System Indicators

Forest Health and Carbon Storage

Forest Biomass and Carbon Storage (2010)

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Carbon is a major constituent of life on Earth, forming an essential component of fossil fuels, vegetation and complex molecules in animals. Forest ecosystems actively participate in the 'carbon cycle' in many ways. Trees take in carbon dioxide, use the carbon molecules to form their woody structure and release the oxygen to the atmosphere where it is breathed in by animals. Trees die, decay and release carbon dioxide back into the atmosphere. Carbon is stored in dead wood on the forest floor and also leaches into the soil, as rain and snow soak dead leaves on the forest floor and then soak into the ground. Carbon dioxide is emitted when forests burn and later when trees killed by pests and fire start to decay. Carbon based fossil fuels are expended to power heavy equipment used to harvest and transport wood products. Those wood products in turn store carbon for decades or centuries in some cases. Woody byproducts from forests are burned to generate electricity which substitutes for carbon in fossil fuels that would have otherwise been used.

The storage of carbon by forests has received increased attention in recent years because of the realization that forests play a critical role in stabilizing large amounts of carbon in the global carbon cycle. There is a growing scientific consensus that the amount of carbon dioxide in the atmosphere has drastically increased since the industrial revolution, changing climate patterns and leading to warming in the Sierra Nevada and California as a whole. As a result, many people are now interested in developing methods to maintain and increase the amount of carbon stored in forests to slow down the increase in carbon in the atmosphere.

The amount of carbon stored in forests is estimated from actual tree measurements. The total living weight of trees in a forest is about half water. The other half is called biomass. Biomass is generally considered to be an indicator of the productivity of the ecosystem. The more productive the forest ecosystem, the higher the biomass that can be found there. Forest biomass is about half carbon. The other half is made up of other elements necessary for tree health and function. Current estimates of forest biomass are based on the weight of above ground living tree matter (minus the half that is water) calculated by using forest inventory data. Carbon is then estimated by halving the amount of biomass per unit area, and is usually expressed in short tons per acre.

The current methods of estimating carbon in forests are not very precise, in part because information on the amount of carbon stored by forest soils is not widely available. Forest soils store carbon as one of a number of 'pools' which also include live and dead trees, forest litter and fuels. More carbon is actually stored in soils in Northern Canadian forests than in the standing live and dead trees. This is because cold causes vegetation to decompose very slowly leading to large areas of carbon rich soil and peat bogs. Conversely, tropical forests store very little carbon in the soil because warm and moist conditions cause organic matter to decompose very quickly. In these tropical systems, most carbon is stored as standing biomass. Carbon stored in Sierra soils is in between these two extremes.

A recent estimate made by looking at data from trees, snags, soils and litter in over 1,100 forest stands (Stewart et al., 2011) suggested California mixed conifer forests store about 107 total

tons of carbon per acre. Only half the stored carbon is found in trees while 21% is contained in the soil (see Table 3).

Table 3. Average distribution of forest carbon in tons per acre for mixed conifer forest

Forest Component	Live tree	Soil	Forest floor	Dead/ Down	Dead tree	Under story	Total
Tons of carbon per acre	55	22	17	8	5	1	107
Percent of total carbon per acre	51%	21%	16%	7%	4%	1%	100%

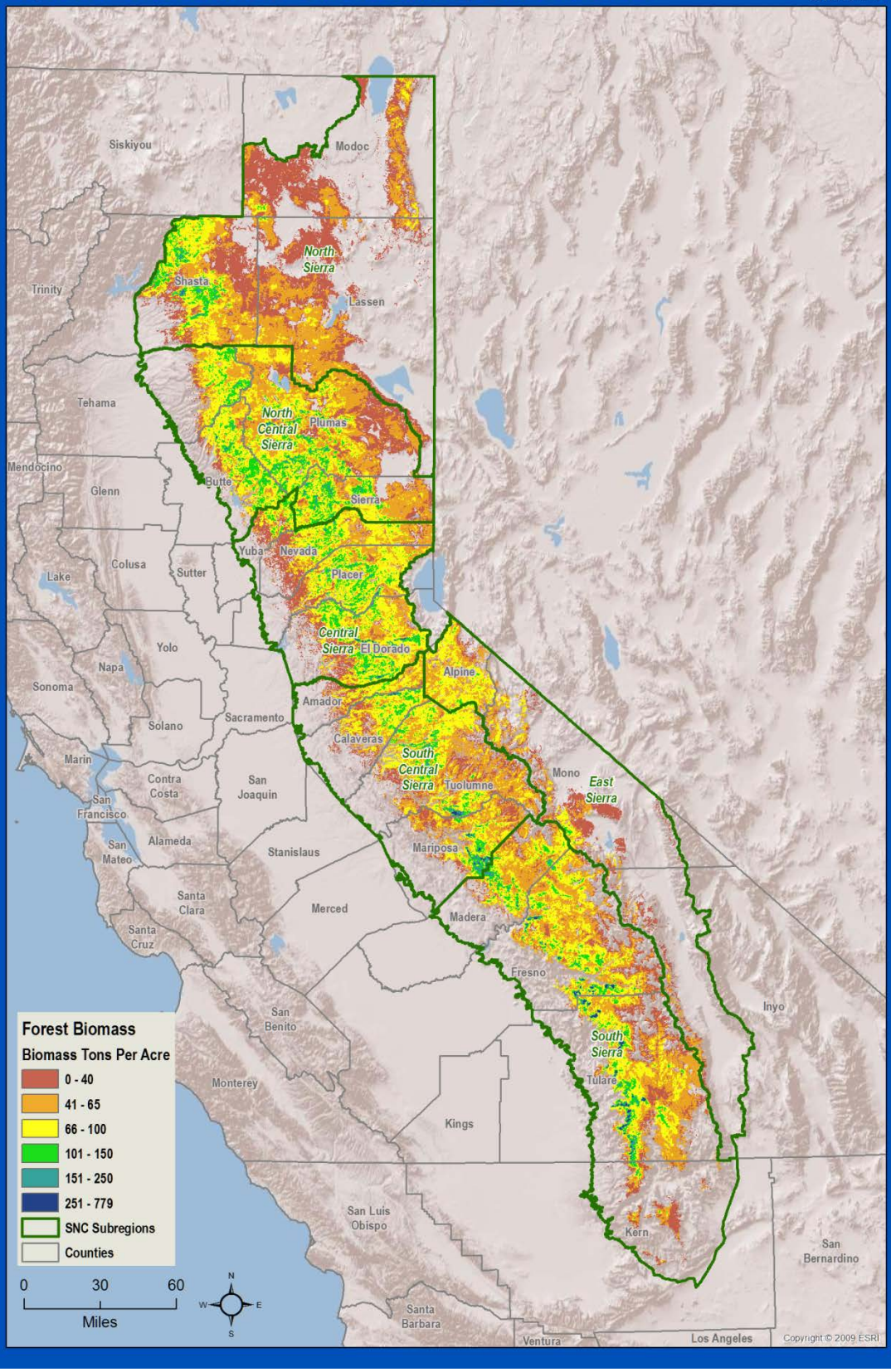
The U.S. Forest Service Forest Inventory and Analysis (FIA) program has developed a spatially explicit dataset of above ground live forest biomass made from measured forest inventory plots for the United States (Blackard et al., 2008). The data was developed by combining FIA plot data and Moderate Resolution Imaging Spectrometer (MODIS) derived image composites and other information into ecologically similar mapping zones for forests of the United States. A subset of data on forest biomass (about half of which is carbon) for the Sierra Nevada was analyzed here. Measurement of below ground biomass was not done, meaning that these estimates are incomplete.

The total above ground biomass accumulation of all productive forests in the Sierra Nevada was almost 840 million tons (see Table 4). About 62% of this forest biomass was owned by the U.S. Forest Service, which is only slightly more than their percentage of Sierra forest land ownership (60%). Concentrations of biomass ranged from very low to over 700 tons per acre in a few isolated giant Sequoia groves in the South Central and South Subregion (see Figure 18).

Table 4. Above ground biomass in the Sierra by ownership

Ownership	Biomass tons (American short tons)	Percent of Total Biomass	Percent of Total Acres
USFS	519,427,710	62%	60%
Private	225,744,095	27%	28%
Other public	93,341,550	11%	11%
Total	838,513,355		

Figure 18. Forest Biomass – Tons of Standing Biomass per Acre



The highest concentration of forest biomass was found in the North Central Subregion where over a quarter of the biomass in the Sierra Nevada is found, with about two thirds of that being publicly owned (see Figure 19). The lowest concentration of biomass was in the East Subregion with only about 4% of the Sierra total, of which 97% was publicly owned.

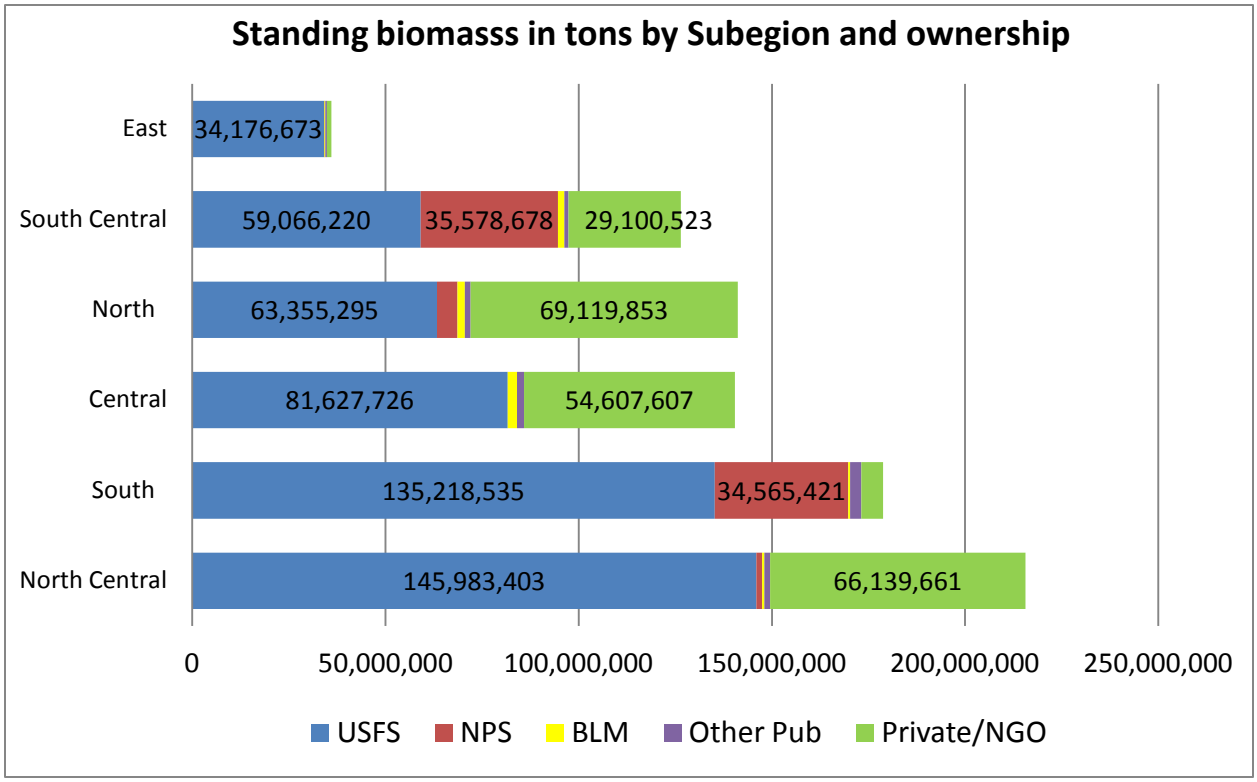


Figure 19. Standing biomass in Sierra Nevada forests

Biomass averaged about 80 tons per acre across all forest types though this included a wide range of values from about 30 tons per acre for Pinyon-Juniper forests to an average of 94 tons per acre in mixed conifer forests. Just over half of the standing biomass was found in the mixed conifer forest type (see Figure 20).

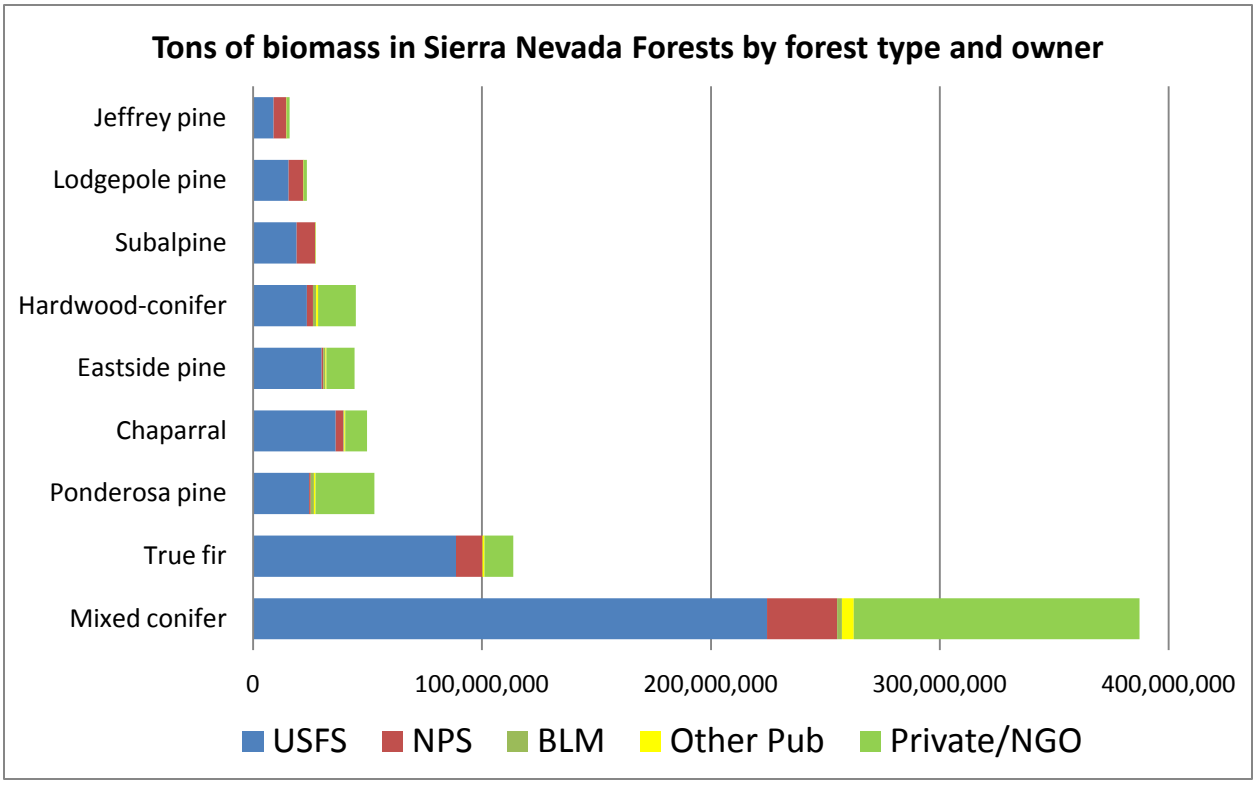


Figure 20. Tons of Biomass in Sierra Nevada forests by forest type and owner

Since the calculation of standing forest biomass has only been done once to date using FIA data, there is no data available on the trends in biomass storage in Sierra Nevada forests. However, recent statewide trends may be extrapolated to the Sierra. CALFIRE's 2010 assessment found that, in general, trees are growing more quickly than they are currently being removed by harvesting so that standing forest biomass in the state continues to build. However, if current wildfire trends continue, it is possible that will start to decrease. They found that forest disturbance from harvesting peaked between 1986 and 1992, while disturbances caused by fire have been most common between 1992 and 2000 (CALFIRE 2010). Another recent analysis by the U.S. Forest Service predicts that standing biomass and associated carbon storage is at risk from wildfire and pest damage in the long-term and so will be determined by how the forest is managed for those risks over the next 100 years (Goines and Nechodom, 2009).

Sierra Nevada forests are currently storing over 840 million tons of biomass. This is probably an increase from historic levels due in part to fire suppression and the reduction in harvesting on public lands. Increasing carbon storage in this way is a benefit to moderating the causes of climate change in the short term. However, in the longer term, it elevates the risk because dense forests are more likely to experience stand-replacing fires that kill many trees and so lead to a large release of carbon when fire killed trees decay.

Another recent analysis by the U.S. Forest Service predicts that standing biomass and associated carbon storage is at risk in the long-term. The analysis predicts California national

forests will become net emitters of carbon by the end of the century because by mid-century forests will accumulate carbon at a slower rate than they lose it through wildfire, pest mortality and inter-tree competition. Carbon storage will be determined by how the forest is managed for those risks over the next 100 years (Goines and Nechodom, 2009).

Though most studies agree that active management to reduce wildfire and forest pest threats reduces carbon storage in the short term, there is less agreement about how and whether thinning improves the stability of carbon storage in the long term. Several recent studies found that consideration of the fate of removed woody material is very important when calculating whether forest fuels reduction reduces long term carbon storage. Using a carbon life cycle analysis, one study found that treated forests in the Sierra "sequester more carbon dioxide than a baseline no-action scenario after 50 years when the woody biomass removed is used for energy generation and the system has frequent fires" (Winford and Gaither 2012, page 7). Another study found that forest fuels treatments reduced loss of carbon to wildfire by 57% but that when carbon removed from the site is added to carbon loss to wildfire, total carbon loss is about 15% greater in treated forests than untreated. However, authors added that "If thinned trees were milled into lumber or the chips used as biofuel, a treatment's carbon loss could be reduced" (North and Hurteau 2011, page 1118).