Research Summaries: Sierra Nevada Forests and Carbon

Sierra Nevada Conservancy (SNC) staff is regularly tracking research that has relevance to the Sierra Nevada Watershed Improvement Program and Sierra Nevada Region. Below are some examples of research of which staff has recently become aware:

Aboveground live carbon stock changes of California wildland ecosystems, 2001–2010

By: Patrick Gonzalez, John Battles, Brandon Collins, Timothy Robards, and David Saah – **2015** Non-journal (and therefore not peer reviewed) full report text link (147pgs)

After the California Global Warming Solutions Act (AB32) of 2006, California set a goal of ensuring "**no net loss of carbon by 2020**" primarily for forest ecosystems. This research compares the state's carbon stocks in 2001 to 2010 to gauge the carbon storage direction of our ecosystems, especially as water-stress and wildfires increase pressure on our plant-based carbon stocks.

It is important to note that this research only looked at changes to the aboveground live carbon pool (e.g. tree trunks, not root systems), therefore any loss in that pool does not equate to a direct emission to the atmosphere. A tree that died in 2005 would be noted as a loss in the aboveground live carbon pool, but the resulting snag (and the carbon therein) could remain on the landscape for decades. The carbon in a snag will mostly decay to the atmosphere over time and is more vulnerable to quickly being emitted to the atmosphere (via fire) than if it were still within a live tree. However, areas noted in the research that changed from forestland to grasslands can reasonably be assumed to have experienced significant carbon emissions from the site even if that is not measured in this research.

The researchers found that between 2001 and 2010, 71 teragrams of carbon were lost from California's forest aboveground carbon live pool. (71 teragrams = 71 million metric tons – note that this is carbon, not CO_2e. To convert carbon to carbon dioxide equivalent, the 71 teragrams would be multiplied by 3.67.) Some direct quotes from the paper:

- We found that areas burned by wildfires, though a small fraction of state land area and carbon stock (carbon stock is the carbon stored in live trees. It makes up approximately 50% of a tree's weight), accounted for a disproportionate share of the state carbon stock decrease.
- Carbon stocks decreased on both public and private lands, with carbon stock loss slightly higher on public lands relative to surface area and carbon stock. Three-quarters of carbon stock loss on public lands came from burned areas while only one-third of carbon stock loss on private lands came from burned areas.

- The disproportionate share of the state carbon stock decrease from burned areas demonstrates the importance of wildfire in the carbon balance of California ecosystems.
- Although prescribed burning, managed wildland fire, and mechanical fuel reduction treatments across public and private lands may release greenhouse gases in the short term, these practices can augment carbon storage in the long term by shifting growing space from many small trees to fewer large, old trees and also enhance resilience to stress and disturbance and potential increases in wildfire frequency due to climate change.
- Our results show that aboveground live carbon losses from ecosystems are as much as 5–7% of state carbon emissions from all sectors. This reversal suggests a new emissions reduction challenge. A suite of forest management strategies, including conservation of high-biomass forests, fire management adapted to future climate change, and reforestation of areas cut for timber, may be necessary for meeting goals for 2020 and beyond.

This research describes a forest ecosystem that, in 2010, was no longer actively storing as much carbon as it had in 2001. Since 2010 we have had four years of drought and some of the largest fires in Sierra Nevada history, so it is unlikely that the situation has improved since then (see the research summary below). *What is most concerning is the conversion of forests to shrublands and grasslands, which can occur after high-severity fire. As opposed to a treatment which slightly reduces carbon stocks on that land briefly, conversion from forests to grasslands can, for the long term, reduce the available carbon storage on that land by 10 to 100 times.* This research demonstrates that our lack of active forest management is making it more difficult for the state to reach its carbon objectives. A comparison of 2010 values to 1990 values would likely be starker than the 2010 to 2001 comparison, and is the next step in this research. *While this research does not answer the question as to whether or not our forests have become net carbon emitters or not, bark beetles (Canada) and drought (Brazil) have been found to lead forests to be net emitters. California cannot afford to suffer a similar fate.*

Recovery of Ponderosa Pine Ecosystem Carbon and Water Fluxes from Thinning and Stand-Replacing Fire

By: Sabina Dore, Mario Montes-Helu, Stephen Hart, Bruce Hungate, George Koch, John Moon, Alex Finkral, and Thomas Kolb – **2012**

The previous article focused on one key role forests have in the carbon cycle, storage. The other two roles are sequestration and emissions, or the rate at which forests absorb or release carbon from/to the atmosphere. We rely upon our forests to pull carbon dioxide from the air to help balance our emissions. But the rate at which carbon is sequestered by forests is not constant and identifying the variables that affect the sequestration rate was the purpose of this research on ponderosa Pine forests in

Arizona (typically drier than Sierra Nevada forests). The authors studied and compared three sites over 5 years – a high-severity burned forest, an undisturbed forest, and a treated forest. The burned site, studied from years 10-15 after the fire, remained a net carbon emitter as the dead trees decayed. The authors estimate that it will take more than 20 years for that land to begin sequestering more carbon than it emits:

- The severe fire had a large and persistent effect on ecosystem carbon stocks and fluxes. Past results at the [burned] site showed that, 10 years after the fire, ecosystem-level carbon was approximately 40% of the carbon stored by the [undisturbed] site, mostly because of a decrease in trees biomass and organic soil. Our measurements were made a decade after burning, during which time additional carbon was lost from the site via decomposition and erosion, and little was stored as new vegetation because of the lack of tree regeneration. If we consider coniferous forests can lose up to 20% of total ecosystem carbon during combustion, our study supports the results of those who documented after-fire carbon losses higher than direct losses during fire.

Compared to the undisturbed site, the treatments themselves resulted in an immediate loss of carbon from the stand. A drought hit the study area in year three of their five-year study, at which point the undisturbed site effectively stopped sequestering carbon while the treated stand continued to sequester carbon. Because it was able to continue to sequester carbon, the authors estimated that the removed carbon from the treatment activities would be re-stored on the site (*this time in likely in larger trees*) within 12 years after treatment. The treated stand is also able to withstand the impacts of climate change much better than the undisturbed site – the treated stand was measured to continue sequestration under higher temperatures (by 5 degrees F) and drier conditions. The authors conclude that not only will treatments reduce the likelihood of severe fires and the shift in vegetation type (forest to shrub or grassland) that can follow those fires, but *thinned ponderosa pine forests of the southwestern U.S. have greater carbon sink strength than unthinned forests during drought, which is predicted to increase with climate warming*.

The research described above, along with the research discussed in the last board report, suggests that the Sierra Nevada is likely faced with two future scenarios: (1) no changes are made to our current management strategies and as a result the current storage level in the Sierra not only drops, but we lose significant future carbon stock potential (conversion of forests to shrublands to grasslands); or (2) we dramatically increase our restoration and thinning activities, reduce carbon on the landscape by a relatively moderate amount, but maintain the carbon stock potential and allow our forests the potential to securely store more carbon than we currently have stored.

Note: text in italics represents conclusions of SNC staff based on the research.