Forest Management Options for Carbon Sequestration: a Western U.S. Perspective

Bernard Bormann*

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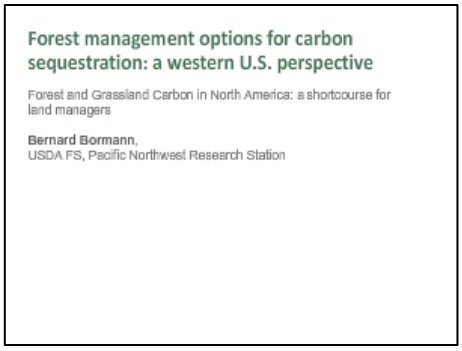
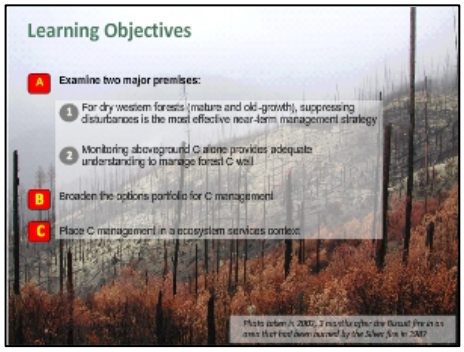
Slide 1. Forest Management Options for Carbon Sequestration



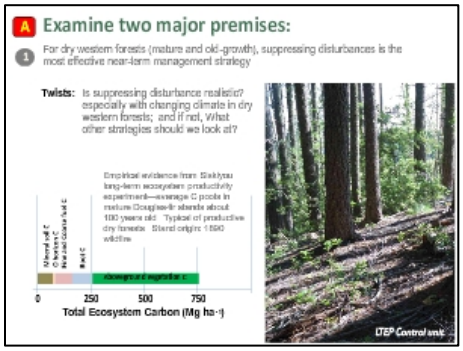
Hello, I'm Bernard Bormann. I'm a research scientist with the Pacific Northwest Forest Experiment Station in Corvallis, Oregon. I'm going to talk to you about some western perspectives on forest management options for carbon sequestration.

Slide 2. Learning Objectives



The learning objectives that I'm seeking today are to present and examine two major premises that you commonly hear about carbon sequestration, and then to examine those in relation to the data that we have available, and to use that process to open up and help you think more broadly about some of the management options that you might consider while managing for carbon. And lastly, I'll attempt very briefly to place carbon management in more of an ecosystem services context.

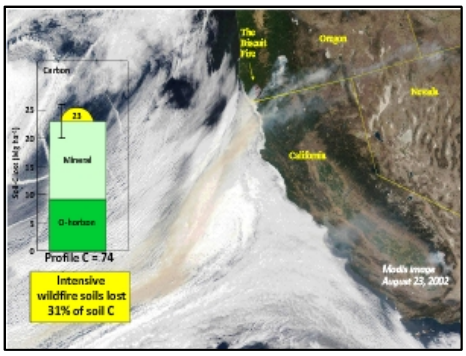
Slide 3. Examine two major premises



Now, for the first premise, which I think you have more or less heard in a number of presentations as the baseline, at least for dry western forests, mature and old growth in particular, suppressing disturbances, keeping that baseline going, is the most effective near-term strategy for carbon sequestration. But I will challenge that premise a little bit by asking if that's truly realistic, particularly in the West where not only is there substantial amounts of disturbance, but it's expected that disturbance will become more frequent as you have heard in earlier presentations. Now to examine the reality of this premise I will only use data from studies that I'm very familiar with, no models. In this case, we're going to start with a stand in southern Oregon on the Rogue River-Siskiyou National Forest, and here is an example of the carbon pools that you can find in a mature, roughly 100-year-old fire origin stand.

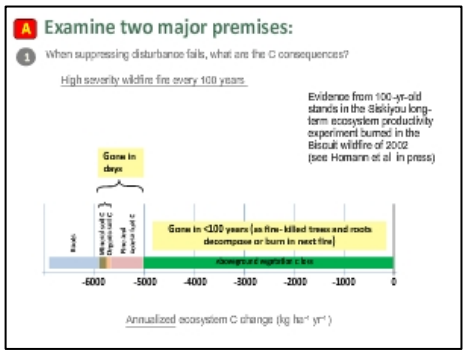
** This document transcribes the presentation given by Dr. Bormann. The presentation is part of General Technical Report NRS-93, "Forest and grassland carbon in North America: A short course for land managers." The full report, comprised of 15 presentations, is in DVD format and can be obtained at http://nrs.fs.fed.us/pubs/order/40110. The presentations and related materials can also be accessed at http://www.fs.fed.us/ccrc/carboncourse/*

Slide 4. The Biscuit Fire



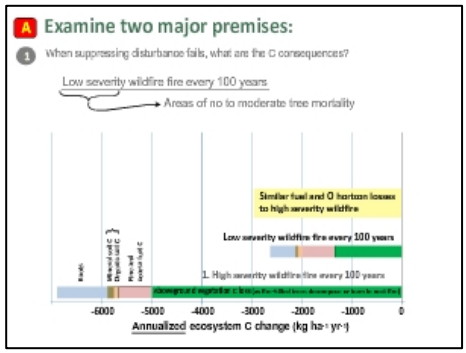
But this baseline was truncated by the Biscuit Fire which happened in 2002 and burned a large portion of that national forest. And because we had measurements of soil carbon and ecosystem carbon before the fire occurred, we were able to get very accurate estimates on the losses of carbon that are attributable to this wild fire. And on the number of stands we looked at that were very intensively burned, we were able to document a loss of 23 metric tons per hectare. And for these stands that constituted an average of 31 percent of the soil carbon, and a lot of that was actually from the mineral soil. We've speculated that one of the mechanisms for this loss was actually convection of mineral particles into the plume, and you can see in this photograph the smoke that traveled from this fire considerably far out into the Pacific Ocean, and this was a typical satellite image for over a month.

Slide 5. High Severity Wildfire



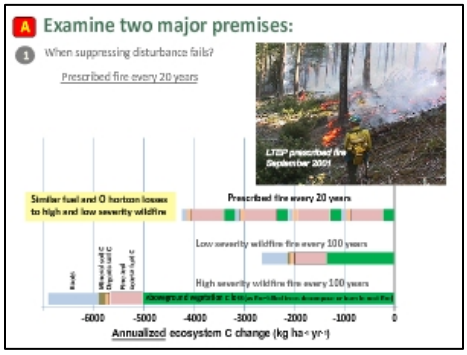
So now I want to quickly review and compare the effects of wildfire and prescribed fire, and I will go through a series of data points for different stands or different severities. High severity, or high mortality as it's commonly referred to, in those particular stands we saw that 23 megagrams per hectare, which is a relatively small proportion of the total, but that disappeared from the system in only a matter of days. The aboveground vegetation was killed and that will disappear over a longer period of time.

Slide 6. Low Severity Wildfire



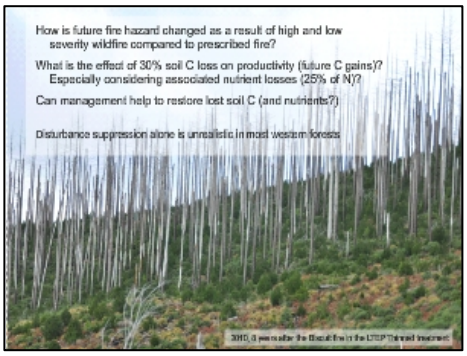
In the lower severity areas where not every tree was killed, the carbon losses were substantially less than half. But that occurred on about 60 percent of the fire. The high severity areas took up about 40 percent of the fire.

Slide 7. Prescribed Fire Every 20 Years



Just quickly, we were fortunate to have measured prescribed fire losses a year before the wild fire occurred, and an individual prescribed fire actually lost less than a low severity wild fire and lost nothing from the mineral soil, and I think that's an important thing to point out. But if you repeat prescribed fires on a 20-year cycle over this 100-year sequence then it exceeds that of the losses of the low severity area. But this comparison is very difficult.

Slide 8. Questions Concerning Wildfire

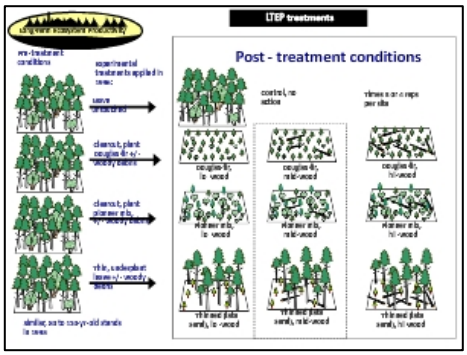


You have to ask questions like, how is future fire hazard changed by the severity of the wildfire? You have to ask the question, if you lost 30 percent of the soil carbon, is that forest going to grow back at the same rate that produced that forest in the beginning? And especially when you think about the other nutrients that were lost like nitrogen, where 25 percent of the nitrogen was lost in the fire. This kind of turns the management thinking in a new direction. How do you restore soil carbon after fire? And I think that's an important management direction to think about.

Slide 9. What If…

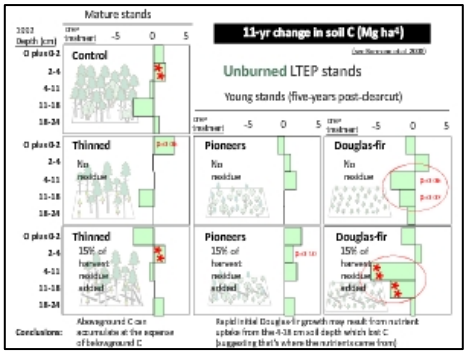
The second premise I want to address is that monitoring aboveground carbon alone is adequate to understanding how to manage forest carbon. But, what if conifers deplete mineral soil carbon in order to grow rapidly? Would that be fair to take carbon from the soil and put it in the aboveground, get credit for that while depleting the portion of the ecosystem that's not being measured? I think that might be a problem. So let's address this question using data from this same study but in an area that was not burned in the fire. The study compares pure dense Douglas-fir plantations on the right with a hardwood pioneering species mixture on the left.

Slide 10. LTEP Treatments



This is a description of the whole study which I will suggest you look at, those of you online could look at in more detail.

Slide 11. Eleven Year Change in Soil

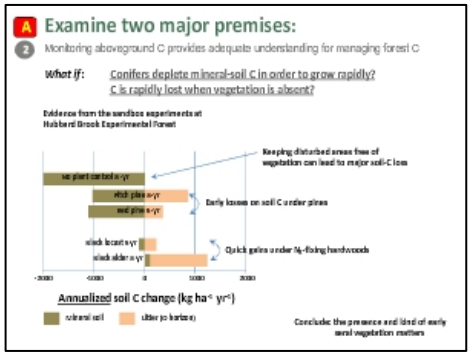


And the results I want to draw your attention to are on the right where we see Douglas-fir treatments actually causing a significant decline in the soil carbon in the zone 4 to 24 centimeters deep. This really surprised us. We were not expecting it, and if you look and compare that to the pioneers, the hardwood treatment on the left, you see although there's no significant change, those trends tend to be to the positive side.

Slide 12. What If…

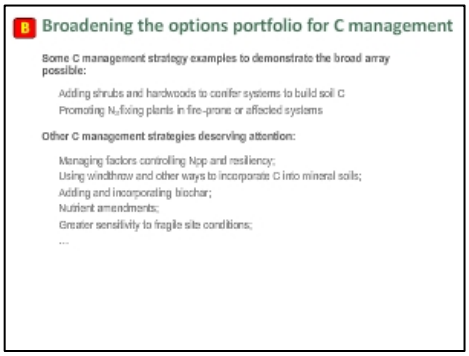
Another source of data we can address this question comes from the Hubbard Brook Experimental Forest where a series of species trials, in essence, were conducted simultaneously on very highly controlled soils in very large lysimeters where the carbon budget was tracked very closely.

Slide 13. Evidence From Sandbox Experiments



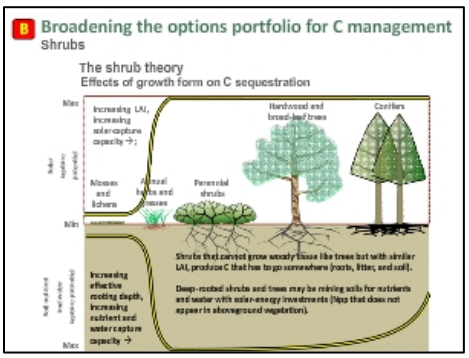
And in this case I want to first draw your attention to the pitch pine and the red pine. Both of these pines also exhibited a loss of soil carbon similar to what we saw in the Douglas-fir. And although there was some accumulations in litter in the organic horizon, there was a significant loss in the mineral soil. But overshadowing that loss was the losses that occurred in the control plots where we had no vascular plants for that period of time. And that loss of biotic regulation from the vascular plants appears to have contributed to a major loss of soil carbon, and this occurred in five-year period. This is a wake-up call. Soil carbon is not constant. You can lose it if you're not careful. On the other hand, the positive side is look at what happened with the hardwoods. They actually increase the soil carbon, at least in the case of the alder.

Slide 14. Broadening the Options Portfolio for C Management



I'm going to seek to get you to think about a wider range of management options that you could use to manage for carbon, for ecosystem carbon, with a focus on soil carbon. The first one I will talk about is shrubs and hardwoods and their potential role in building soil carbon. The second one is in using nitrogen-fixing plants. I don't have time to address a whole host of other issues. I wish I did but there are other ones like windthrow and biochar which are very intriguing and deserve further attention.

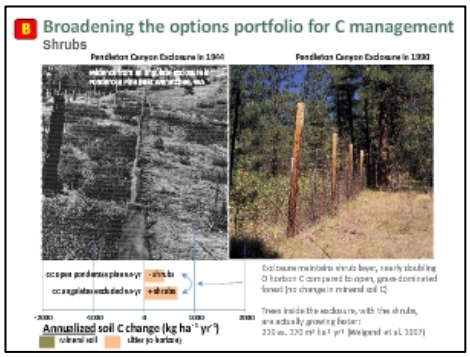
Slide 15. Shrubs



But turning first to the shrub question, I want to revert to a theory. This is not a model, this is a theory. There's a difference. And in this case, if you think about the growth forms in an ecosystem and how they can sequester carbon, you come up with an interesting story. Mosses and lichens fundamentally without a vascular system cannot develop an array of foliage to capture sunlight in any great quantity. Likewise, they don't have root systems. Annuals have developed that vascular system, but it's limited in how much an annual plant can grow in a year, and they tend not to grow over the entire growing season. Shrubs and trees, on the other hand, can develop a leaf area index that is capable of absorbing

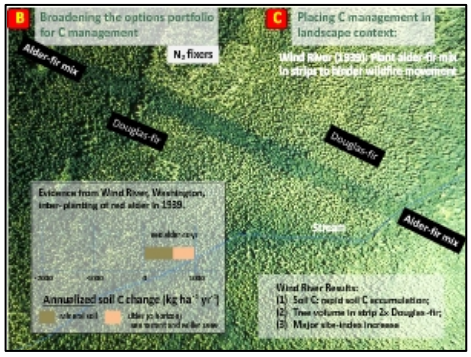
essentially all of the solar radiation coming in, but their growth form dictates a different carbon sequestration allocation. And in the case of conifers, they're very, very efficient at taking that photosynthate and converting it into woody biomass and carbon. Hardwoods a little bit less so, and shrubs have this fundamental problem. They tend to produce flowers at the end of their terminal buds, and they can't produce that amount of woody tissue. But, if they have the same leaf area index, I think it's fair to assume they have the same rates of solar capture. So the question then becomes where does that carbon go? And I would argue its most likely going to the belowground. And let's look at one example.

Slide 16. Pendleton Canyon Exclosure



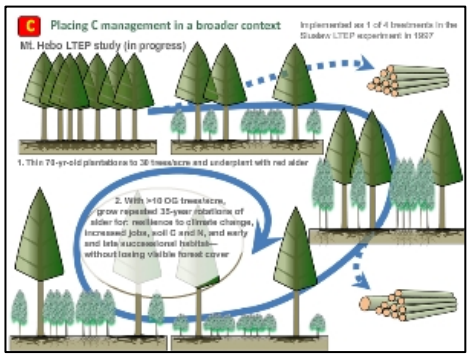
In 1939, a forester outside of Wenatchee, Washington after clearcutting a ponderosa pine stand noticed the larger populations of deer and elk. He was concerned about them, and he put up an exclosure to see what would happen if the deer and elk weren't there. And a fairly quick result occurred. The ungulates ate the shrubs and killed the shrubs and it converted it to principally an annual grass. And you can see in this picture in 1944, it's persisted to this day. It's this rather lush understory of shrubs, and what has happened in terms of the soil carbon was there was no change in mineral soil carbon. There were some nutrient changes but no carbon change, but the organic horizon came close to doubling inside the exclosure where the shrubs existed. And this being a droughty area you would think perhaps that increase in the water holding capacity might have an effect on the system. And in fact it is reflected in higher growth rates of the ponderosa pine inside the exclosure. So it's kind of a different take on shrubs than you normally hear. I will not use the word brush, you notice.

Slide 17. Nitrogen Fixers



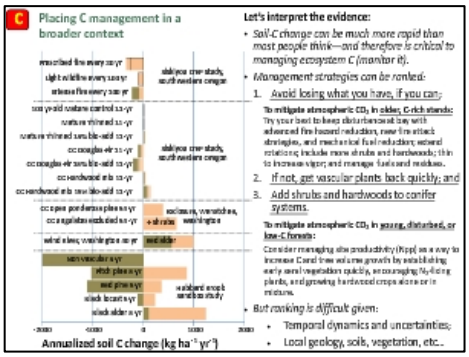
Turning quickly to nitrogen fixers, there's a wonderful example of a carbon management treatment that was implemented also in 1939, this time by a very forward-looking forester who was operating at the landscape scale who had just experienced a series of intensive fires called the Yacolt Burn, and because there was a sequence, he was getting sick of replanting these plantations that would then reburn, so he noticed the fire died out when it ran into alders. So he went and interplanted alder from the stream all the way to the ridge, and the result can be seen today in this green swath that you see on the slide there. The effect of that interplanting, and the alders were actually younger than the Douglas-fir seedlings, they were two or three years younger, planted two or three years later, was stunning. The carbon accumulation was about 1,000 kilograms per hectare per year averaged over 40 years. The tree volume doubled inside this strip, and the site index for Douglas-fir went up a whole site class. It's available for use.

Slide 18. Mt Hebo LTEP study



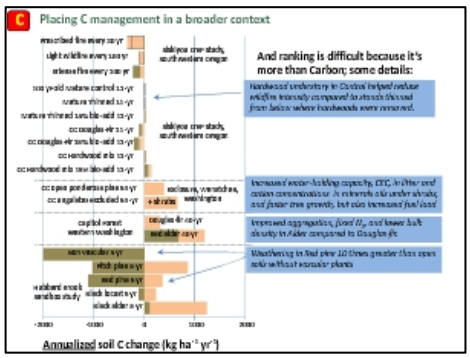
There's another study. This is a study, not really a management plan, but is something that the Siuslaw Forest implemented where they thinned an existing plantation, an older plantation, with the idea of eventually producing only 10 large conifers per acre, but then planted alder underneath this and it is growing 35-year rotations of red alder underneath and in between these eventually 10 trees per acre of Douglas-fir. It would have clear carbon benefits I would suspect, and we're going to be able to test that, but it also has a lot of other benefits.

Slide 19. Let's Interpret the Evidence



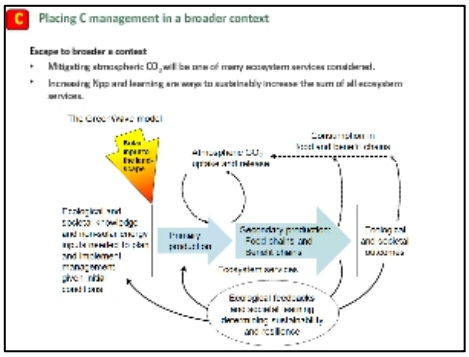
So let me try to sum up the evidence that we have to this point. The first thing I want you to keep in mind is that soil carbon can change much faster than you probably thought it could, and this is very important to know. Secondly, we could attempt to rank some of these strategies that I've been talking about, and I would probably say avoiding losses of what you have if you can is a great strategy, if it works. But I would focus that strategy, if it was me, on older carbon-rich stands where you could try your best to keep disturbance at bay, and to look at improving your fuel reduction strategies and improving your fire attack strategies, look at the whole story. You know, think fire suppression. It's ok for this portion of the landscape. You need to protect those stands, but you can do some other things as well without compromising that. If you cannot protect the stands or you're working with younger lower productivity stands or in any disturbed stands, I think it's really important to get those vascular plants back as soon as possible, and I don't think we want to go back to the day of trying to keep the stands completely open and planting conifers and then, you know, herbiciding the competing species. I don't think that's a good story for carbon, at least in the short-term and maybe not in the mid-term, but probably also not in the long-term. At any rate, adding shrubs and hardwood to conifer systems seems like a no-brainer to me. It's not that hard. There's multiple other benefits, wildlife for example. In young and disturbed stands, I think you might really start thinking about focusing on managing site productivity rather than managing carbon stocks, because in the end, as I'll show you in a minute, I think site productivity and net primary production ultimately drives ecosystems services. But I'll throw the uncertainties out that there are many temporal dynamics and uncertainties. There are many local geologic soils and vegetations, things that need to be taken into account. There's no generalities that can be made. You're going to have to put a lot of work into this for your local area.

Slide 20. Ranking is Difficult



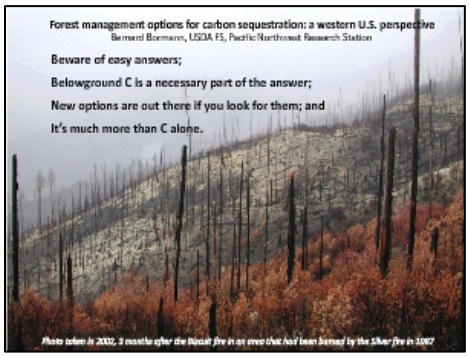
Here are some reasons why it's more than carbon. You can look at online.

Slide 21. Escape to Broader Context



And lastly, I think we all need to start trying to escape to a broader context than carbon management. Mitigating CO2 will be one of many ecosystem services, and we have this model we've been working on called the GreenWave which actually looks at solar energy capture and conversion to carbon and biomass and energy as it flows through primary production, secondary production food chains, and benefit chains to benefit society.

Slide 22. Final Points



So to finish up, I will say that the lessons I hope you take away are beware of easy answers, you have to work at it, you have to think about it, you have to be skeptical. Belowground carbon is a clearly a necessary part of the answer. There are many new and innovative options out there and you need to look for them, and it's much more than carbon alone. Thank you very much.