatic changes in forest and fire management today. The obstacles are considerable, but not insurmountable. A major need is to overcome the forest mythologies and misinformation that have marked so many of the advocacy campaigns of recent years. Where we can move toward policies and practices based on sound science and experience, the results will help debunk the worst of the misinformation.

The challenge is to begin. In my view, this needs to start with pilot projects that are similar in nature to the pilot projects that the energy industry has done so effectively in other areas of carbon sequestration and emission reductions. Starting small, with sound scientific grounds and good monitoring, is what is needed. These pilot projects will probably need the help of Congress, both from financial and policy standpoints. Given the current efforts to find workable solutions through legislation like the Healthy Forests Act, that may be possible, if the energy industry were to join with the forest management community in seeking new solutions to fire management for healthy forests and significant climate change impacts.

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