Sequestering Carbon Case Study II:

Estimating Carbon Sequestered through Volunteers Protecting Legacy Pines in the Caples Creek Ecological Restoration Project

Lester Lubetkin, our chapter's Conservation Co-Chair, along with staff from Sierra Forest Legacy, organized chapter volunteers and others in 2019 to pre-treat (that is, to cut ladder fuels, to pile dead fall, and to rake pine needles and duff) within the planned prescribed burn in the Caples Creek drainage near Kirkwood, California. Lester also estimated the carbon sequestration of this volunteer effort.

Lester Lubetkin
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El Dorado Chapter's Carbon Neutral Pledge

In 2019, the El Dorado Chapter of the California Native Plant Society (CNPS) adopted a pledge to decarbonize its activities, meaning that the chapter's activities would add, in net, no greenhouse gases to the atmosphere. The chapter is doing this in phases: For the time being we are focusing on just our transportation carbon footprint ("Scope 1 emissions"), that is, the fuel we use to attend meetings, events, plant sales, etc.

At the beginning of last year we estimated the chapter's annual transportation carbon footprint to be 20 tons per year (CO_2). Because of the various restrictions and social distancing during 2020, the carbon footprint was re-estimated to be 7 tons (CO_2). To put these 7 tons in perspective, the average carbon footprint per person in the U.S. is 15 tons per year (CO_2).

To become carbon neutral, the first step is to reduce a carbon footprint as much as feasible. What remains of a carbon footprint can then be compensated for: one way is to purchase carbon credits. A second more direct and satisfying way is to take a hand in efforts that increase the carbon sequestration of the land around us. Some of the chapter's conservation projects are of this more direct kind: They not only preserve and restore native plants areas, but also build up the land so that it can sequester more carbon. A major difficulty in using a conservation project toward compensating for our carbon footprint is that there are few guides that estimate how much carbon a conservation project actually sequesters.

This paper provides such an estimate. In a nutshell, every tall tree saved is a large carbon factory that can continue to pull carbon from the atmosphere and to lock that carbon into the tree's biomass. The data indicates that if the area had burned as a wildfire, 23% of the tall trees would have been killed in the fire, whereas none appear to have died several months after the prescribed burn.

Caples Creek Ecological Restoration Project

The Caples Creek canyon is filled with a mixed conifer-oak forest interspersed with brush-fields, aspen groves and large subalpine meadows. The mixed conifer-oak forests have adapted to thrive with fires every 10 to 15 years. With fires this frequent the duff and understory vegetation do not become so thick and dense that fires "burn hot". Many tree species have ways to defend against milder fires, such as growing thick bark, and oaks trees have also adapted by sprouting new growth from their stumps after a fire.

Eldorado National Forest: Home to 400^{+} Year Old Legacy Conifers
(Photo: U.S. National Forest)

With frequent fires, the large pines and cedars are naturally well spaced and are not competing with smaller trees for the limited water and nutrients in the dry summer. Frequent fires also release needed nutrients back into the soil.

Caples Creek: A Home in Need of Housecleaning
(Photo: L. Lubetkin)

Forest management for the last century, however, has been to suppress wildfires. The result is that the forests have become denser, having a more closed canopy and many small trees which compete with the grand, mature trees. The amount of fuel accumulating on the forest floor has been increasing significantly and now there are "fuel ladders", allowing fire to spread from the forest floor, to the smaller trees and lower tangled branches, and up into the canopy of the large, "legacy" conifers. Even the mix of tree species is changing: whereas pines, cedars and oaks were the dominant species originally, white firs (a shade-tolerant species) have become more prevalent.

Building Burn Piles
(Photo: K. Barco)

The Eldorado Forest has developed a plan to reintroduce fire into the forest in the Caples Creek canyon. One of the requirements of the plan was to avoid killing the large legacy conifers. Past studies (1) have shown that removing duff and litter around the bases of the legacy conifers helps to protect the conifers from mortality during a fire.

During the summer of 2019, the El Dorado Chapter of CNPS took a lead role in the coordination of volunteers to protect legacy conifers. Volunteers worked with the Forest Service fire crews to cut down small trees next to the 400 to 700 year old Ponderosa, Jeffrey and sugar pine giants, and to rake needles and duff away from their bases. Some of these legacy conifers were over 5 feet in diameter. Had a fire come through this stand of trees, the fire would have girdled many trees, killing them. Or, had the trees survived the fire, their shallow roots would have been "cooked", reducing the trees' ability to take in water and nutrients needed to survive and to ward off insects and disease. This secondary impact can be just as fatal to the trees as being severely burned.

Raking Needles and Duff
(Photo: L. Lubetkin)

Over 80 volunteers participated in 11 workdays and protected about 200 trees over an area of about 100 acres (2).

Pile Burning First
(Photo: U.S. National Forest)

Understory Burning Next
(Photo: U.S. National Forest)

Finally, on September 30, 2019, some of the piles of branches and small trees were lit. There was snow on the ground in places and the weather was cool with some rain anticipated. On October 4th, the prescribed burning plan shifted from pile burning to the "understory" burn phase. In this phase the fire is allowed to creep along the ground, consuming the duff and litter on the forest floor and killing some of the smaller trees.

The fuels were lit along the ridgeline on the north side of the canyon with the fire creeping downhill toward Caples Creek. Fire managers had projected that they would have been burning well into the latter part of October, weather permitting. The conditions at the time that the burning was started met the requirements for the prescribed burn, although a warming trend and afternoon winds were forecasted for later in the week.

The weather pattern did shift with afternoon winds driving the prescribed fire to the east. Then on October 10, very strong, variable winds began causing burning embers to fly beyond the area prepared for the understory burn. This led to spot fires starting up ahead of the fire front. At

that time, the “prescribed fire” was declared a “wildfire”. With that declaration, additional fire fighters were called in to help control and extinguish the fire. The wildfire was eventually contained in late October. Overall, a little over 1,000 acres were burned during the prescribed fire phase, and another 2,300 acres burned as a wildfire.

Likely These Trees Will Live
(Photo: B. Solvesky)

After the wildfire was extinguished, a Fire Behavior Study (3) was completed to assess the impacts of the wildfire and prescribed burn. The study determined that the larger trees within the area of the prescribed burn survived the understory burning, whereas in the area that burned as a wildfire, 23% of the large trees were killed by the fire.

Calculating Annual Carbon Dioxide Equivalent Sequestered

For purposes of calculating annual carbon sequestered due to the efforts of the volunteers, we want to calculate how much more carbon is being sequestered in the treated prescribed burn area compared to the untreated wildfire area. The following calculations were made:

1. Determine the volume and weight of annual growth of the trunk of an average legacy conifer: 110 lbs.

2. Determine an adjustment for total biomass of an average legacy conifer. This adjustment accounts for branches and foliage not otherwise included in the trunk calculation: 280 lbs.

3. Convert from biomass to sequestered carbon for an average legacy conifer. Multiply by the total number of legacy trees in the area. Reduce the amount of annual carbon sequestered to 23% of the total, to account for the number of trees that lived that likely would have died if not pretreated in advance. Further, reduce the amount of annual carbon sequestered by 50% to account for the thinning and other fuel reduction work done by others in the project area: 1.5 tons.

4. Convert carbon sequestered in the legacy conifers to carbon dioxide: 5.6 tons.

It is estimated that the El Dorado Chapter CNPS volunteer efforts associated with raking around the legacy conifers and removing ladder fuels adjacent to these trees would lead to an additional sequestering of **6 tons of CO_2 annually** as compared to the same legacy conifers facing a wildfire.

Following are the assumptions and detailed calculations:

1. Annual Growth Volume and Weight

The raking and ladder fuel removal was focused around legacy Ponderosa and Jeffrey pines as these are the most vulnerable and hardest to replace. In the Caples Creek canyon these trees range from 48 to 72 inches in diameter at breast height (dbh) and range from 100 to 200 feet tall. The trees are often recognizable by the distinctive yellowish to reddish bark and rounded canopy. Younger trees of these species tend to have a more pointed canopy shape. Based on this range in tree sizes, the average volume of the bole of the legacy conifers can be calculated based on the formula:

$$V = \pi r^2 (h/3)$$

where **V** is volume, **r** is tree radius at breast height, and **h** is tree height. To determine the annual growth volume (V_{ANNUAL}), however, we must subtract the volume of the bole in the prior year (V_1) from the volume of the current year's bole (V_2). The annual growth is estimated to be the width of an annual growth ring as observed in tree ring cores, which is approximately one to two millimeters per year (0.039 to 0.079 inches per year).

Thus, r_1 = 30 inches (average dbh = 60 inches), r_2 = 30 +0.059 inches (average width of growth ring) and $h_1 = h_2$ = 150 feet =1,800 inches:

$$V_1 = \pi \times 30^2 \times (1{,}800/3) = 1{,}696{,}000 \text{ cubic inches}$$
$$V_2 = \pi \times 30.059^2 \times (1{,}800/3) = 1{,}703{,}000 \quad \text{“}$$
$$V_{ANNUAL} = V_2 - V_1$$
$$= 1{,}703{,}000 - 1{,}696{,}000$$
$$= 7000 \text{ cubic inches}$$

The dry weight of this volume of annual growth can be determined based on the dry density of yellow pine (Ponderosa and Jeffrey pine) (4, 5), which is 28 lbs./cubic foot (or 0.016 lbs./cubic inch). Therefore, the dry weight of a year's growth of an average pine's bole is **110 lbs**.

2. Adjustment for Total Biomass

The weight of the annual growth of a legacy pine's bole is not all of the annual growth of these magnificent trees. There is also growth of the branches and foliage. The relationship between tree diameter and total dry biomass has been studied and calculated (6) This work indicates that for Ponderosa pine up to 24 inches in diameter (dbh), the total growth of a tree is about 2.5 times the growth of just the bole and bark. Applying this to our 60 inch diameter (dbh) legacy conifers, their total annual biomass growth would average **280 lbs. per tree per year.**

3. Annual Carbon Sequestered

The total amount of carbon stored within this total biomass is approximately 50 percent (7). From this, we can estimate that the annual amount of carbon that is sequestered in an average legacy conifer is **140 lbs.** per year. The two hundred legacy conifers that the volunteers pretreated for the prescribed burn would, therefore, sequester **28,000 lbs. of carbon in the project per year**.

Twenty-three percent of those legacy conifers would likely not survive a wildfire based upon the conclusions of the Fire Behavior Study (3.): this 23% will be taken as the carbon sequestered because of volunteer pretreatment:

23% of 28,000 lbs. = 6,400 lbs. or 3 tons of carbon sequestered due to pretreatment

Other crews and forest staff completed fuel reduction efforts in the project area in advance of the prescribed burn, including crews from the American Conservation Experience (ACE) that thinned small trees and hand piled slash, a Generation Green crew that raked around some legacy conifers, and Forest Service hand crews that piled slash and helped to thin ladder fuels around legacy pines. A 50% reduction factor is applied to account for this additional work.

50% of 3 tons = 1.5 tons of carbon sequestered due to El Dorado Chapter's pretreatment

4. Convert Total Annual Carbon Sequestered to Carbon Dioxide (CO_2)

Although the trees do not directly store CO_2, they do take in CO_2 from the atmosphere and retain the carbon in the trees' structure. We want to compare the amount of CO_2 that is released by the activities of the El Dorado Chapter with the additional amount of CO_2 that the Caples' trees take in. To do this, we convert the total annual carbon intake to its CO_2 equivalent. Carbon has an atomic weight of 12 and oxygen has an atomic weight of 16. The total atomic weight of CO_2 is 12 + (16 X 2) = 44. Therefore, to convert the total amount of carbon to its CO_2 equivalent, we multiply the weight of carbon by the ratio of 44 divided by 12 which is 3.7:

1.5 tons of carbon x 3.7 = 5.6 tons CO_2 sequestered due to El Dorado Chapter's pretreatment

Alternative Methodology Not Attempted

The Forest Service has developed several tools to assist in Forest management, including the Forest Inventory and Analysis (FIA) tool set. Within the FIA there is the FSVeg tool that allows one to model forest stand condition data to determine the effects and outputs from various stand treatments, as well as prescribed burn results. These

models require detailed stand inventories as the initial input. The models were not developed to calculate the annual growth and carbon sequestration from the more limited activity of raking and ladder fuel reduction around legacy conifers. No attempt was made to try to use this tool to calculate the annual CO_2 equivalent stored in the legacy conifers that were pre-treated.

Lester Lubetkin has a Master's degree from Stanford in engineering geology. He is dedicated to the health and resilience of the Eldorado National Forest, where he retired 8 years ago as recreation program manager. He is happiest spending time with Alice in the woods, mountains, or any place outdoors.

More chapter conservation projects are planned for this year. If you are interested in being notified of them, let Lester Lubetkin know at https://www.eldoradocnps.org/about-us/contact-us

References

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